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PLASTICS

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1. This standardization handbook was developed for the Department of Defense in accordance with established procedure.

2. This publication was approved on 17 March 1975 for printing and inclusion in the military standardization handbook series.

3. This handbook provides basic and fundamental information on plastics for the guidance of engineers and designers of military materiel. This handbook is not intended to be referenced in purchase specifications except for informational purposes, nor shall it supersede any specification requirements.

4. Every effort has been made to reflect the latest information on plastics. It is the intent to review this document periodically to insure its completeness and currency. Users of this document are encouraged to report any errors discovered and recommendations for changes or inclusions to Army Materials and Mechanics Research Center, Watertown, Massachusetts 02172.

PREFACE

This handbook is one of a group which covers metallic and nonmetallic materials used in the design and construction of military equipment. The purpose of these handbooks is to provide current technical information and design data of direct usefulness to engineers and designers of military equipment.

The intent of this handbook is to provide fundamental guidelines for engineers and designers concerned with Plastics applications. It does not purport to provide specific information and data on the multitude of plastics and related products used; rather, it is the intent to point out basic design considerations and emphasize potential pitfalls. In this latter regard, it cannot be overemphasized that designers and engineers should seek the assistance of a qualified plastics technologist, rather than rely solely upon the many qualitative and quantitative tables that abound in available handbooks, periodicals and other technical literature.

The properties and data presented in this handbook are not intended to be used for purposes of providing manufacturing or procurement specifications. Such requirements are adequately covered by applicable specifications.

Draft preparation was accomplished by Picatinny Arsenal in cooperation with and for the Army Materials and Mechanics Research Center.

Comments on this handbook are invited. They should be addressed to Director, Army Materials and Mechanics Research Center, Watertown, Massachusetts 02172. Attn. AMXMR-MS.

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CHAPTER 1

INTRODUCTION

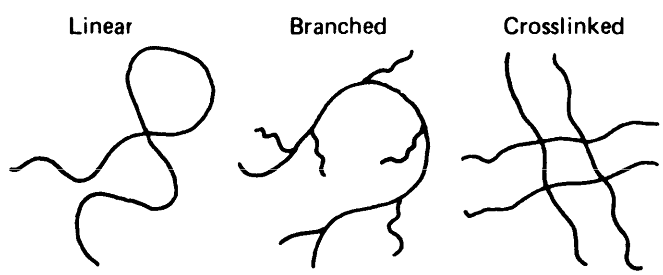
General Information

1. Definition. The term "plastics" usually refers to a class of synthetic organic materials which, though solid in the finished form, at some stage in their processing are fluid enough to be shaped. There are two basic types of plastics: thermoplastics which, like paraffin, may be softened and resoftened repeatedly without undergoing a change in chemical composition; and thermosetting resins, like phenol-formaldehyde, which undergo a chemical change with application of heat and pressure, and cannot be resoftened. Plastics in finished form consist of long chain molecules (polymers), which are built by combining single molecules (monomers), under heat and pressure. Cross-linking is a permanent connection between two polymer molecules binding them together through a system involving primary chemical bonds.

What polymers are . . .

The covalent bonding of carbon to carbon, starting with relatively small chemical units (called monomers) which are capable of reacting with one another, results in relatively large molecules called polymers. The unique properties associated with these materials are due to sizeable interactions between the molecules over extended lengths, and over large surfaces.

The repetition of the units in the molecule may be structures linear and chain-like, and with or without appendage segments called branches, or crosslinked structures which form three-dimensional, network-type molecules:



It should be noted that the chain-like molecules may have degrees of flexibility and that the primary interactions between the molecules are physical—either in the form of weak van der Waal's forces, or the stronger electrical forces associated with polar groups if they are present. The molecules may also be physically entwined one in another, especially when they are quite long and relatively coiled. In this instance, they may be thought of as being represented by a bowl of cooked spaghetti.

The application of energy in the form of heat to such an assembly of molecules causes increased molecular motions, first in the form of segmental motion and later with increased heat, a liquid-like flow where the molecules are free to slide over one another. Such materials are referred to as thermoplastics. Common examples are polyethylene, polystyrene, and nylon.

If, on the other hand, we consider the crosslinked structures, where the individual chain segments are chemically attached to one another, then the application of thermal energy does not result in extensive chain mobility, and the polymers do not soften with heat. This type of material is commonly referred to as a thermoset. Examples are the phenol or urea formaldehyde polymers, and crosslinked polyethylene. These materials are usually formed initially in a linear, flowable stage, and then set or crosslinked into final, intractable non-flowing form by application of heat,and pressure, radiation, or chemical crosslinking agents.

Structures of polymers

It is obviously necessary to attempt to understand its structural characteristics in order to obtain maximum correlation with properties. The basic aspects of polymer structure depend upon chemical composition, atomic arrangement, and molecular size and shape.

Chemical composition: The chemical makeup of a polymer molecule is most important in its effect upon chemical as well as physical properties. The sizes of the atoms in the polymer chain influence the molecular packaging capabilities of the assembly of chains, and have an important bearing on the ability to crystallize. Clearly, large chlorine atoms attached to a chain will have different packing characteristics than small hydrogens. Furthermore, chemical nature controls the chemical reactivity and electrical polarity of the molecules. Such important properties as thermal and oxidative stability depend upon chemical makeup. By the way of simple example, the strong C-F bonds in polytetrafluoroethylene are more resistant to oxidation than polyethylene or polypropylene C-H bonds. The "hydrogen bonding" results in relatively strong forces along the lengths of the chains, and causes higher melting points than would ordinarily be expected.

Atomic arrangement: Given a particular chemical composition, there may be several ways of constructing the molecules; and these almost certainly will differ in properties. Branched molecules are usually less crystalline and lower melting (i.e. linear polyethylene melts at 135° C. whereas branched polyethylene melts as low as 110° C.), and we can see the importance of atomic placement in the case of atactic vs. stereo-regular polypropylene.

The details of these atomic arrangements may be established most readily through the use of infrared, X-ray diffraction, and nuclear magnetic resonance techniques.

Sizes and shapes of molecules: Since properties are so dependent on molecular weight, this is one of the most important measurements for proper understanding of polymers. Another important factor in understanding polymer behavior is molecular shape. The latter is influenced by chain stiffness, and inter- and intra-molecular forces as well as structure. Information on these may be obtained from studies of solution properties. The effects of molecular weight, chain stiffness, and atomic arrangement are best studied in the solid state under the general heading of polymer crystallinity, and morphology and properties.

From a structural property point of view, we may summarize some more important properties features as follows:

1) Stiff chains (those containing large side groups or phenyl groups within the chain) tend to have a higher Tg and, if they are crystallizable, tend to have high melt temperatures. Chains that can crystallize, and which have polar groups, have high melting points.

2) Regular chains (those having stereo regular structure or simple regular structure) can crystallize most readily.

3) Effect of molecular weight:

a) on crystallization—shorter chains are more mobile and may crystallize more rapidly and to a greater extent;

b) on melt flow properties—longer chains have a very large effect on increasing melt viscosity;

c) on physical properties—many properties, such as density, increase with molecular weight and reach relatively constant value at moderate molecular weight. Toughness, however, increases with increasing molecular weight because of the greater tendency to have chain interactions.

Plastics properties related to processing methods

Thought on the subject will immediately show that the very conditions required to fabricate plastics materials may have profound effects upon end item properties. The commonest forms of plastics processing, injection and extrusion, involve high temperature and high shear environments. These may cause molecular weight degradation and buildup of low molecular weight ends at the expense of long chain molecules. Since it is the latter that are responsible for plastics toughness, serious property loss may result.

Another obvious area of possible difficulty is the degree of crystallinity in finished parts. This will, of course, depend upon quenching rate and will be affected by mold temperature, stock temperature, and cycle time. With many materials, a broad range of crystallinity may be achieved through control of the above processing factors. Superposed on these is polymer molecular weight, low molecular weights crystallizing more readily. Dimensions may be affected due to altered shrinkage; impact strength and degree of brittleness may also be affected.

In injection and extrusion processes it is also possible to vary the orientation of polymer chains depending on shear rates that are used.

2. Applications. The modern age of plastics molding materials began with the discovery (in the early 1900's) of a practical way of taming and utilizing the reaction between phenol and formaldehyde. At this time, plastics were thought of as substitutes for other engineering materials. With the advent of the mass production of automobiles, telephones and radios, it was soon recognized that plastics offered combinations of properties and economics of production that were unique, and existed in no other material.

While it must be realized that plastics are not the answer to all design problems, they have proven to be the answer to many engineering problems that could not be solved by conventional materials. Self-lubricated bearings in food and textile machinery, grit-resistant bearings in rock crushers, tubing which is flexible at cryogenic temperatures, light-weight high-strength films in high-altitude balloons, electronic components, large high-strength radomes, rocket cases, and other structures may be produced virtually without tooling.

The choice of a plastic in engineering applications now includes thousands of available plastic types and formulations. There are some thirty distinct families of plastics, and within each family there are many different types such as low-, medium-, and high-density polyethylene. Each type can be produced in a variety of different forms having different properties within a given range. Although the diversity of plastics is great, in practice the choice for a given application will lie within a relatively narrow band of the plastics spectrum.

3. Compositions. Plastics usually are compounded materials containing a base resin (polymer or copolymer) and one or more of the following ingredients:

Filler – an inert material such as flock, metal powders, wood flour, etc., and may be added to the base resin to modify physical properties, reduce cost, or serve as a base for color effects.

Plasticizer – a material incorporated in a plastic to increase workability, flexibility and distensibility.

Colorant – a dye or pigment added for color effect.

Stabilizer – a chemical substance added to the base resin to increase chemical stability and durability of the base resin.

Catalyst – a substance added in minor proportions to accelerate a chemical reaction, and is usually employed as a curing aid for thermosetting resins.

Reinforcement – is an inert material usually incorporated to add mechanical strength. It is normally in the form of a filament, tape or woven fabric. Originally such forms as pieces of asbestos or chopped canvas were used, but higher strength demands led to the use of glass fibers and woven fabric. Recently graphite and boron fibers are used in specialized applications and other high strength reinforcements are in development.

4. Properties. Plastics have many desirable characteristics, chief among which are their light weight, high strength-to-weight ratio, and ease and economy of fabrication. Their specific gravity ranges from 0.92 to 2.3, and their weight from 0.033 to 0.079 pounds per cubic inch (compare these characteristics to specific gravity range of 0.091 to 0.108 for aluminum, and 0.283 pounds for steel). In addition, most of the plastics have excellent electrical resistance, high heat insulation properties, and good resistance to corrosion and chemical action.

Many plastics have self-lubricating characteristics; they can be made transparent, translucent, opaque, and colored, or with variegated colors. A substantial increase in temperatures will cause a decline in physical properties of most plastics. Although some plastics soften at 180°F., most of them can resist temperatures up to 300°F. and some varieties can be used successfully in temperatures of 500°F. to 600°F. While many plastics should not be used at temperatures below -40°F., a few specially designed types can be used at cryogenic temperatures. They are subject to higher thermal expansion, creep, cold flow, low temperature embrittlement and deformation under load than metals. Some varieties change dimensions through solvent and moisture absorption, and are degraded by ultraviolet and nuclear radiation.

Plastics have a higher cost per pound than some other materials, such as steel, but their low gravity may still make them the most economical material to use. Plastics, despite their relatively low operating temperature, may be superior to metals as high temperature heat shields for short exposures. A plastic surface exposed to a radiant-heat source soon becomes hot at its surface and may suffer surface degradation, but this heat will not be transmitted to its opposite surface as rapidly as in metals. Some reinforced plastics (glass reinforced epoxies, polyesters and phenolics) are now nearly as strong and rigid (particularly in relation to weight) as most steels, and they may be more dimensionally stable. Some oriented films and sheets (oriented polyesters) may have greater strength-to-weight ratios than cold-rolled steels. Some plastics are now cheaper than metals (nylons versus brass, acetal versus zinc, acrylic versus stainless steel). Some plastics are actually tougher at low than at normal temperatures. Several plastics are now cold workable by conventional metal-stamping and cold-heading techniques (polycarbonates and acetals). Combination of plastics with metals also extend the use application range for both materials.

Effects of Processing

5. General. Polymer processing is an engineering specialty concerned with operations carried out on polymeric materials or systems to increase their utility. These operations produce one or more of the following effects; chemical reaction, flow, or a permanent change in a physical property. Processing techniques and the accurate control of processing techniques are vital in determining the end-use properties of a plastic part. During processing, plastic materials are subjected to high thermal and shear effects under pressure for varying times. The molded part is finally ejected and usually goes through a variety of finishing operations before the process is completed.

The pressures employed during fabrication cause considerable modification of physical properties. Optimum fabrication pressures cannot be determined on a theoretical basis. They must be determined by trial since they are influenced by part size, geometry of part, and the equipment used.

Fabricating temperature and time (total application of heat) exert important effects on the strength characteristics. Low temperatures and short fabricating time may result in weak pieces due to insufficient cross-linkage of thermosetting base resins. High temperatures and prolonged fabricating time may result in inferior strength due to decomposition or chemical modification of both thermosetting and thermoplastic base resins.

The following types of stresses can develop in processed articles which affect their end use and properties: (1) orientation stresses caused by forced alignment of molecules; (2) packing stresses caused by forced filling of a mold during thermal contraction of the material in the mold; and (3) thermal stresses caused by uneven cooling of an article in the mold or thermal shocking of the whole molded article. Finished molded parts having these built in stresses are affected by heat, as evidenced by dimensional changes which take place as a result of their attempt to relieve themselves of these stresses. Also, stressed parts which have low elongation levels have a tendency to crack and craze. This tendency is accelerated by contact with solvents, reagents or aqueous solutions of polar compounds; or by exposure to ultraviolet light, solvent fumes, and oxidizing conditions.

6. Test and Evaluation. Specification sheets showing property values which are based on American Society for Testing and Materials test data or similar testing procedures can only be used as a guide, as the actual fabricated shape will not necessarily meet these property values.

Hundreds of tests have been developed and used by people connected with the plastics industry in order to understand plastics behavior, to control processing, to identify plastics, and to performance-test the finished items. These tests can be divided into two categories: screening tests, which are similar to the conventional metal tests; and functional tests, which are especially designed to test the finished plastic part under simulated service conditions.

7. Screening Tests. The screening tests are described in Federal Test Method Standard No. 406 and The American Society of Testing and Materials Standards on Plastics. The data generated by this type of testing is available in the manufacturer's literature and the many text books covering the subject of plastics. The significance of these tests is limited by the fact that they are conducted under standard conditions, while the properties of plastics are markedly affected by variations in temperature, loading rate, time, environment, compounding, and processing. However, the values obtained by this type of testing are useful for identification and material quality control tests for specifications. In addition, these values when properly interpreted and correlated with individual plastic behavior, can aid in determining the effects of the factors which cause variation in property values. A simplified description of the more important physical and mechanical tests used to generate plastic property data is listed below:

Specific Gravity – A cubic centimeter of water at +4°C. weighs one gram. This natural standard of volume and weight is the basis with which one compares the weight of any other material at equal volume and temperature. The ratio of these weights per-unit-volume is the specific gravity. Specific gravity can be employed as a control on compounding and fabricating conditions, as well as identification property for material. In fact, polyethylene is classified into low-, medium-, and high-density types based on their differences in specific gravity (density).

Refractive Index – Light travels at different speeds in different transparent materials. The ratio of this speed in vacuum to the speed of light through a material is called the refractive index of the material, and is extremely useful in establishing the identity of transparent materials.

Tensile Strength –Fasten a cylindrical plastic rod of one-square inch cross-sectional area by its upper end, and apply a steadily increasing load to the lower end of the rod. If a break occurs at, for example, 2000 pounds, then it is said that the tensile strength of the plastic is 2000 pounds per square inch. Tensile strength is dependent on temperature and rate of loading. Generally defined, tensile strength is the weight in pounds required to break the test specimen, at a given temperature and loading rate, divided by the number of square inches in area at the break.

Modulus of Elasticity – As the load on the plastic rod (described above) was increased, the rod stretched. Up to a certain point, load removal will cause a snap-back to the rod's original form. This snap-back quality is called elasticity. Beyond the snap-back point, there is a loading point where the material will remain stretched; this point is called the elastic limit. Where stretching is proportional to load (that is, for each addition of 100 pounds of load, an equivalent increase in rod length takes place), a property known as elastic modulus can be determined for the material. This value is obtained by dividing the stress (pounds per square inch) by the amount of stretching (inches per inch). A higher modulus of elasticity indicates a more rigid or stretch resistant material. This value is dependent on test temperature and rate of loading.

Compressive Strength – Place a one-inch cube of material on a firm foundation, and gradually apply a load to the top surface until the point of material collapse. This point is the compressive strength of the material expressed in pounds per square inch. Here again, one finds temperature and load rate dependency for plastic test values.

Flexural Strength – Apply a gradually increasing load downward to the center of a bar (supported at both ends) until the bar starts to break. From the load recorded at the breaking point and the cross-sectional area of the bar and the distance between the bar supports, the flexural strength in pounds per square inch is calculated. In this test, the upper half of the bar is being compressed while the lower half is under tension.

Impact Strength – Visualize a swinging pendulum with a hammer head for its end. Firmly fix a plastic specimen at the lowest point of the pendulum path, and allow the hammer head pendulum to fall freely and break the sample. Record the upswing of the hammer head. Repeat the procedure, with no plastic sample present to impede the upswing of the hammer head. The difference in upswings represents the energy lost by the breaking of the plastic. Impact tests are usually determined by the Charpy or Izod method and the results may be reported in: 1) foot pounds of energy to break; 2) foot pounds per inch of width – this value is obtained by dividing the value in (1) by the specimen width; and 3) foot pounds per inch of notch – this value is obtained by dividing foot pounds of energy to break by the cross-sectional area below the notch.

Hardness – The indentation hardness of plastic materials (as opposed to surface hardness or scratch resistance) is measured by the Brinell or Rockwell methods. In both cases, a hardened metal ball is pressed into the plastic. The Brinell number is calculated from the measurement of indentation depth and spherical indentation area. In the Rockwell method, ball sizes and loads may be varied for different hardness materials. The depth of penetration is measured, and a number is assigned on an arbitrary "R" or "M" scale, with the "R" scale being for softer materials. Higher numbers on either scale indicate harder materials for that particular scale.

Thermal Conductivity – This is a measure of the volume of heat that will pass through a material in a given time for a given temperature differential. For purposes of comparison, it is reduced to elementary units. A calorie (the standard unit of heat) is the volume of heat necessary to raise the temperature of one gram of water $1^{o}C$. Thermal conductivity shows the number of calories conducted through a cubic centimeter of sample material in each second under a temperature difference of $1^{o}C$. The numerical values for plastic are in the range of 0.002 to 0.0020; for aluminum, the value is 0.5000.

Specific Heat – This is the amount of heat (calories) necessary to raise the temperature of one gram of a substance one degree Centigrade. The specific heat for water is one calorie; for plastics, between 0.025 and 0.50; and for copper, 0.09.

The lower the specific heat of a plastic, the lower the heating costs for the plastic when it is subjected to a molding process.

Coefficient of Thermal Expansion – All materials change in dimension as the temperature changes. The coefficient of thermal expansion represents the change in dimension caused by a temperature rise of $1^{o}C$. When plastics are used in combination with other materials such as metals, the difference between the expansion tendencies of each necessitates certain precautions in design and fabrication. Otherwise, loose fitting parts may be the end result.

Volume Resistivity – All materials resist the passage of electricity to a greater or lesser degree. Volume resistivity is determined by measurement of the reciprocal of current (ohms) which will pass between electrodes covering opposite faces of a unit centimeter cube of the material, when unit potential gradient exists between the electrodes. The resistivity of good insulators should be approximately 10^{16} ohms per centimeter. At the opposite extreme, a metal conductor is recorded as having a resistivity of 10^{-6} ohms per centimeter. All of the plastics have high resistivities and are, therefore, good insulators.

Dielectric Strength – This is the point at which electrical insulation breaks down under an applied voltage. The voltage recorded at the break divided by the thickness of the insulation in thousandths of an inch (mils), is the volts per mil shown in property tables. Sixty cycles per second are assumed, since this is the standard in this country for alternating current. Higher frequencies yield different results. Thickness is a factor in changing values, as thin insulation will stand more volts per mil than thick insulation. In practice, three methods of expressing the dielectric strength of an unknown are used. In the instantaneous method, the voltage is increased at a slow uniform rate until breakdown occurs. In the step-by-step method, the voltage is increased in steps until breakdown occurs. In the endurance method, the plastic is subjected to a high voltage for a long time.

Dielectric Constant – The dielectric constant of any material is the ratio of the capacity of a given condenser with the material as a dielectric, and the same condenser with air as a dielectric. The value of the constant obtained is a measure of the effectiveness of the material as an insulating medium, when it is placed between the two charged plates of a condenser. The values for dielectric constant vary with variation in electrical frequency. Plastics usually have high dielectric constants.

Power Factor – The measure of power absorbed in percentage by an insulating material in the presence of an alternating current field is known as the power factor. Polystyrene and Polyethylene approach the zero value and, therefore, are excellent insulators. Variations in temperature, moisture content, cold flow, compounding agents, and high frequences encountered in the communications field all have a tendency to raise the power factor.

Elongation – The elongation of a material is the amount of increase in length resulting from tension required to break a specimen, and is expressed in terms of percentage of the original length. This determination is made simultaneously with the tensile strength test.

Heat Distortion Temperature – This test is a determination of the temperature at which appreciable thermo-softening takes place under certain defined conditions. A 2½ x ½ x 0.050 inch molded piece is clamped at one end, a load of 27.5 grams is applied 2 inches from the clamping point, and the whole setup is immersed in an oil bath. The temperature of the oil is raised 2 to 3 degrees centigrades per minute, and the softening temperature is reached when the cantilever beam deflects 0.06 inches.

Stiffness – This is a measure of the resistance to a bending stress within the elastic limit of a material. A conditioned 5 x 1/2 x 1/8 inch injection molded test piece is placed in a tester, and a 600 gram load is applied at the center of the supported test piece. After 5 seconds, the stiffness (in millimeters of deflection) is read off from a dial gage.

8. Performance Tests. The performance tests must be designed to simulate the actual operating conditions a plastic part must endure. These tests are of great importance in choosing the proper kind, type and grade of plastic for a job. In addition, they will help to establish proper processing conditions, proving the soundness of the design of the product checking the uniformity of molded articles and the changes in any factor in the manufacturing cycle.

Performance testing must be considered from the standpoint of the behavior patterns peculiar to plastics. An important aspect of any parts performance testing program, is the sampling plan. Unless the samples are representative and sufficient in number, the results of tests may not be reliable. It is obvious from an economic standpoint, except in exceedingly critical cases, that 100 percent inspection should not be performed. In devising a sample plan, simple tests with well defined limits should be selected. The plan should provide for increased inspection when rejections are encountered. These provisions are available in MIL-STD-105 titled "Sampling Procedures And Tables For Inspection By Attributes".

Most testing programs for plastic parts follow a fairly well-standardized pattern. A typical program is described below.

a. Appearance. If the customer does not like what he sees, further evaluation may stop right at this point. However, the type of defect observed by the producer can be a valuable tool to correct existing production problems. Poor color or color uniformity indicates material impurities, material degradation or poor distribution of material. Surface roughness of a part may indicate poor mold finish, lack of adequate pressure control during molding, improper mold packing or inadequate material dispersion. Injection molding problems are detected by splays, sinks, fish eyes, silver-streaking and surface voids. Poor extrusion may be evidenced by die lines or pits Cracks around inserts are also a sure sign of trouble. These defects are obvious to the naked eye. A wide variety of instrumentation exists for the purpose of defining appearance in a quantitative fashion. Microscopes can detect surface defects which are invisible to the naked eye. Fluorescent dye penetrants can assist in detecting fine cracks, crazing, and surface voids. Transparent parts allow the use of polarized light to indicate double refraction or birefringence which gives a quantitative measure of molded in stresses. Commercial instruments and standardized test methods are available for measuring gloss, transmittance, reflectance, color, color difference, and haze of plastics. Tests are being developed for yellowness and transparency of clear plastics, and image-obscuring power of diffusing plastics.

b. Dimensional Stability and Testing. The original shape and dimensions of a molded part are established primarily in the mold. However, when dealing with plastics, subsequent changes may take place. These changes are functions of the inherent property of the material being molded and the molding technique employed. Since retention of original dimensions through long periods of service is vital for sound engineering design, an understanding of the causes and of methods of producing such changes in the Laboratory is important to the proper application of plastics. Changes in dimensions are caused by the following:

Deformation Under Load (Cold Flow) – This change is caused by externally applied forces, such as fastening devices, inserts or stacking during shipment. Thermoplastics parts are much more susceptible to deformation, especially at elevated temperatures, than are thermosetting plastics. Deformation under load is usually measured by placing the molded article between two anvils and applying a load on the article, approximating its maximum service stress for a specified period of usually not less than 6 hours nor less than 120°F. The reduction in height of the article is measured by a dial indicator between the anvils. The dial reading divided by the original height of the article and multiplied by 100 is the deformation under load (cold flow) value for the article. It is obvious that this type of test can be designed and varied with regard to load, time and temperature so as to fit the particular service requirements for a given part.

Moisture Absorption and Drying – Tendencies to swell and shrink, as a result of moisture absorption and drying, are observed particularly in articles molded of cellulosic compounds. Federal Test Method Standard No. 406, Method 6011, covers normalizing, humidifying and drying, and can be used for any single set of conditions.

Aging Due to Moisture Absorption and Drying – In materials which tend to swell and shrink as a result of moisture absorption and drying, it is found that if the cycle is repeated, progressive linear shrinkage takes place over extended periods of time. It may be determined by subjecting the molded article to at least three cycles of the test method procedure noted in the preceding paragraph. Measurements are made at the completion of each normalizing cycle. The difference between the dimension at the completion of the normalizing cycle and the final normalizing cycles, measured in mils per inch, is known as age shrinkage.

Weathering – The problem of engineering evaluation of the resistance of materials to outdoor exposure has occupied the attention of technologists for many years. Plastics are subject to change and degradation by exposure outdoors, and experience loss of engineering properties, original appearance, and, in extreme cases, complete deterioration. There is no simple way in which the weathering resistance of plastics may be determined. Installation and maintenance of exposure racks in various locations by government agencies, organized technical societies or large corporations is being accomplished. Accelerated weathering tests conducted in the laboratory require fairly elaborate equipment and a high degree of interpretive know-how.

Molding Stresses – These stresses may result from injecting the molten plastic into too cold a die. When the plastic is suddenly chilled, some portion of the unspent force exerted by the injection ram is locked within it. Application of high heat may cause release of these stresses and consequent dimensional changes of the article. The change in dimensions caused by internal stresses can be determined by first normalizing the article for 24 hours and then measuring the significant dimensions; then, the article is subjected to a specified temperature and time, and the significant dimensions are remeasured after normalizing.

Temperature Changes – When plastics and metals are used in combination in precision devices, the higher coefficient of expansion of the plastics over metal is a significant factor to consider.

c. Testing of Critical Parts. The appearance and dimensional checks previously described are adequate methods for noncritical applications, but are not sufficiently definitive where parts are important and vital components of critical systems. Plastic parts may have to withstand mechanical stresses, shock, thermal and chemical exposures in such applications, as are found in missile components, where 100 percent reliability is not only desirable but a necessity. This type of critical requirement has demanded the utmost in engineering test skills to determine reliability with unerring accuracy. The testing possibilities include both nondestructive and destructive types.

In nondestructive tests, weighing the part is simple and useful; an ideal process should give a normal statistical distribution of weight. Serious deviations can spell trouble. Low weights may be ascribed to voids, under-filling of the mold cavity, or excessive shrinkage. High weights may reveal incorrect mold loading or improperly compounded material.

X-rays are capable of detecting voids or measuring material distributions in a variety of plastics.

Ultrasonic testing can detect flaws, delaminations, and incomplete cures in plastic parts. This type of testing is commonly used to test thermoset or composite systems. Each part, when subjected to an appropriate vibration, will exhibit a characteristic damping frequency which is fundamental for the geometry and composition of that particular part.

Rigidity testing, by measurement of deflections and indentations under load or pressure, is employed for determining cure, poor integrity due to voids, and incorrect material distribution in plastic parts.

A steel ball rebound tester has been found useful for the determination of thermophysical characteristics of plastic parts.

Anti-static properties of plastics may be measured by several simple methods. One such method is to induce a charge on a plastic surface by rubbing with a rapidly moving cloth or tissue, and using a static meter to measure the acquired potential.

Odor characteristics of plastics are determined, by a panel of individuals having keen senses of smell, by comparison with a standard.

Any of the conventional tests for strength, stability or chemical composition may be used to test finished parts. In most cases, these tests are miniature destructive simulated service tests. In strength testing of parts, it is of fundamental importance to design good holding jigs which do not induce their own stresses and cause premature destruction of the parts. Hydrostatic burst tests on pipes or tanks, ball-drop tests for pipes and packaging containers, pendulum and tumbling impact tests, and projectile impact tests are all commonly used strength tests for plastic parts. Heat aging of tube and pipe can show up improper fabrication as evidenced by cracks in the part. Distortion or cracking at low temperatures may be used to evaluate the quality of plastic foams, or of plastics containing metal inserts. Brittleness of plasticized materials, such as vinyls, at low temperatures is frequently a good check of plasticizer dispersion. Plasticizer dispersion may also be checked by measurement of plasticizer migration and loss on heat aging. Exposure of plastics to solvents and hot aqueous detergent baths is useful for the determination of crazing and cracking resulting from molded-in stresses. Solvent extraction techniques have been developed for determining the extent of cure of thermosetting resins.

Tests have been developed for determining the fatigue endurance limits for a plastic article that must be repeatedly stressed in service. Fatigue endurance limit is the stress below which the material may be stressed for an infinite number of cycles (usually taken as ten million) without failure. There are many types of wear and abrasion tests which have been developed and will continue to be developed for specified end uses of items. Nuclear radiation and heat ablation tests are being developed and explored for improvement and utilization studies of plastic components for space vehicles and missile applications. For the severe stresses encountered in aerospace applications, tests have been developed for determining LOX compatibility, stability under vacuum, and NOL Ring strength on fiberglass reinforced plastics.

9. Testing Summary. To summarize, only those properties that have engineering significance are useful for selection and evaluation of plastics. Creep and stress relaxation are two of the most important properties, because of their time and rate of loading dependence. Due to temperature dependency, property characteristics should be determined over the useful temperature range. The conventional stress-strain properties are not very useful in design; however, if measured over a range of stain rates, they correlate with rate of loading sensitivity and appear to correlate with impact resistance.

Design Considerations

10. General. In plastics, the design engineer has a host of new materials at his disposal, which can be selected, compounded, processed and assembled into useful finished end products. Plastics are unique in that they have combinations of good properties and are easily fabricated into multifunctional end items. Selection of a suitable plastic for a particular application requires that the engineering team: 1) determine and prepare a check list of all essential characteristics, including performance characteristics under all service conditions, required of the finished product; 2) select a resin, and the compounding agents, that is, other materials added to the resin to improve properties or aid in processing; 3) select an economical and favorable method of fabrication; 4) mold an item and performance test it; 5) make necessary design changes; and 6) prepare all engineering documentation and quality control information for production.

11. Mechanical properties. A knowledge of the strength and stiffness of materials as functions of time, temperature and environment, allow the engineer to select the most suitable material for an application and to design the part accordingly, using basic elastic theory. However, a structural part which has been designed according to basic elastic theory does not always behave in the manner expected, primarily because the actual loading conditions are different from those for which the part was designed. Also, since basic elastic theory does not recognize the time dependence of materials behavior, a premature failure may occur. Therefore, it is necessary to know not only the physical capabilities of materials, but also the actual loading conditions of the fabricated part in order to assure reliability in the intended applications. The physical capabilities of plastics are measured in the terms outlined in table I. The properties in this table are deduced from stress-strain (load-elongation) curves obtained by loading test pieces of the material in tension, compression, and shear. Figure 1 shows a typical stress-strain curve and demonstrates how such a curve is employed for evaluating the five basic properties listed in table I.

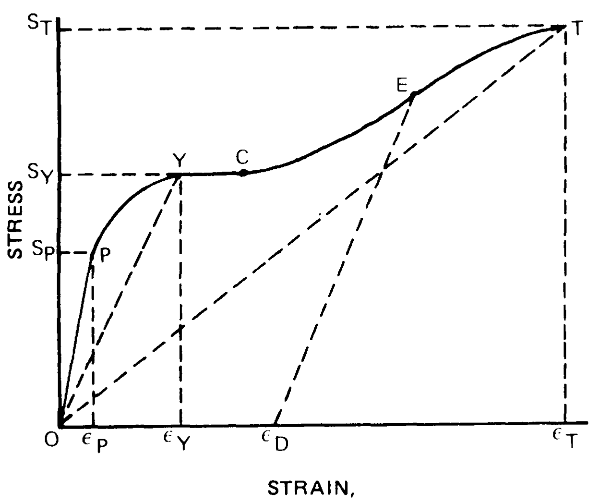


FIGURE I. Typical Stress-Strain Curve with Elastic-Strains Exaggerated

Table I — Practical Meanings and Criteria For Determining Engineering Properties of Plastics

Property	Practical Meaning	Criterion
Stiffness	Ability to carry stress without changing dimension	Modulus of elasticity
Elasticity	Ability to carry stress without suffering permanent set	Yield point (elastic limit)
Resilience	Ability to absorb energy without suffering permanent set	Resilient energy. Area under elastic portion of stress-strain curve
Strength	Ability to carry dead load	Ultimate strength, or yield strength
Toughness	Ability to absorb energy and undergo large permanent set without rupturing	Ultimate energy resistance. Total area under stress-strain curve.

In figure 1, the Hooke's law region is shown by OP. As the applied stress is increased, a point P is reached beyond which the linear relationship between stress and strain no longer holds. Point P marks the proportional limit. A point Y is found beyond which the deformation is no longer elastic. The point Y is known as the yield point or elastic limit. For stresses up to S_Y, the material is ideally elastic; that is, the strain disappears on release of the stress. Beyond Y, the material is no longer an elastic body but is behaving as a plastic solid. Section YC, which is practically horizontal, shows that the material is ductile and is flowing under practically a constant stress. After point C, an increase in stress is required to effect further elongation (strain hardening) until a failure called the ultimate tensile strength is reached at T. A second rise (from C to T) in the stress strain curve means that the stress-induced plastic deformation between Y and C has resulted in a change in structure, which in this case results in reinforcement. If the stress is removed at point C, and the sample is removed from the testing machine, it will be found to have a different structure than the originally introduced sample. If the stress is removed – after the yield point but before the ultimate strength, for example at point E – the material will have a permanent set ϵ_D.

Stiffness (E) – Apparent stiffness is indicated by the slope of the elastic portion of the curve OP and is called elastic modulus (Eo or Young's modulus). Tangent modulus at a given stress is the instantaneous slope $ds/d\epsilon$ of the stress-strain curve at that stress. The secant modulus between two stresses is the slope of the lines joining the two corresponding points on the stress-strain diagram. For example, the slope of OY is the secant-modulus of elasticity between zero stress and the yield stress. The slope of OT is the secant modulus between zero stress and the ultimate tensile stress. When materials exhibit large elongations of a non-Hookean character, secant moduli are more useful than Young's or Tangent moduli in evaluation and comparison of materials. The slope of the secant modulus OT is sometimes called the average stiffness.

Elasticity – This is measured by the yield stress, or elastic limit S_Y, which is the stress at yield point. For plastics, the yield strain Σ_Y is of great significance.

Resilience – This is evaluated by the area OPY Σ_Y O under the elastic portion of the stress-strain curve. This area represents the work required to deform the material to its elastic limit, or the energy that the material can absorb without undergoing permanent deformation.

Strength – The ultimate strength is S_T; that is, the strength corresponding to the highest point reached on a stress-strain curve. It is obvious that for materials which are to be used for structural members or parts which must maintain their original dimensions closely, the ultimate strength is not nearly so good a criterion as S_Y, the yield stress.

Toughness – This is evaluated by the total area OPYCT ϵ_T O under the stress strain curve. It is the total work that must be done to rupture the material. When the total work to effect rupture is low, the material is said to be brittle.

Yield Strength – From the preceding discussion, it is evident that the yield strength of a material is a characteristic that is of outstanding practical importance. It is the stress value at which deformations cease to be elastic and become permanent, due to the onset of flow. It, therefore, marks the limit of usefulness for materials that are to be used for fabricating parts that must stay true to dimensions.

Plastics for the most part are viscoelastic and, as such, their mechanical properties change with time, temperature, and applied stress. Viscoelasticity can best be illustrated (see figure 2) with a simple Maxwell Model of an elastic spring and a dashpot filled with a viscous oil.

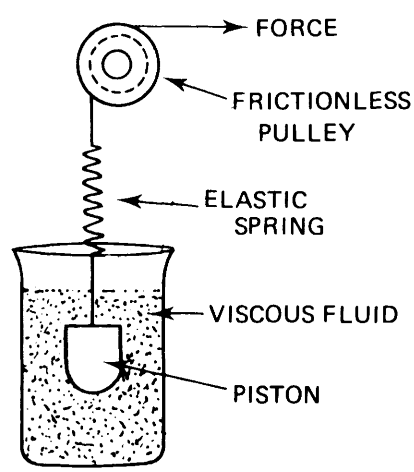


FIGURE 2. Maxwell Model Illustration of the Viscoelastic Nature of Plastics

If stress is applied to the system (shown in figure 2), the elastic spring will deform slightly and return to its original dimension when the stress is removed. The dash-pot, at first, remains stationary under the applied stress. If stress is maintained for a period of time, oil slowly leaks past the piston and deformation gradually takes place. When the stress is removed, there is no return to its original dimension as in the case of the elastic spring. A viscoelastic material then tends to behave both as an elastic spring and as a viscous dash-pot. The properties of the elastic component are independent of time, but the properties of the viscous component are highly dependent on time, temperature and stress.

Like other materials, plastics are subject to a phenomenon known as "creep" or "cold flow", as illustrated by their viscoelastic behavior, This means that if the material is free to act under stress, its dimensions will gradually change, resulting in creep or cold flow shown in figure 2. On the other hand, if the part is originally deformed to some predetermined shape and then restrained in that position so that total deformation will neither increase or decrease, then a second phenomenon known as "stress relaxation" occurs. Here, the initial stress locked into the piece, as it tries to resist deformation, gradually decreases and, if left long enough, would theoretically decrease to zero. If the part were then removed from the deforming force, the part would retain completely the shape into which it had been forced.

Various applications for plastics make use of materials, in such a way, that they are subject to either creep, stress relaxation, or a combination of both. A knowledge of the rate and the extent to which materials will creep or relax, is necessary to be able to predict and design for the expected performance of the material.

Actually, the two phenomena of creep and stress relaxation are closely related, and the end result is identical in that permanent deformation of the part occurs. The mechanism of change in the orientation and rearrangement of molecules is essentially the same in both cases, but the rate and extent to which they proceed will be somewhat different because of the difference in the way that part is loaded. Because of their close relationship, however, a knowledge of the creep behavior of a plastic will enable one to calculate, approximately, the amount of stress relaxation that would occur in those applications where the part is initially deformed and then restrained in that position. The reverse is also true. The amount of creep or stress relaxation is dependent first of all on the material itself. In addition, the temperature, the magnitude of the applied load, and the length of time the part is under stress will also determine the rate and extend of creep and stress relaxation.

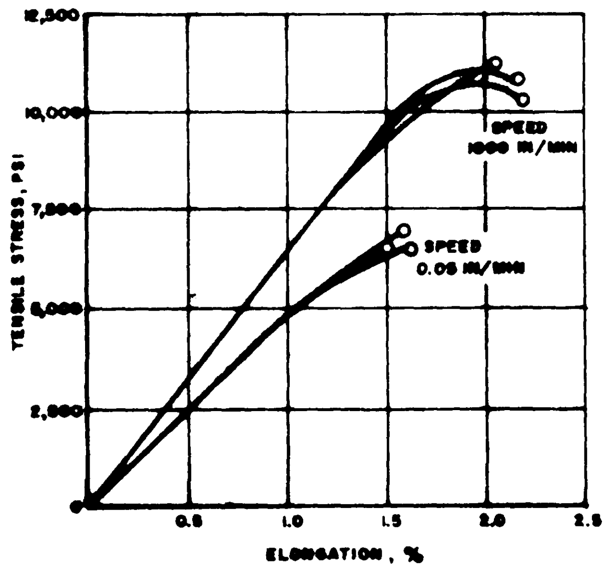


FIGURE 3. Effect of Rate of Load on Tensile Behavior of Polystyrene

If failure of a part occurs, it means that for a particular combination of material, environment, temperature and time involved, the applied stress was too high. This implies that design strength has no fixed value, but is entirely dependent on the factors cited.

The following considers the effect of time, temperature and environment on the strength of plastics.

Time – The tensile stress-strain curve shown in figure 3 illustrates the effect of rate of loading on tensile behavior of polystyrene. At the 0.05 inch/minute rate of loading, which is conventional for testing plastics, the typical response of a stiff non-yielding material up to the point of fracture is observed. At 1800 inches/minute, a much greater strength at failure, implication of yielding and an apparently greater modulus of elasticity, are observed. In addition, the toughness or total energy absorption, which is a direct function of the area under the curve, is greater at the higher speed. Thus, a material normally considered ductile appears to be stiff and rather brittle, when tested at conventional rates of loading. The time effect observed is readily understood by considering the viscoelasticity of plastics. At conventional rates of straining, the viscous component of the material was allowed the time to make its presence known. At the high rate of testing, the time dependent behavior of the viscous component did not have time to act, so that the elastic behavior was magnified. The evaluation of structural materials from conventional stress-strain tests is not always adequate, because the rate of loading in the application, or the time to failure, is either higher or lower than the practical applications of many load bearing plastic structures.

Stress-relaxation measurements are a convenient way to define the time dependency of the strength of a material. To do this, carefully prepared test specimens are deformed (strained) a predetermined amount and then held in this position. Total strain is not allowed to increase or decrease during this test. The specimens are maintained at constant temperature in a constant environment, and as time proceeds, measurements are periodically made of the actual stress remaining in the specimens (see figure 4).

If the stress applied is too great, the part will fail by cracking at some time as shown in the top three curves in figure 4. Joining the three points of failure in figure 4 will trace a design strength-time type of curve, and will indicate the maximum stress that can be applied to the part for that period of time without failure. It should be noted that the greater the applied stress, the shorter the time to failure. The lower two curves in figure 4 represent behavior of the plastic at combinations of time, stress and strain below the limiting stress.

Using the same failure data obtained in the stress-relaxation curves of figure 4, one can plot a stress versus strain curve for various times. A typical plot of such data is shown in figure 5. The ultimate point of failure is noted at the end of each stress-strain line for the time indicated.

The designer now has a complete stress-strain curve for a wide spectrum of failure times at different rates of loading and, consequently, the apparent modulus for different load rates on a given plastic. As can be seen in figure 5, the apparent modulus (ratio of stress-to-strain at application load rate) becomes smaller as the time factor increases. On the other hand, the elastic modulus (Young's Modulus) is determined at conventional rates of loading (0.05 to 20 inches per minute) and does not consider the effect of creep over longer periods of time.

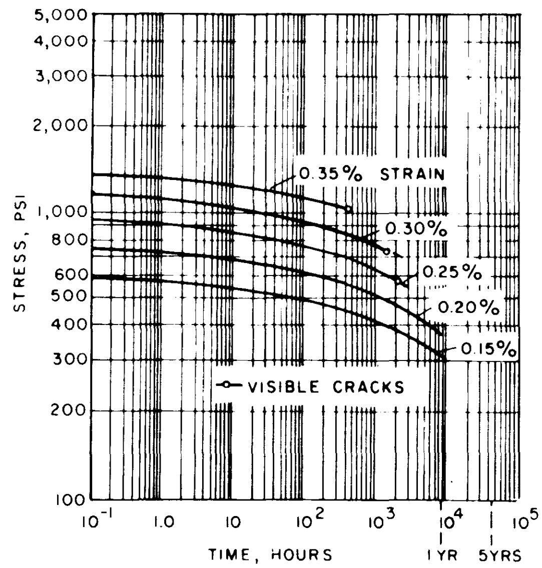


FIGURE 4. Stress Relaxation Curve of a Typical Plastic

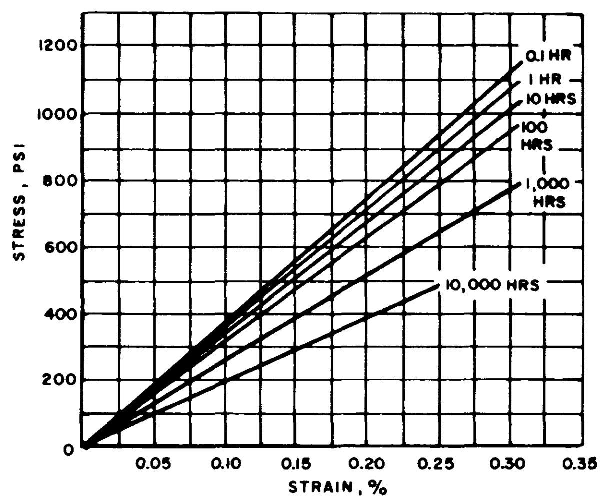


FIGURE 5. Stress-Strain-Failure Time Plot of a Typical Plastic

The considerations given for stress-relaxation data are almost similar to the considerations given in the literature for creep failure data except that stress-relaxation failures start by cracking, and creep failures are indicated by abrupt rupture of the materials. The first visible failure (cracking) will occur at a smaller stress for a given time than will creep rupture. The choice of the use of creep or relaxation data, as a design criterion, will depend upon the nature of the application.

Temperature – The effect of temperature on mechanical properties can be illustrated by referring to figure 2. At high temperatures, the dash-pot fluid thins out and movements of the plunger are more evident, giving greater extensions. At lower temperatures, the fluid thickens and failure occurs before appreciable extension, as is typical of a brittle fracture.

An interesting and useful correlation can be made between the effect of temperature and the rate of loading; lower temperatures approximately correspond to higher rates of loading. It is common practice to explore the effects of temperature as the analog of time, because temperature extremes are more readily attainable and more easily controlled. The general effects of temperature can be memorized by using the behavior of parrafin wax as a memory aid: hard and brittle when cold; soft, weaker, extensible and finally molten as the temperature increases.

Figure 6 shows representative effects of temperature on tensile strength, elastic modulus, and ultimate elongation of plasticized (cellulose acetate) and unplasticized (polystyrene) thermo-plastics and a thermoset (phenolic) tested at conventional rates of loading.

Environment – The great majority of strength and stiffness measurements have been made in air under normal conditions, with no regard for environment which includes thermal and chemical conditions as well as atmospheric conditions. Some environments may appear to have little or no effect on the strength properties of an unstressed plastic part; however, this same environment may have a marked effect on the strength of the same plastic part under stressed conditions. Materials with high water absorption may lose up to 20-percent of their strength at very high humidities, in addition to changing in dimensions. In view of these circumstances, it is imperative for the design engineer to utilize data obtained from testing the part under simulated environmental conditions for the given application of the part.

Many factors affect the design strength and properties of plastics; for example, the method of molding. The tensile strength of a molded part is greater along the flow lines than across them, an effect explained by orientation of the molecular particles (anisotropism). Another important factor is fatigue, which is characterized by failure or loss of mechanical properties of a part after repeated stress or strain applications.

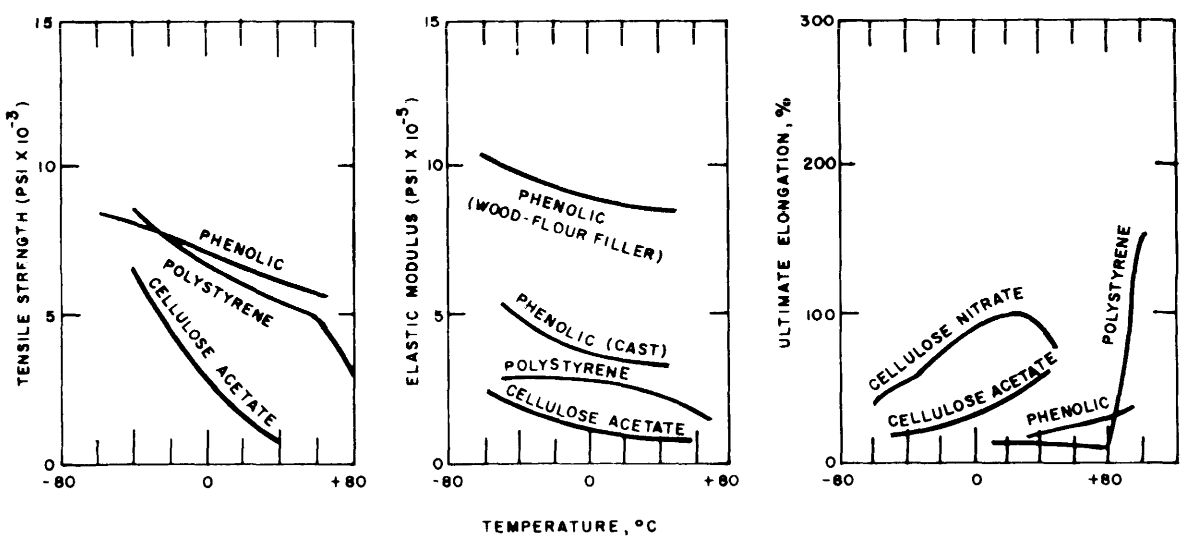


FIGURE 6. Representative Effects of Temperature on Tensile Strength, Elastic Modulus and Ultimate Elongation of Plastics

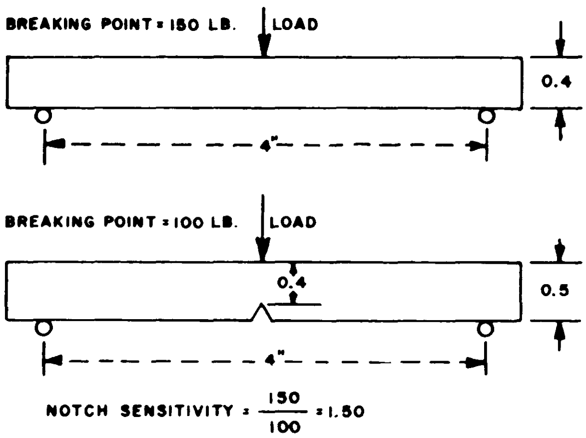


FIGURE 7. Effect of Notch on the Flexural Strength of Plastics

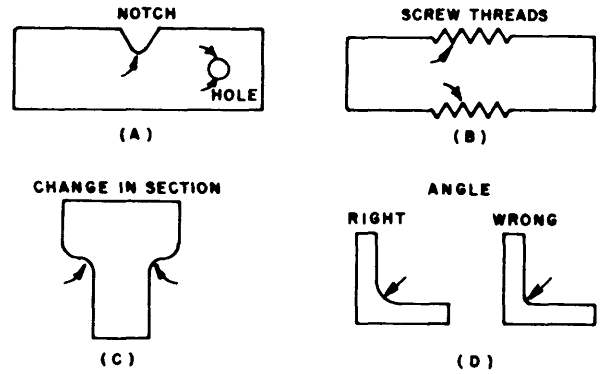


FIGURE 8. Notch Effect and its Contribution to Weakness of Plastic Components

Fatigue data is generally defined as the number of cycles of stress or strain needed before the material fails at a given stress or strain level. The fatigue endurance limit is the stress below which, for practical purposes, the material will never break. For many thermoplastics, the limit is between 20 and 35 percent of the materials static tensile strength. Thus, in designing a structural unit subject to vibration, it must be designed to the maximum stress permitted by the fatigue limit, rather than simply below the material tensile strength.

Another important factor to be considered by the designer is the notch sensitivity of a material, which is defined as the ratio of the strength of an unnotched sample to that of a notched sample of equal depth behind the notch (see figure 7).

The notch in the lower specimen in figure 7 induces a high local stress concentration and causes the specimen to break at a lower flexural loading than if the specimens were unnotched. Holes, threads, corners or angles at changes in section act to reduce flexural strength in the same manner as notches. Therefore, their importance in respect to design and material selection is obvious. Consider two materials with flexural strengths of 12,000 and 9,000 p.s.i., respectively. Assume the respective notch sensitivities, for a notch radius of 0.010, to be 2.0 and 1.0. The effective flexural strength in a member containing such a curvature will then be 12,000/2 or 6,000 p.s.i. for the first material, and 9,000/1 or 9,000 p.s.i. for the second material. In figure 8, arrows indicate points of stress concentration and weakness.

Simple design rules may be stated as follows:

(1) avoid notches, corners, holes, angles, and changes in section whenever possible: and

(2) when such discontinuities must be present, minimize notch effect by making radii of curvature as large as possible (see figure 8 (d)), and use the materials of construction on the basis of nominal strength divided by the notch sensitivity for the notch radius employed.

Impact Resistance and Toughness – Impact resistance is the ability of a material to resist breaking under a shock loading, or a stress delivered at a high rate of speed. Tough materials are ones that are difficult to break. Impact implies a very high rate of loading, but toughness is not related to any particular rate of loading. The designer must consider a broad spectrum of velocities which might be responsible for failure of the part.

Since the strength of plastics are time dependent, it is important to (1) know the velocity at which the object is most likely to receive a blow, and (2) the relative resistance to impact at that velocity of the materials being considered for the application. The velocity of some typical impact blows is shown in figure 9.

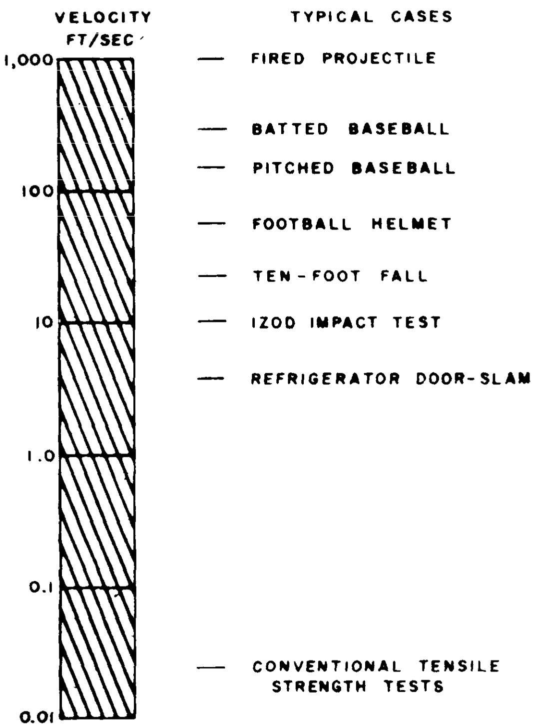


FIGURE 9. Illustration of Typical Velocities of Various Projectiles Against Which Plastics Provided Impact Resistance

The geometry of the part, the manner in which the impact blow is delivered, and the degree and distribution of molecular orientation incurred during molding of the part will influence the toughness or impact resistance. Simple tensile tests conducted over a range of velocities from the conventional (0.2 to 20 inches/minute) to very high speeds in the impact range (up to 10,000 inches/minute), provide a reliable basis for comparison of the relative toughness or impact resistance of plastics; these provide a useful screening tool for materials that might be used. The tests also provide a basis for studying orientation effects; however, since the amount and distribution of molecular orientation varies from part-to-part, studies of this nature should be made on preproduction samples. Although impact strengths do not predict performance in service in the same analytical manner as tensile, compressive and fatigue strengths, they are useful for qualitative estimates of ability to stand up after handling and general wear and tear.

Hardness, Scratch Resistance and Abrasion Resistance – These properties require separate evaluation for each application. Generalized test data is usually meaningless, except as relative performance indices. Hardness tests are most commonly used to approximately indicate cure of thermosets. It is usually desirable to produce a limited number of finished parts and test them under conditions likely to be encountered in service, to be certain of satisfactory performance.

12. Thermal Properties. The design of plastic components for use at elevated temperatures, requires a knowledge of their aging characteristics and load-bearing behavior under these conditions. The material selected must be able to support the design load, without objectionable creep or distortion. In addition, the material must not suffer aging or degradation, to the extent of mechanical or visual failure, during the expected service life.

Heat Resistance – It is common practice to obtain a single deflection temperature (temperature at which an arbitrary deformation of 0.01 inch is obtained) at 66 p.s.i. for semi-rigid materials and 264 p.s.i. for rigid materials. For design purpose, data generated by this type of testing can lead to serious misinformation, because the actual loading conditions are not used and the ranking may be changed. Therefore, comparisons of deflection temperatures should be made at the approximate fiber stress level expected in the application. In figures 10 and 11, the deflection temperature versus fiber stress, at 0.01 inch and 0.04 inch allowable deflections, illustrates that the deflection temperature range for the relatively load insensitive material, polystyrene, is rather narrow but exhibits a rapid deflection at the second order transition temperature point of the material. For polyethylene, which is more load sensitive, the deflection temperature range is broad because a gradual deflection occurs with increasing temperature alone. The result is a difference in deflection behavior that is not readily apparent by single point or even single curve analysis.

The maximum safe continuous-operating temperature of a plastic part is that temperature which the material will withstand, over the service life of the part, without blistering, charring, distorting or failing to function as required. A temperature of 20°F. to 40°F. below the "zero-load" deflection temperature, approximates the continuous operating temperature of a material.

The maximum intermittent operating temperature is that temperature to which the materials can be exposed for short periods of time without objectional property effects. A temperature slightly below the "zero-load" deflection temperature approximates the maximum intermittent operating temperatures of material.

If a part is under stress, maximum continuous and intermittent operating temperatures are correspondingly lower. This is especially important for load sensitive material.

Thermal Conductivity – Plastics are excellent thermal insulators and for this reason plastics, unlike metals, are comfortable to the touch when cold. Fillers of a suitable type can be used to improve heat dissipation where required. In cyclicly stressed members, the lack of thermal conductivity is one of the factors determining heat buildup.

Thermal Expansion and Contraction – The high thermal expansion and contraction of plastics is often a major disadvantage in their application. The unequal thermal expansion and contraction of plastics and other materials, such as metals, may cause problems such as buckling, cracking and loosening in assemblies of these materials. Plastics parts, particularly for aircraft, are frequently tested by chilling to -70°F. and then heating to 120°F., often in repeated cycles. This will cause failures in improperly molded or designed parts. Over a large range of temperature, the change of coefficient of thermal expansion must be considered. The thermal expansion coefficient is essentially constant, as long as the temperature range over which measurements are made does not include a transition temperature.

At the first (temperature at which molecular crystallinity disappears) and the second (temperature at which rigid materials turn to rubbery materials) order transition points, abrupt changes in coefficient of expansion take place. It is necessary in design work to use the correct coefficient, or combination of coefficients, for the temperature range in question.

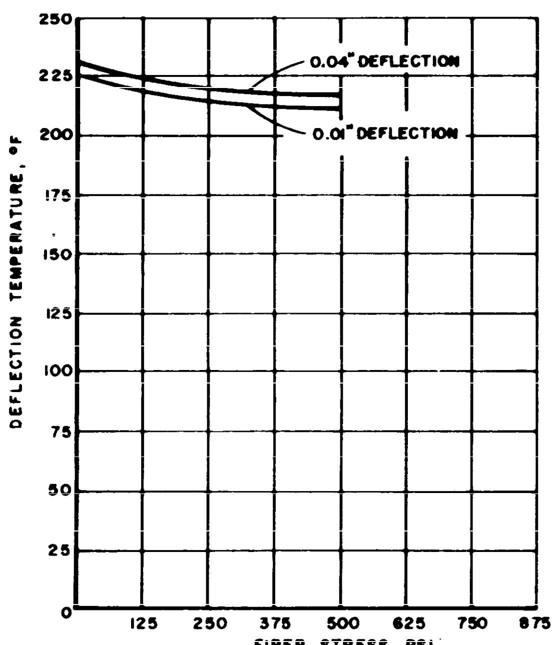


FIGURE 10. Effect of Fiber Stress on Deflection Temperature of Polystyrene

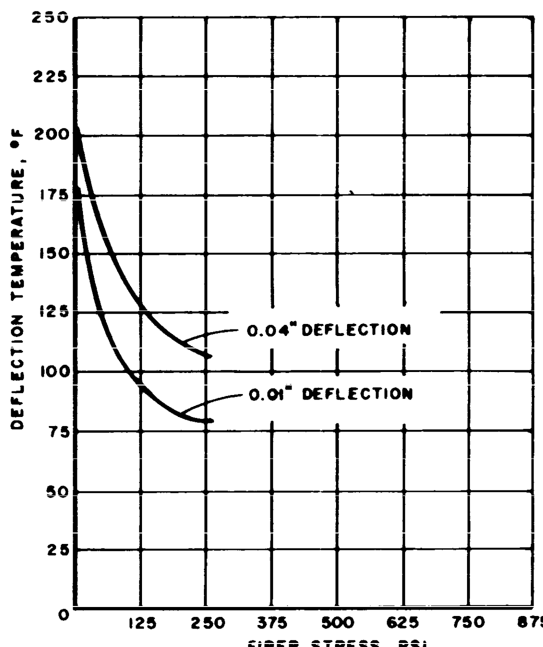


FIGURE 11. Effect of Fiber Stress on Deflection Temperature of Polyethylene

If a given piece is isotropic (does not exhibit directional effects), the cubical coefficient of expansions will be essentially three times the linear coefficient. If the piece is anisotropic (exhibits different directional effects) as found in injection molded parts, the linear coefficient of will be different, in different directions, in the specimen, and the appropriate value must be used in design calculations. Linear coefficients of thermal expansion can be used to calculate the stresses resulting from temperature change in plastic, which is rigidly bonded to another material, by combining the equations for dimensional change and resultant stresses as follows:

$S = E\ (\delta\rho - \delta x)\ \Delta T$

where S = stress, p.s.i.

E = Elastic Modulus

δp = Linear coefficient of thermal expansion of the plastic in./in./^{o}F.

δx = Linear coefficient of thermal expansion of the companion material in./in./^{o}F.

ΔT = Temperature change, ^{o}F.

To complicate matters further, there is an intrinsic shrinkage which many plastics undergo after molding, particularly when heated.

13. Electrical Properties. Generally, plastics are electrical insulators. In practice, the choice of a particular plastic for an electrical application is based on other properties and its processability, as well as its electrical characteristics.

14. Optical Properties. Many applications of plastics require favorable optical characteristics. The designer can select plastics for application in which he may color them, or take advantage of their ability to transmit, reflect, diffuse and polarize light. Once again the choice of a particular plastic will be based also on mechanical, thermal and chemical properties. Both mechanical and chemical properties influence the optical stability of plastics. Chemical decompositions or transformations may cause changes in color and transparency; cracking, scratching or wrinkling of the surface alters gloss and light transmission and cause distortion of transmitted vision; creep alters the focal length of a lens. Many transparent plastics deteriorate optically, upon normal exposure to the atmosphere. Haziness may develop owing to reactions with light, oxygen, the absorption of moisture, the elimination of decomposition products, or the formation of cracks on or under the surface. This deterioration is termed aging. The high frequency components of light are usually most active in causing photochemical deterioration. Aging may be hastened by metallic impurities and catalysts left in the product; it may be accelerated or retarded by different dyes, pigments, stabilizers, or plasticizers. Thus, compounding ingredients must be chosen very carefully when optical properties are of paramount importance.

15. Chemical Resistance Properties. Articles made from plastics are frequently expected to withstand contact, in service, with environments which may not only exert chemical reaction, but also physical reactions. A number of effects may occur upon contact with water, chemicals or solvents in solid, liquid and vapor states. These effects may be summarized as follows: (1) change in size or shape (swelling, shrinkage, distortion); (2) change in color (absorption, extraction and chemical reaction); (3) change in weight (absorption and extraction); (4) change in surface quality (crazing, cracking, loss of gloss, softening); (5) change in physical properties, such as strength and stiffness.

Standardized chemical resistance tests are carried out at 75^{o}F. in the absence of external stress. However, locked-in molding stresses may cause stress-cracking. An effort must be made to segregate such effects from those depending more directly upon the inherent properties of the plastic. The test data generated from these tests is useful in choosing candidate materials for service testing. In the end analyses, for each finished article a specific procedure of testing must be devised to simulate actual service condition, exposures, and contacts in order to choose the best material.

16. Fabrication Ease and Styling. Aside from the combination of good properties processed by plastics, they can be easily converted into end items by a variety of processes (see chapter 4). Combinations with metals, glass filaments, cloth and other filler materials greatly extend the range of useful properties. The styling possibilities with plastics are greater than with any other engineering material. Plastics are setting styling trends through the availability of integral pastel and muted shades, as well as brilliant colors and

metallic finishes. In many applications, the economy of the part may be in proper use of assembly technique. To achieve the maximum in styling, plastics may be heat-joined, cemented, welded, press-fitted, snap-fitted, machined, drilled, sawed, tapped and threaded.

17. Costs. The designer must choose a plastic not only for its optimum properties, but also for minimal costs. Costs of a fabricated article are dependent on raw materials cost, production method, number of parts to be produced, tooling required, finishing inspection, packing, shipping and labor costs and reclaim value of rejects.

Plastic parts are competitive with other materials on the basis of direct material replacement, manufacturing cost, and design simplification. Although many plastics cost more than most metals on a cents per pound basis, the cents per cubic inch picture is reversed due to the lower specific gravity of the plastics.

The extreme low density of plastics provides incentive for space vehicle usage, where weight can be an extremely important design consideration.

Generally, plastics processing techniques convert basic raw material directly into a finished part with a minimum need for post-processing operations. One operator may tend 2 to 19 molding machines, where high production volume is required.

Processing characteristics and physical properties of plastics contribute to design simplification of multifunctional components. Production of parts with transparency or integral color saves money in many cases.

Lubricating properties of some plastics permit built-in bearing surfaces. Corrosion and abrasion resistance and toughness of plastics can be considered for low cost pumps, check valves, and containers of all sorts.

Wherever possible, the designer should discuss his design with an experienced processor or material supplier. They can supply cost data which can be used to obtain the ultimate part price, and their suggestion on basic design configuration may avoid, at an early stage, problems related to performance and production of the part.

Plastics Industry

18. General. The modern plastics industry had its start in the early nineteen hundreds when diversified products of chemical research laboratories first came into commercial use. The industry consists of the following:

Resin Manufacturers – This group usually includes large chemical companies who, through the efforts of their research laboratories and production facilities, convert basic raw materials (such as coal, water, and petroleum) into intermediate chemical materials and finally into the elementary plastic resin.

Filler Manufacturers – This group is diversified and supplies pigments, stabilizers, and other filling materials (such as glass fiber reinforcements) in order to alter the properties of the plastic resin and make it especially suitable for specific end use application.

Processors – This group includes companies engaged in molding, extruding, casting, calendering and laminating the raw materials into solid or semi-solid form.

Fabricators – This group includes companies who further fashion and decorate the product.

CHAPTER 2

THERMOPLASTICS

General Description

19. Categories. Thermoplastics are a relatively large group of synthetic organic materials, and may be divided into three broad categories: (1) rigid load bearing materials, (2) environmental resistant materials, and (3) general purpose materials. These materials can be repeatedly softened and hardened by heating and cooling, and are particularly susceptible to the effects of temperature, time, environment, loading rate and processing. These effects must be charted for each material in order to evaluate engineering usage in relation to end item performance requirements. The thermoplastics categories and the materials found in each category are discussed below.

Table II is a Plastics Properties Chart which gives engineering properties for most of the materials discussed.

20. Rigid Load Bearing Materials. These materials approach Hookean behavior; that is, where stress is proportional to strain. For these materials, reasonable predictability of behavior may be based on the established equations of state for metals. In this category are found: ABS materials, acetals, phenoxies, polyallomers, nylons, polycarbonates, high density polyethylenes, modified polystyrenes, polypropylenes, and rigid vinyls.

21. Environmental Resistant Materials. These materials do not possess outstanding load bearing characteristics and are non-Hookean; however, they are extremely durable in one or more properties such as hardness, wear and abrasion resistance, chemical resistance, heat resistance and weathering. In this category are found: acrylics, chlorinated polyethers, low and medium density polyethylene, flexible vinyls, cellulose acetate butyrates, ethyl celluloses, and fluorocarbons.

22. General Purpose Materials. These materials are neither outstanding in load-bearing or environmental resistance. Their use is based on processing ease and good appearance factors. In this category are found: general purpose polystyrenes, cellulose acetate, and cellulose proprionate.

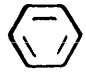
23. Raw Material Costs. Thermoplastics differ not only from conventional engineering materials, but also from each other. There are many readily distinguished families, and in certain families, such as polyethylene there are distinguishable types, such as high, medium and low density polyethylenes.

Choice of a thermoplastic for a given application is influenced by the raw material cost. Variables such as the type of compound, quantity of parts to be made, special processing, design tolerances, fabrication, etc., will also affect the final cost of the material in the part. Because of the rapidly changing cost of raw materials any comparison of resin costs would be impossible in a handbook of this nature.

ABS (Acrylonitrile-Butadiene-Styrene) RESINS

24. General.

$HC = CH_2$



STYRENE

$HC = CH_2$

CN

ACRYLONITRILE

H H

$H_2C = C - C = CH_2$

BUTADIENE

Three basic monomers (acrylonitrile, butadiene, and styrene) go into the creation of ABS thermoplastic, and are combined in varying proportions to form the following commercially available major types of ABS resins. The acrylonitrile gives chemical resistance, the butadiene gives greater toughness and increased impact resistance. The styrene, acrylonitrile copolymer provides good processability strength and rigidity. The main types are:

Medium Impact – This type is a hard, rigid, tough material used for appearance parts which must have high strength, good fatigue resistance, surface hardness and gloss.

High Impact – This type is used for similar medium impact applications, where additional impact strength is required at the expense of hardness and rigidity.

Extra High Impact – This type has the highest impact strength, but further decreases in rigidity, strength and hardness are to be expected.

Low Temperature Impact – This type is designed for high impact strength at temperatures as low as -40°F. Strength, rigidity and heat resistance are lowered.

High Strength and Heat Resistant – This type is widely used, and provides maximum heat resistance (heat distortion point at 264 p.s.i. is about 229°F.). Its impact strength is comparable to the high impact type, but has higher tensile and flexural strength, stiffness and hardness.

25. Engineering Properties

(1) Good long term load-carrying ability over a wide temperature range.
(2) Increase from 66 to 264 p.s.i. drops heat distortion point only 12°F.
(3) Ultimate tensile and tensile yield strength are the same, and range from 3000 to 9000 p.s.i.
(4) Good insulation characteristics; however, flammability of the resin precludes ABS from use as primary insulation.
(5) Low moisture absorption.
(6) Good dimensional stability.
(7) Excellent surface characteristics for electroplating of metals.
(8) High hardness and rigidity.
(9) Good wear and mar resistance.
(10) Good impact resistance down to -40°F.
(11) Low coefficient of friction.
(12) Good appearance retention.
(13) Negligible creep at room temperature, when under several thousand p.s.i. for 10 years.
(14) Approved for food exposure usage.
(15) Excellent resistance to acid, alkalis salts, chlorine gas, bleach, castor oil and many other corrosive materials.
(16) Attacked by solvents such as esters, ketones, and aldehydes.

26. Available Forms. ABS resins are available as compounds for injection molding, blow molding, extrusion and calendering, and as sheet for thermoforming.

27. Typical Applications. ABS resins are used in instrument panels, typewriter housings, portable mixer housings, pipes and fittings, helmets, electrical connectors, refrigerator door levers, knobs and handles, luggage shells, and grills and deflectors for hot air systems.

ACETAL RESINS

28. General. At present there are two basic types of acetals: a homopolymer and a copolymer. In general, the copolymer has better stability and resistance to heat aging, while the homopolymer offers slightly better "as molded" mechanical properties.

29. Engineering Properties.

(1) One of the strongest (tensile strength 10,000 p.s.i.) and stiffest (modulus in flexure 410,000 p.s.i.) thermoplastics.
(2) Highest fatigue endurance limits of all thermoplastics.
(3) Excellent dimensional stability.
(4) Excellent resistance to solvents.
(5) Low coefficient of friction.
(6) Excellent long term stability of physical properties both at room and elevated temperatures.
(7) Excellent recovery from loading.
(8) Good impact and shock resistance, and retains good impact at sub-zero temperature.
(9) Only slightly affected by moisture; high modulus is retained even when continuously immersed in hot water.
(10) Compressive and tensile results show linearity with temperature from -45°F. to 230°F.
(11) Good abrasion resistance and hardness.
(12) Odorless, tasteless, nontoxic and stain resistant to food and beverages.
(13) Very good electrical properties which are little affected by aging, changes in frequency and temperature up to 250°F.
(14) Strong acids and oxidizing agents will attack.
(15) The homopolymer is attacked by strong bases at elevated temperatures more rapidly than the copolymer.
(16) Relatively high permeability to vapors of water, methyl alcohol and acetone.
(17) Resistance to radiation is limited.

30. Available Forms. Acetal resins are available as compounds for extrusion, injection and blow molding. Fiberglass reinforced acetals are also available.

31. Typical Applications. Acetal resins are used as replacements of metals where higher strength of metal is not required, and costly finishing and assembly operations can be eliminated. Typical parts are pump impellers, gears, appliance cases and housings, automobile dash-boards, pipes and fittings, machinery parts, conveyer belt sections, carburetors, and bearings.

ACRYLIC RESINS

32. General. The acrylic resins are based largely upon the homopolymerization of methacrylic or acrylic esters to form the polymer molecule.

33. Engineering Properties.

(1) Crystal clarity.
(2) Outstanding weatherability in optical properties and appearance.
(3) Excellent dimensional stability.
(4) Excellent stain resistance.
(5) Resistant to non-oxidizing acids, salt water, photographic solutions, and chemicals used in treating water.
(6) Good impact strength down to -40°F.
(7) Good resistance to cracking after thermal shock.
(8) Good bondability and heat sealing properties.
(9) Good electrical properties.
(10) Immune to attack by fungal organisms.
(11) Tendency to cold flow.
(12) Low softening point (160°F. to 200°F.).
(13) Low scratch resistance.
(14) Affected by oxidizing acids, ketones, esters, aromatics and chlorinated hydrocarbons.
(15) Low water absorption.

34. Available Forms. Acrylic resins are available as compounds for extrusion, injection molding, blow molding and casting. Sheet and film are also available.

35. Typical Applications. Acrylic resins are used for transparent aircraft or automotive enclosures, radio and television parts, lighting and drafting equipment reflectors, control panels, containers, lenses, optical systems, models, architectural panels, outdoor signs, and displays.

CELLULOSICS

36. General. Cellulose plastics are not synthesized by the usual polymerization of a monomer, but instead they are prepared by chemical modification of the natural polymer cellulose. There are four prominent industrial cellulosics: cellulose acetate, cellulose acetate butyrate, cellulose propionate, and ethyl cellulose.

37. Engineering Properties

(1) The butyrates, propionates and acetates can withstand sharp blows without shattering.
(2) In the thinner extruded sheets, the material can be flexed for assembly purposes.
(3) Acetate, butyrate and propionate provide exceptional clarity.
(4) Acetate, butyrate, and propionate have excellent colorability in a wide range of transparent-to-translucent colors.
(5) Butyrates in ultraviolet inhibited formulation possess excellent outdoor weatherability in optics and appearance.
(6) Propionates and acetates maintain hard glossy surfaces.
(7) Variety of properties may be obtained by modification of resin with plasticizers.
(8) Good fast molding characteristics.
(9) Cellulosics can be modified to provide self-extinguishing characteristics.
(10) Ethyl cellulose (see Table II) has good low temperature impact resistance, performance at a wide range of ambient temperature, good gloss, colorability, clarity, heat resistance and excellent dimensional stability.
(11) Tendency at elevated temperatures for plasticizers to migrate to surface of molded parts.
(12) Soluble in ketones and esters.
(13) Slight softening and solubility in alcohols.
(14) Decomposed by strong acids and bases.
(15) Good resistance to oil and grease.

38. Available Forms. Cellulosics are available for extrusion, injection and blow molding. Sheet and film are also available.

39. Typical Applications.

Cellulose Acetate – Used in photo and x-ray film, safety goggles, shields, small motor housings, optical frames, map overlays, knobs, appliance housings and handles.

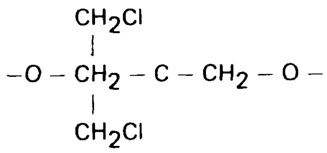
Cellulose Acetate Butyrate – Used in warning lights, light filters, flashlight parts, battery caps, radio and radar parts, instrument panels, protective cases, tool handles, hot-dip corrosion-protective compounds, steering wheels, tubing and developing tanks.

Cellulose Propionate – Used in telephone and radio housings, pens, blister packaging, clear tubular packaging, vacuum cleaner attachments, typewriter and business machine keys.

Ethyl Cellulose – Used in arm rests, cases, helmets, gears, radio cabinets, refrigerators, rods, rollers, slides, sweepers, handles, and tubing.

CHLORINATED POLYETHERS

40. General. Chlorinated polyethers are corrosion-resistant thermoplastics that have proven exceptionally useful in the design and production of equipment for chemical and processing systems. They are characterized by the following molecular structure:



41. Engineering Properties.

(1) Excellent chemical and corrosion resistance at temperatures up to 275^{o}F.
(2) Retains strength and mechanical properties up to 280^{o}F.
(3) Unusually low water absorption.
(4) Heat distortion at 66 p.s.i. is 285^{o}F.
(5) Heat distortion at 264 p.s.i. is 210^{o}F.
(6) Lower thermal conductivity than most thermoplastics.
(7) Excellent dimensional stability under wet and dry conditions.
(8) Excellent creep resistance.
(9) Attacked by fuming nitric and sulfuric acids.
(10) Self-extinguishing.
(11) Excellent electrical properties.

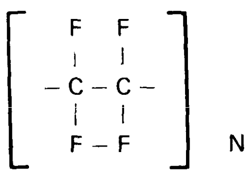
42. Available Forms. Chlorinated polyether compounds are available for injection molding, extrusion and fluidizing bed coatings. Filled compounds offer higher stiffness, heat distortion temperature, and hardness.

43. Typical Applications. Chlorinated polyethers are used in pumps, linings, pipe and fittings valves, tanks and meters.

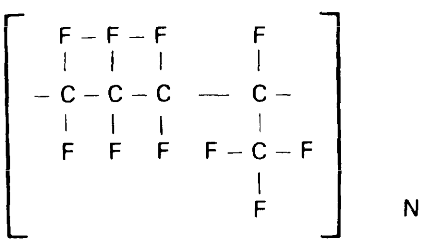
FLUOROCARBON RESINS

44. General. Six classes of fluorocarbon resins are commercially available:

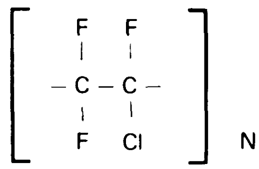
(1) TFE, polytetrafluoroethylene, whose basic unit consists of four fluorine atoms symmetrically attached to two carbon atoms; that is:



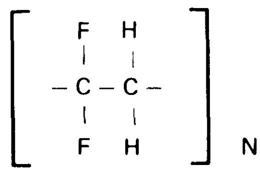
(2) FEP, a copolymer of polytetrafluoroethylene and hexafluoropropylene:



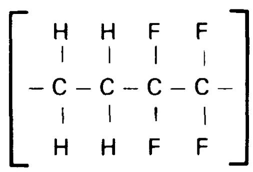
(3) CTFE, polychlorotrifluoroethylene, a resin that contains chlorine as well as fluorine. The basic unit is:



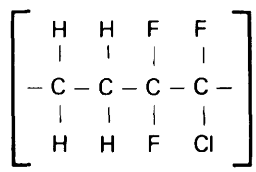
(4) Vinylidene Fluoride, whose basic unit is:



(5) EFTE is a copolymer of ethylene and tetrafluorethylene. The basic unit is:



(6) E-CTFE is a copolymer of ethylene and chlorotrifluoroethylene. The basic unit is:



45. TFE and FEP Resins.

a. Engineering Properties

(1) Almost universal chemical inertness. Only molten alkali metals, gaseous fluorine at high temperatures and pressures, and a few rare halogenated compounds show any effect on these fluorocarbons.
(2) Relatively impermeable to many chemicals.
(3) Exceptional thermal stability, with TFE and FEP being rated for continuous service at 550°F. and 400°F., respectively.
(4) Minimal weight losses of only 0.0002 percent an hour at 600°F.
(5) Strong and tough down to -450°F.
(6) Extremely low coefficient of friction
(7) Excellent release properties; almost nothing sticks to their surfaces. However, they can be bonded to other surfaces with the aid of special adhesives and surface preparations.
(8) Excellent weather resistance, including ultraviolet and ozone; do not absorb moisture.
(9) Outstanding electrical characteristics, such as high dielectric strength, low dissipation factor, and arc-resistance over wide frequency range (60 cps to 50 mc) and the materials temperature range.
(10) Cold flows under heavy loads.
(11) TFE resin has high melt viscosity characteristics, and cannot be processed by conventional melt extrusion and injection molding techniques.
(TFE can be processed by ram extrusion and paste extrusion and by a perform sinter type of molding.) FEP resin can be molded by conventional techniques.

(12) Excellent vibration damping properties at both sonic and ultrasonic frequencies.
(13) TFE and FEP parts return to original dimensions after a deformation. Recovery is complete when the part is raised to sintering temperature for 15 minutes after stress is removed.
(14) Excellent impact strength over a wide temperature range.

b. Available Forms.

(1) TFE resins are supplied as granular powders for compression molding or ram extrusion, as powders for lubricated extrusion, and as dispersions for dip coating and impregnating.
(2) FEP resins are supplied in pellet form for melt extrusion and molding, and as dispersions.
(3) A number of reinforced TFE and FEP materials have been developed to provide low coefficient of friction materials which have good resistance to deformation and abrasion. Fillers, such as molybdenum disulfide, graphite, asbestos, and glass fibers have been utilized to provide increased stiffness, hardness, and compressive strength while reducing elongation and deformation under load.

c. Typical Applications.

(1) TFE resins are used in nonlubricated bearings, chemical resistant pipe and pump parts, high temperature electronic parts, wire and cable.
(2) FEP resins are used in wire insulation and jackets, high frequency connectors and microwave components, coils, gaskets, electrical terminals, tube sockets and terminal insulators.

46. CTFE Resins.

a. Engineering Properties.

(1) Resists attack of all corrosive chemicals and all but a few solvents.
(2) Property retention is good over a temperature range of -400°F. to +400°F.
(3) Excellent mechanical strength and stability.
(4) Good resistance to cold flow.
(5) Low rate of thermal expansion or contraction.
(6) Lowest permeability of any known plastic material to water, water vapor, and other fluids.
(7) Moisture absorption is nil.
(8) Quick-quenched amorphous resin is less dense and more elastic than the slow cooled crystalline resin.
(9) Flexible and tough at cryogenic temperatures.
(10) High volume and surface resistivity, low dielectric constant and good power factor at high frequency ranges.
(11) Excellent ultraviolet and weathering resistance.
(12) Excellent thermal resistance.
(13) Hardness falls off rapidly at 300°F.
(14) Good dimensional stability.

b. Available Forms. CTFE resins are available for compression injection and transfer molding, extrusion and dispersion coatings.

c. Typical Applications. CTFE resins are used in oxygen regulator seals, corrosion resistant liners, liquid oxygen lip and static seals, blood filters, rocket propellant barriers, pump stators, valve linings, corrosive-liquid sight glasses, microporous electrolytic diaphragms, beakers, bottles, centrifuge and test tubes, thermal sintering devices, needle valves, syringes, packings, oxygen compressor piston rings, flowmeter tubes, tank linings, capacitor seals, insulation, electrical connectors, coated wire, radome covers, printed circuits, coil bobbins, tube caps, test-point jacks, tube sockets, resistor sleeves, spaghetti tubing, jacketed cables, valve seats, flexible joints, self-locking bolts, self-lubricating gears and bearings, O-rings, retainer rings, slip rings, rods, tube, sheeting, and infrared windows in missile gage facings.

47. Vinylidene Fluoride.

a. Engineering Properties.

(1) Higher tensile strength, resistance to abrasion, and higher resistance to cold flow under load, (up to about 200°F.) than TFE.
(2) Lower specific gravity than TFE.
(3) Lower service temperature (300°F.) than TFE.
(4) Higher dielectric constant and dissipation factor than TFE (especially at high frequencies).
(5) Slightly higher coefficient than TFE.
(6) Chemical resistance is good, although less than TFE.
(7) Useful temperature range of -420°F. to 300°F.
(8) Excellent weatherability.
(9) Flame resistant.
(10) Attacked by fuming sulfuric acid at room temperature, and by strong sulfuric acid and other sulfonating agents at elevated temperatures.

b. Available forms. Vinylidene fluoride resins are available for compression, injection, transfer and blow molding, extrusion and dispersion coatings.

c. Typical Applications. Vinylidene fluorides are used in processing tanks, valves, tubes, pump lining, and impellers for handling corrosive chemicals or in food processing. Films or coatings can be used in the packaging industry.

48. ETFE

a. Engineering Properties.

(1) Resistant at elevated as well as ambient temperatures to all corrosive chemicals.
(2) Molding rates fast in comparison to other fluoropolymers.
(3) Has high flex life.
(4) Exceptional impact strength, even at very low temperatures.
(5) Good abrasion resistance.
(6) Outstanding electrical properties – dielectric strength high, resistivity is excellent, dissipation factor is low and varies with frequency.
(7) Passes the flammability tests both vertical or horizontal on insulated wire.
(8) Under UL 94, it is rated 94 VE-O; its L.O.I. (limiting oxygen index) is 30.
(9) Good thermal properties, long term continuous service temperature is 300°F., with intermittent service to 400°F.
(10) Will tolerate relatively large dosages of radiation.
(11) Weather resistant.

b. Available Forms. Sold under the trade name, TEFZEL, ETFE resins are available for extrusion and injection molding. Also available as a fiber and film. ETFE is the first fluoroplastic that can be reinforced, not merely filled with glass fiber. Because the resin will bond to the fibers, strength, stiffness, creep resistance, heat distortion temperature, and dimensional stability are enhanced.

c. Typical Applications. ETFE has uses in labware, valve liners, wafer baskets, electrical connectors, sockets and coil bobbins. Also used as electrical insulation on wire for computers and industrial equipment, utilities, military and commercial aircraft, and surface transportation equipment.

49. E-CTFE.

a. Engineering Properties.

(1) Highly impact resistant.
(2) Retains useful properties over a broad temperature range.
(3) High tensile strength.
(4) Retains useful properties from cryogenic temperatures up to 325°F.
(5) Highly resistant to corrosive chemicals even at elevated temperatures.
(6) Essentially resistant to organic solvents except hot amines. It also becomes slightly plasticized in a few halogenated and oxygenated solvents. When solvent is removed the mechanical properties are restored to their original values.
(7) Polymer is self extinguishing.
(8) Good electrical properties.
(9) Good weather resistance.
(10) High flexural life.
(11) Good abrasion resistance.
(12) Relative ease in processing.
(13) Will tolerate relatively large radiation dosage.

b. Available Forms. Sold under the trade name Halar, E-CTFE is available in pellet and powder forms and can be extruded, injection molded, transfer molded, compression molded and dispersion coated, rotationally molded and powder coated.

c. Typical Applications. Due to its good electrical properties E-CTFE is used in wire and cable coatings for computers, air frames and rapid transit equipment. Used also in chemically resistant linings and coatings in mixing tanks and drum liners. Used also as fibers and films.

IONOMERS

50. General. Ionomers are copolymers of unsaturated hydrocarbons and salts of unsaturated acids. At moderate temperatures the polymers behave as cross-links due to the aggregation of the salt groups. At elevated temperatures the aggregates breakdown and therefore the copolymers can be processed as a usual thermoplastic.

51. Engineering Properties.

(1) Limitation in mechanical uses due to upper temperature range (160-180°F).
(2) Excellent transparency levels.
(3) Outstanding abrasion, cut and puncture resistance.
(4) Good flexibility, resilience, high elongation and impact strength.
(5) Excellent low-temperature toughness.
(6) Good dielectric characteristics.
(7) Special types very resistant to environmental stress-cracking.
(8) Under excessive ultraviolet radiation or weathering conditions there is a breakdown of mechanical and optical properties.
(9) Classified as slow burning.
(10) Insoluble in organic solvents at rm. T.
(11) Good water resistance.

52. Available Forms. Ionomer resins are available for extrusion coatings, films, injection molding and blow molding.

53. Typical Applications. Ionomer resins are used in film lamination and food packaging. Also used in golf balls and in all aspects of shoe manufacturing.

NITRILE BARRIER RESIN

54. General. Copolymers of high acrylonitrile (approximately 25% content) are lightweight, transparent and impact resistant. The other comonomers are butadiene and an acrylate ester.

55. Engineering Properties.

(1) Flavor barrier characteristics approaching those of metal and glass.
(2) Easily processed into containers for food products.
(3) Containers transmit no flavor or odor.
(4) Resistant to attack from aqueous solutions, esters chlorinated solvents, weak acids and alkalies and most organic liquids.
(5) Can be disposed of in normal waste channels without affecting the environment.
(6) Affected by sunlight after outdoor exposure for several months.
(7) Equipment must be designed with no high shear regions with processing temperatures from 390 to 420°F.
(8) A high polish is necessary to obtain a clear bottle with a high surface gloss.
(9) Affected by the solvents acetonitrile and certain ketones.

56. Available Forms. Available for blow molding, thermoforming and injection molding.

57. Typical Application. Used for containers in foods and beverages.

POLYALLOMERS

58. General. Polyallomers introduced commercially in 1962 are defined as highly crystalline polymers prepared from two or more monomers namely propylene and ethylene by a polymerization process. They have a degree of crystallinity normally found only in homopolymers. Physical properties of these polymers differ from those of homopolymers, blends of homopolymers and from copolymers produced from the two monomers by other polymerization processes.

Formulations are available with high stiffness, medium impact strength and moderately high stiffness, high impact strength or extra high impact strength.

59. Engineering Properties.

(1) Good impact strength.
(2) Good "hinge" properties.
(3) Compared to polyethylene (high density), the polyallomers have greater resistance to distortion at high temperatures, greater dimensional stability, greater stress-crack resistance, greater surface hardness, and lower and more uniform shrinkage.
(4) Film strength is higher than polyethylene or polypropylene.

60. Available Forms. Polyallomer formulation can be injection molded, extruded and thermoformed. Tough parts can be produced without the necessity of rapid cooling which is essential for producing the same type of part from polyethylene and polypropylene.

61. Typical Applications. Polyallomers are used in wire and cable jacketing, textile bobbins, cases with integral hinge, bottles, pipe fittings, bowling ball bags, and fishing tackle boxes.

POLYAMIDES (NYLONS)

62. General. Nylon is the common name for polyamides. Some of the nylons are identified by the number of carbon atoms in the parent diamine and dibasic acid. The reaction product of hexamethylene diamine (a 6-carbon diamine) and adipic acid.

63. Engineering Properties.

(1) High strength and high elongation give nylon a toughness on which many applications depend.
(2) High modulus in flexure.
(3) Good impact strength.
(4) Low coefficient of friction.
(5) High abrasion resistance.
(6) Good resistance to nonpolar solvents, including aromatic hydrocarbons, esters, and essential oils.
(7) Softened by and absorb polar materials such as alcohols, glycols and water.
(8) Unstabilized nylons can be used continuously up to 175°F. Heat stabilized grades can be used continuously up to 250°F. and, with proper design, can be used intermittently to 400°F.
(9) Nylons are attacked by strong acids, strong oxidizing agents, phenols, formic acid, and high concentrations of certain salts.
(10) Good fatigue resistance under vibration conditions.
(11) Good creep resistance.
(12) High moisture absorption causes dimensional changes.
(13) Classified as having self-extinguishing characteristics.
(14) Nylon is adequate for most 60-cycle power applications, but is not an optimum primary insulator.
(15) Excellent wear resistance.
(16) Requires finely dispersed carbon black stabilizers for outdoor usage.

64. Available Forms.

(1) General purpose nylon molding materials are available for extrusion, injection molding, blow molding and casting. Sheet and film are also available.
(2) Molybdenum disulfide, a solid lubricant, is used as a filler for type 6,6/6,6/10 and 6/12 nylons, to improve wear and abrasion resistance, frictional characteristics, flexural strength, stiffness and heat resistance.
(3) Glass fiber reinforced nylons show substantial improvement in tensile strength, heat distortion temperatures, and in some cases, impact strength.
(4) Sintered nylons are fabricated by processes similar to powder metallurgy. The resulting materials have improved frictional and wear characteristics, as well as higher compressive strength. However, tensile strength, elongation and impact strength are reduced.
(5) Nylon 11 and 12 have exceptional dimensional stability because of their low moisture rates and offer complete resistance to zinc chloride.

65. Typical Applications. Polyamides (nylons) are used in gears, arms, and other sliding contact devices; hinges, gaskets, wire insulation, coil forms, high pressure flexible tubing, boat propellers, chemical containers, belting, and wear pads.

POLYARYL ETHER

66. General. Polyaryl ethers are high heat engineering thermoplastics known for their high impact strength.

67. Engineering Properties.

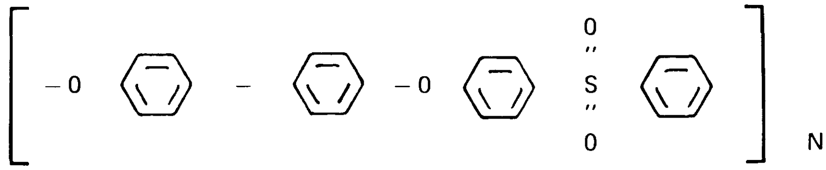
(1) High heat deflection temperature.
(2) High impact strength exceeded only by polycarbonate.
(3) Excellent chemical resistance, resists all but chlorinated aromatics, esters and ketones.
(4) Low shrinkage factor which enables molding without voids or sinks.
(5) Insensitive to moisture.
(6) Can be solvent welded, chrome plated and painted without pretreatment or priming.

68. Available Forms. Polyaryl ethers are available as injection molding compounds.

69. Typical Applications. The easy processing characteristics make polyaryl ethers useful in the appliance and electrical industries. Its excellent paint adhesion and temperature resistance make it useful in oven-baked painted automotive trim. Used also in plumbing fixtures.

POLYARYL SULFONES

70. General. Polyaryl sulfones are useful because of their thermoplasticity and retention of structurally useful properties at 500°F. They differ from polysulfones in that they don't have any aliphatic groups which are liable to oxidative attack. The possible structure is:



The aromatic structure gives the molecule resistance to oxidative degradation and accounts for its retention of mechanical properties at high temperatures. The ether oxygen gives the polymer chain flexibility

71. Engineering Properties.

(1) Very high heat deflection temperature.
(2) Resistance to oxidative degradation indicated by its ability to retain its tensile strength after 2000 hrs. at 500°F. air-oven aging.
(3) Room temperature mechanical and electrical properties are excellent.
(4) At -320°F. material still has some toughness.
(5) Good chemical resistance to most common solvents; highly polar materials such as N,N-dimethylacetamide, and N-methylpyrrolidone are solvents for the material.

72. Available Forms. Polyaryl sulfones are available as compounds for injection molding and extrusion. It is also amenable to cold forming and forging and can be machined easily.

73. Typical Applications. Polyaryl sulfones are used for electrical connector bodies, integrated test sockets, high temperature bobbins and sleeving for high-temperature solderless terminals.

POLYBUTADIENE

74. General. As a result of some chemical and physical improvements polybutadiene is a much more useful product today than it was three years ago. Chemical improvements include additional vinyl functionality together with other functional end groups with low molecular weight resins. Physical improvements include control of stereo regularity, narrow molecular weight distribution, and higher molecular weight forms.

75. Engineering Properties.

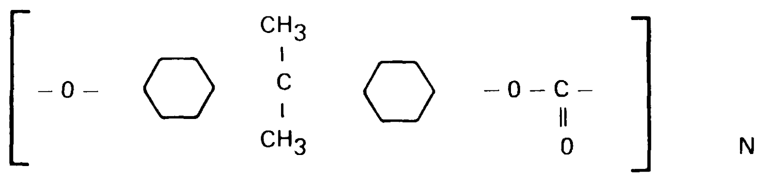
(1) Low molecular weight polymers regarded as intermediates or prepolymers.
(2) Prepolymers need to be reacted with different agents for faster cure.
(3) Cured with peroxide catalysts to produce carbon to carbon bonds at the double bonds.
(4) Fully cured resin processes good dielectric properties, and good chemical resistance superior to polyethylene.
(5) Heat deflection temperature in excess of 500°F.
(6) Different peroxides produce different end products (if a softer cured product is desired, it can be made).

76. Available Forms. Polybutadienes are available for injection and rotation molding, laminates, metal die molding and filament winding.

77. Typical Applications. Combination of butadiene with elastomers is a typical application. Also the combination of butadiene with other plastics that are susceptible to peroxide crosslinking is a large volume application. The forming of alloys between thermoplastics and thermosets has unlimited possibilities.

POLYCARBONATES

78. General. Polycarbonate resins are derived from aromatic and aliphatic dihydroxy compounds. These thermoplastics have exceptional combinations of properties which make them useful in many applications. While many variations are possible in the final structure, the present commercial product is based on bisphenol A. This polymer has the following structure which is similar to the phenoxy resin structure:



79. Engineering Properties.

(1) Excellent rigidity and toughness.
(2) Excellent impact strength over a wide temperature range.
(3) Maintains dimensional stability over a wide range of conditions.
(4) High elastic modulus is coupled with high ductility.
(5) Excellent creep resistance at room and elevated temperatures.
(6) Low water absorption.
(7) Excellent heat resistance; heat distortion temperature ranges from 270°F. to 280°F., when stressed at 264 p.s.i.
(8) High refractive index and good clarity, but adversely affected by weathering because of ultraviolet sensitivity.
(9) Essentially insoluble and stable in water, salts, acids, aliphatic hydrocarbons, animal and vegetable oils and fats, and higher alcohols. Partially swelled by most chlorinated hydrocarbons and by ethyl acetate, acetone and toluene, and soluble in methylene chloride, dioxane, and chlorobenzene. Weak bases have slight effect, but strong bases will hydrolize. Partial solvents such as carbon tetrachloride can be used for stress-cracking detection in molded parts. Polycarbonates are stain resistant and have been approved by the Food and Drug Administration for safe use with all types of foodstuffs.
(10) Unusually good electrical properties, in that only slight changes occur over a wide range of temperatures, frequencies and humidities. However, should not be used when strong arcing is involved.
(11) Inherent self-extinguishing properties.
(12) Fatigue endurance is low and should not be stressed above 10% of its tensile or compressive strength in long term loading.
(13) Good initial coefficient of friction against metal, but may gall under high speeds and load.

80. Available Forms. Polycarbonate molding compounds are available for extrusions, injection molding and blow molding. Film and sheeting with excellent optical and electrical properties are available. Glass-reinforced polycarbonates, at an additional 4.7 cents per cubic inch cost, will double the materials tensile strength, quadruple the flexural modulus, and double the tensile modulus.

81. Typical Applications. Polycarbonates are used in safety shields, lenses, electrical relay covers, housings, helmets, pump impellers, sight gages, coil forms, computer card guides, fuse caps, filter bowls, centrifuge bottles, electrical switch components, electrical connectors, radio knobs, instrument cases, soldering iron handles, baseball catcher's masks, and photographic and x-ray films.

POLYETHYLENES

82. General. Since 1958 polyethylene has been the largest in both sales and production. It has a variety of formulations that have such properties as: toughness from -70° to 200°F; stiffness characteris–

tics ranging from flexible to rigid. It has excellent chemical resistance and can be fabricated by all thermoplastic processes.

Polyethylene varies from type to type according to the particular molecular structure of each type (i.e., its crystallinity, molecular weight, and molecular weight distribution). The molecular structure is in turn dependent upon the temperatures, pressures, catalyst types, modifiers and reactor design used in the manufacture of the polyethylene raw material.

Basically polyethylene is produced by polymerizing ethylene gas with a catalyst in a reactor at some combination of temperature and pressure. In general high pressure gives a branched polymer while low pressure gives a relatively linear one.

The terms low, medium and high density refer to the ASTM designations which have become an industry standard. This along with melt index are the most common means of categorizing polyethylene. The density of the resin is an indication of crystallinity while the melt index is an indicator of average molecular weight. The primary differences among the three types are in rigidity, heat resistance and ability to sustain loads. In general as density increases, hardness, heat distortion point, stiffness, ultimate strength and impermeability to liquids and gases increases. As density decreases, impact strength, mold shrinkage and stress crack resistance increases.

Several additives are incorporated in polyethylene. The most common are slip and antiblock agents used in film materials. Other additives used include dyes and pigments, antistatic agents, flame retardants, ultraviolet light stabilizers, and antioxidants.

Low Density Polyethylene – This material has a density range from 0.910 to 0.925 g./cc. It is flexible (stiffness modulus 13,000 to 30,000 p.s.i.) with high impact strength and relatively low heat resistance. Its maximum recommended continuous service temperature is 140°F. This material was used for underwater cable coating and radar cable and line wire during World War II. Originally all material was sold in cube or pellet form, but now powders are available.

Medium Density Polyethylene – This material has a density range from 0.926 to 0.940 g./cc., a stiffness modulus of 31,000 to 80,000 p.s.i. and a maximum service temperature of 160°F. Some medium density resins are made by blending high density and low density resins together. Film and sheeting is the largest single use for low and medium density polyethylene.

High Density Polyethylene – This material has a density range from 0.941 to 0.965 g./cc., a stiffness in flexure of 81,000 to 150,000 p.s.i. and a maximum service temperature of 180°F. Most high density materials are classified as homopolymers (0.96 densities) and copolymers (0.95 densities). The copolymers are usually butene or hexene copolymers. The homopolymers are stiffer and more suited for thin wall containers where stress cracking is not likely. The copolymers are more stress crack resistant and more suitable for other applications. Major markets include molded containers and blown bottles.

Copolymers – When under 5% of a comonomer is used the product is called modified. When over 5% is used the product is a copolymer. Some important copolymers use vinyl acetate or ethyl acrylate. Both are tougher, softer, more flexible and less heat resistant than low density polyethylene.

In addition polyethylene can be crosslinked by chemical means or by irradiation forming an infusible thermosetting material having relatively high heat stability and good cut-through resistance, as compared with unmodified polyethylenes.

83. Engineering Properties.

(1) Excellent chemical resistance.
(2) Excellent electrical properties which are independent of either frequency or temperature.
(3) Load bearing characteristics are poor.
(4) Flexibility can range from fair to excellent.
(5) Weatherability is not good. Addition of ultraviolet inhibitors or well dispersed carbon black improves weatherability.

(6) Materials are flammable and require special formulation to attain flame resistant characteristics.
(7) Low water vapor permeability.
(8) High permeability to air and gases.
(9) High coefficient of thermal expansion.
(10) Heat distortion temperatures are fairly low.
(11) Tough at low temperatures.
(12) Relatively high mold shrinkage.
(13) Relative ease of processing.
(14) Low melt index polyethylene has better stress-crack resistance than high melt index material of the same density made by the same process.
(15) Chemical resistance increases slightly as density is increased.

84. Available Forms. Polyethylene compounds can be extruded, injection molded, blow molded and centrifugally cast. Film and sheet are available as are systems filled with carbon black (for ultraviolet stability), asbestos (for improved high temperature performance), and glass fiber (for improved mechanical properties). Cellular polyethylene, a foam-like material has improved mechanical and electrical properties which make it an excellent insulator. Rigid foam as well as fine powder are also available.

85. Typical Applications. Polyethylenes are used in housewares, toys, containers, industrial parts, extruded film, sheet, electrical insulation, pipe, coatings, molded bottles and tubes, housings, heater ducts, and battery parts. New markets include refuse bags, grocery sacks, fuel tanks and large containers. These are ecologically pure since their combustion products are primarily carbon dioxide and water.

POLYIMIDE

86. General. Polyimides are usually based on an aromatic dianhydride and an aromatic diamine. However, they can be produced from the reaction of a primary amine with either the free acid, ester or anhydride. Since most resins soften or degrade when exposed to temperatures of 300 to 400°F. the polyimides can stand exposure to temperatures as high as 900°F. Many are difficult to process because of their high or nonexistent melting points.

Depending on the choice of polyimide, they may be thermoplastic, thermosetting or pseudo thermosetting. Polyimides of the A-type class have a distinct crosslinking reaction which converts a fusible polyimide prepolymer into an infusible (thermoset) polyimide. The more conventional condensation polyimides are actually processed in the amide-acid form and are converted to a pseudo thermoset by intramolecular condensation to the imide. Pseudo thermosetting because actual crosslinking may be absent, however the imidized polymer is inherently insoluble and infusible. It is important to differentiate between these various materials whereas currently there are available polyimides that are soluble and/or fusible in their imidized state and these are actually "thermoplastics".

87. Engineering Properties.

(1) Excellent for very high temperature application.
(2) Good radiation resistance.
(3) Can withstand heavy loads and high rubbing velocities.
(4) Continuous service in air at 500°F.
(5) Good wear resistance and low friction qualities.
(6) Good strength toughness and dimensional stability.
(7) Good dielectric strength.
(8) Incorporation of fillers like graphite greatly improves wear resistance and lowers coefficient of friction.
(9) Good chemical resistance. They are attacked by strong alkali and aqueous ammonia solutions. Not suitable for prolonged exposure to hydrazine, nitrogen dioxide or to primary and secondary amines.
(10) Exposure to steam or water at 212°F. produces a decrease in tensile and flexural strength.

88. Available Forms. Polyimides are available as bars, sheets and films, prepregs and molding compounds. They are fabricated by machining, punching of the fabricated forms, and by molding compounds.

89. Typical Applications. Used in jet engines, valve seats and seals, TV cameras, business machines, communication equipment. Also used in applications as soldering fixtures, welding gun components, bushings and sideblocks used around hot processing machinery. Polyimide film is used as insulation for high temperature wire and cable.

POLYMETHYLPENTENE

90. General. Polymethylpentene is produced from 4-methylpentene-1 with Ziegler-type catalyst at atmospheric pressure. Its relatively high melting point and transparency have made it attractive to industry. Comonomers are added to enhance optical and mechanical properties, and to optimize its molding characteristics.

91. Engineering Properties.

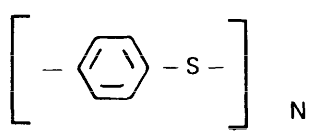
(1) High crystalline melting point of 464°F.
(2) Useful mechanical properties at 400°F. and retention of form stability to near melting.
(3) Transparent with light-transmission value of 90%.
(4) Low density.
(5) Excellent electrical properties.
(6) Behaves similarly to polypropylene in oxidizing conditions and under high-energy irradiation. It is not recommended for continuous use in sunlight or high-energy irradiation.
(7) Its chemical resistance is similar to other polyolefins being attacked by strong oxidizing agents while some light hydrocarbons and chlorinated solvents can cause swelling.

92. Available Forms. Available in transparent or opaque granules for injection molding and extrusion.

93. Typical Applications. Used in laboratory ware and is distinguished by glass like clarity, lightweight and better impact performance than glass. Used in medical ware components where it is required to be subjected to sterilization with steam, hot air, ethylene oxide and high-energy irradiation. Also used in lighting diffusers, lenses and reflectors. Used also in coffee-making equipment and vending machines. Probably the largest application area is in food packaging and catering. It is used as a cook-in food container for air ovens and microwave type heating.

POLYPHENYLENE SULFIDE

94. General. A crystalline polymer with a symmetrical rigid backbone consisting of recurring para-substituted benzene rings and sulfur atoms as:



This chemical structure is responsible for the high melting point (550°F.), outstanding chemical resistance, thermal stability and nonflammability of the polymer.

95. Engineering Properties.

(1) Has no known solvents below 375 to 400°F.
(2) High stiffness and good retention of mechanical properties at elevated temperatures.
(3) Requires special treatment to adhere to metals.

(4) Slurry coating formulations may be applied by spray gun followed by baking at 700°F., for 30 minutes.
(5) At normal temperatures the unfilled polymer is a hard, relatively brittle material, with high tensile and flexural strength. These properties are increased by the addition of fillers, especially glass.

96. Available Forms. Polyphenylene sulfide is available for slurry coating, fluidized bed coating, flocking and injection molding.

97. Typical Applications. Molded items have applications where chemical resistance and high temperature properties are of prime importance.

POLYPROPYLENES

98. General. Polypropylenes joined polystyrene, poly-vinyl chloride and polyethylene as one of the major volume thermoplastics. It offers a balance of properties rather than one outstanding characteristic. It is the first commercial example of a man-made polymer with regular steric or spatial features. This is done with a Ziegler/Natta coordination catalyst. The incoming monomer unit is inserted into the catalyst-growing polymer interface in such a way as to give geometric placement of the methyl groups along the same side of the growing chain. The catalyst and polymerization conditions can be varied to give four main types of polymers: isotactic, syndiotactic, atactic and stereoblock. Commercial polyethylene is generally highly isotactic with only small amounts of atactic material present. The stereoregular structure of polypropylene and its ability to partially crystallize is responsible for its combination of good mechanical properties.

99. Engineering Properties.

(1) Maintains mechanical strength up to high temperatures. Only above 140°C. does it lose stiffness rapidly.
(2) Low temperature properties, e.g., impact strength, can be improved by using different copolymers or small amounts of elastomers, which lower the glass transition temperature.
(3) The chemical and biological resistances are outstanding.
(4) Stabilizers are required to prevent oxidation of polypropylene. With proper stabilization, polypropylene is suitable for severe environments such as electric washing machine agitators and dishwasher parts. Food-grade stabilizers are also available for food packaging applications and pharmaceutical applications.
(5) Stabilizers have been developed which help maintain good mechanical properties in severe environments.
(6) Its balance of rigidity, strength and hardness makes it suitable for parts requiring high stiffness in thick sections, along with flexibility in thin areas.
(7) Load bearing properties significantly affected by time.
(8) Good resistance to environmental stress cracking, does not absorb moisture and is highly resistant to chemical attack and staining. Unaffected by inorganic salts, mineral acids and bases and polar organic solvents. However halogens, fuming nitric acid and other active oxidizing agents attack polypropylene.
(9) High strength to weight ratio.
(10) Lightest of all plastics, means more parts per pounds.
(11) Excellent electrical properties even at high frequencies, heat and humidity.
(12) High surface hardness and abrasion resistance.
(13) Excellent dimensional stability.
(14) Excellent resistance to gas and water vapor.
(15) Aromatic and chlorinated hydrocarbons will soften and swell polypropylene especially at elevated temperatures.

100. Available Forms. Polypropylenes are available as molding compounds for extrusion, injection molding, thermoforming and blow molding. Film and sheet are on the market along with several different

types of filled molding compound. For the most part the filled polypropylenes use talc or glass fibers. These materials offer excellent impact strength and stiffness up to 250°F.

101. Typical Applications. Polypropylenes are used in housewares, containers and closures, unbreakable medical and hygienic equipment which can be sterilized, appliance applications such as washing machine tubs and agitators, radio and television cabinets, pipe and fittings, automotive interior parts, carrying cases with integral hinges, pump impellers, communication wire insulation, coil forms, electrical connectors, extrusion coating and packaging film.

POLYSTYRENES

102. General. Polystyrene is the third most widely used thermoplastic resin surpassed only by polyvinyl chloride and polyethylene. Polymerized to a clear thermoplastic by a free radical agent by three established techniques: bulk, solution and suspension. The mechanical properties can be altered by addition of modifying agents such as rubber (for impact strength), methyl or alpha methyl styrene (for heat resistance), methyl methacrylate (for light stability), and acrylonitrile (for chemical resistance). The high heat resistant materials are produced as copolymers while the high impact materials are produced by blending. Polystyrene can be classified as general purpose or impact types. The general purpose are transparent, clear and brittle. The impact types have shock-absorbing characteristics derived from the 3-12 wt % of polybutadiene.

103. Engineering Properties.

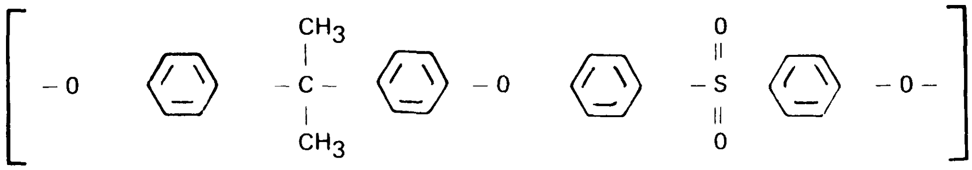
(1) Low resin cost, and fabrication ease and versatility.
(2) Clear, colorless properties permit an almost infinite range of color possibilities which are stable in indoor lighting and can be light stabilized for outdoor use.
(3) Some additives are used as processing aids, some are to extend performance parameters.
(4) Mechanical properties are affected by temperature, time and environment.
(5) Rubber modified polystyrene offers a combination of good rigidity and toughness, and exceptionally good performance in thin walled parts.
(6) Low moisture absorption.
(7) Excellent dimensional stability.
(8) High hardness.
(9) Excellent dielectric properties.
(10) Good clarity.
(11) Rubber reinforcement extends impact strength and elongation.
(12) Good fatigue life.
(13) Material is flammable but burns at a slow rate.
(14) Will pick up dust through static electricity.
(15) Expanded foams have excellent heat insulation and floatation properties.
(16) Even with stabilizers polystyrene is not recommended for long term outdoor exposure.

104. Available Forms. Extrusion, injection, compression, rotational and blow molding polystyrene compounds are available as are polystyrene film, sheet and foam. Glass fiber reinforced polystyrene is also available.

105. Typical Applications. Polystyrenes are used in pipes and fittings, non-magnetic fiberglass reinforced mines, structural and chemical refrigerator parts, automobile interior parts, appliance housings, battery cases, TV picture works, dials, knobs, washing machine filters, packaging and housewares.

POLYSULFONE

106. General. Polysulfone is produced by the reaction between the sodium salt of 2,2 bis (4-hydroxyphenol) propane and 4,4′ dichlorodiphenyl sulfone. The following structure is an example:



The basic repeating structure consists of benzene rings connected by a sulfone group, an ether linkage, and an isopropylidene group. The sulfone group imparts thermal stability and oxidation resistance; the other groups make the backbone of the polymer flexible, imparting toughness to the resin, and making it readily processable.

107. Engineering Properties.

(1) High strength and the highest service temperature of any melt-processable thermoplastic.
(2) Stable and self extinguishing.
(3) High heat deflection temperature.
(4) Long term temperature use from 300° to 340°F.
(5) The addition of glass fibers greatly improves environmental stress-crack resistance.
(6) High thermal stability. Stable in air up to 500°C.
(7) Good chemical resistance. Will be attacked by polar organic solvents as ketones, chlorinated hydrocarbons and aromatic hydrocarbons.
(8) Good electrical properties over wide temperature range up to 350°F., and after immersion in water.
(9) Maintains good performance under physical stress at room and elevated temperatures over long periods of time.
(10) Good creep resistance.
(11) It can be reprocessed without loss of properties.
(12) It is easily colored.

108. Available Forms. Polysulfone resins are supplied as pellets in various grades for injection, extrusion and blow molding and wire extrusion. Glass-filled polysulfone is offered along with sheets and films.

109. Typical Applications. Polysulfone is used in the electrical and electronic area, integrated circuit carriers, housings for meters, switches and electronic components. Also used in automobiles in under-the-hood switches and relay bases. Used in aircraft-cabin interior parts because of its self-extinguishing and low smoke-density characteristics. It is also used for face shields for astronauts because of heat and radiation resistance. It also is used in appliances such as coffeemakers, humidifiers and high intensity lamps.

STYRENE-BUTADIENE

110. General. Conventional elastomers (e.g., SBR, IR, or natural rubber) derive their rubbery properties as a result of permanent joining of polymer chains with sulfur crosslinks during vulcanization. The rubbery and thermo-plastic character of styrene-butadiene block copolymer comes from a network structure held together by "physical crosslinks" that melt out on heating and resolidify on cooling. The melting-solidifying cycle is reversible, and can be repeated many times.

111. Engineering Properties.

(1) High elongation and elastic recovery.
(2) High tensile strength.
(3) Good low temperature flexibility down to -120°F., however they soften with increasing temperature and have a service temperature.

(4) Good frictional properties.
(5) Unaffected by water, alcohol, dilute acids or alkalies. They are soluble in ketones, esters, and many hydrocarbons.
(6) Excellent thermal stability under normal processing conditions (250 to 400°F.).
(7) Scrap can be reprocessed, but preferably is blended with virgin feed, and this may be repeated several times with little degradation or loss of physical properties.
(8) Because of their chemical similarity, thermoplastic rubbers and styrene-butadiene rubbers have similar weather resistance.

112. Available Forms. Material is supplied as pellets ready to use in conventional extrusion, injection molding, or blow molding equipment. It is also supplied as ½ inch rubber crumbs.

113. Typical Applications. Used as adhesives, asphalt products, coatings, packaging of foods, medical and pharmaceutical products, sealants, low-cost rubber items, general-purpose rubber goods, molding equipment, sheeting, belting and tubing.

SPECIALTY RESINS

114. Phosphonitrilic. The phosphonitrilic ring consists of nitrogen and phosphorous in a six-membered ring that has been called "inorganic benzene." Applications range from rubber compound adhesive to diamond grinding wheels.

115. Parylene. The basic member of this class is parylene N (poly-paraxylene) other members have mono or dichloro substitution. These polymers have high melting points (535 to 760°F.), and are insoluble at ambient temperatures in most acids, alkalies and solvents. Parylene is not marketed in polymer form but is supplied as a dimer. It can be used for continuous coatings as thin as 250 angstroms. Used where physical and barrier properties are the most critical considerations.

116. Poly(amide-imide). These polymers are based on the combination of trimellitic anhydride with aromatic diamines. These polymers have found wide commercial acceptance as high-temperature magnetic wire enamels, high performance decorative coatings, laminates and adhesives.

POLYVINYL CHLORIDE

117. General. The vinyls are versatile groups of thermoplastic resins that range in properties from soft flexible sheetings to hard rigid pipes. The term "vinyl" comes from the chemical radical $CH_2 = CH-$, which has many derivatives. When attached to a chlorine atom, it becomes vinyl chloride $CH_2 = CH\ Cl$; when attached to an acetate group, it becomes vinyl acetate $CH_2 = CH\ COCH_3$. Other derivatives are the alcohols, butyrals, formal, and the new heat resistant chlorinated polyvinyl chloride (CPVC). With these derivatives, a great many polymers can be made, either as homopolymers of themselves, or copolymers in combination with another vinyl derivative or other monomeric material.

Pure polyvinyl chloride resin shows a tendency to decompose slowly on long standing in the light, or on long exposure to moderate warmth. This tendency is accelerated at elevated temperatures, or by the action of catalytic material such as traces of iron or zinc compounds. An alkaline material such as barium oxide, or certain organic compounds of tin or lead, can act to stabilize polyvinyl chloride by removing traces of hydrogen chloride chemically as fast as it forms, thus eliminating the autocatalytic effect. Lubricants, fillers, and plasticizers are added to ease processing and for property modification.

118. Engineering Properties.

(1) Polyvinyl chloride and chlorinated polyvinyl chloride (CPVC) retain good strength properties over their temperature range. The CPVC, a high heat resistant material, withstands temperatures about 60°F. higher than other vinyls; for example, at 212°F. the material retains a strength of 2100 p.s.i.

(2) Rigid vinyls withstand many strong acids and alkalies, metallic and ammonia salts, and organic media such as alcohol and aliphatic hydrocarbons. Industrial fumes and salt water do not seriously degrade the property of rigid vinyls. CPVC has excellent chemical resistance even at 212°F. Material can be used with hot acids and alkalies, and a wide variety of other corrosive liquids. Vinyls are not resistant to ketones and esters, and will swell if exposed to aromatic hydrocarbons.

(3) Rigid polyvinyl compounds have good flame retardant characteristics.

(4) Stabilized rigid vinyls have good weather resistance and aging, tensile and flexural strength, hardness, impact and abrasion resistance.

(5) Polyvinyl chloride and CPVC offer dimensional stability, colorability, ease of fabrication and comparatively low cost.

(6) Excellent dielectric strength and resistance to moisture.

119. Available Forms. Vinyls can be extruded, cast, coated, injection molded, blow molded, rotationally molded, and calendered. Film and sheet are available, as are both rigid and flexible foams.

120. Typical Applications. Vinyls are used in pipe and fittings, insulation, electrical wire, valve seats, chemical storage tanks, adhesives, coatings, packaging, house siding, and window sash.

CHAPTER 3

THERMOSETTING RESINS

General Description

121. Characteristics. These materials are a general class, and can be easily distinguished from other plastics by one characteristic property: once they are crosslinked, they do not soften under heat. With the application of heat, those plastic materials classified as thermosetting resins undergo a series of changes that are irreversible. The chemical change that occurs during such heat-processing is known as polymerization. Some thermosets cure or polymerize by a condensation reaction, and some by addition (no by-products given off during heat-cure reaction).

122. Properties. Thermosetting molding and casting materials permit a high degree of freedom for enhancing the existing properties of the basic polymers. With thermosets, use of reinforcements and fillers is the rule rather than the exception. Some unfilled flexible polymer systems are available. Generally, however, the tightly cross-linked, high-molecular-weight thermosetting polymers are inherently weak and easily fractured. Proper types and proportions of reinforcements and fillers, can assure functional designs with retention of the desirable properties of the polymers. These include rigidity, resistance to cold flow, good electricals, elevated temperature capabilities, and a broad range of variation to meet many of the designers specific requirements. Curing cycle flexibility can widen the materials utility range; for example, heat distortion temperature, dimensional stability, and resistance to deformation can be improved by length of curing during casting or molding, or by post-curing. The reinforcements and fillers may be organic or inorganic. They may be in the form of powder, discrete fibers, woven or mascerated fabric. The particle geometry and the effects of processing plays an important part in the end properties of the compound.

Many factors enter into a proper choice of polymer, reinforcement, and filler. The properties of the combination can be determined within a reasonable range, although the relationship between filler and polymer is not a straight-line function. It is essential that the designer work in close liaison with the material suppliers, processors and fabricators in order to take full advantage of the extensive tailoring capability of thermosets. The designer should remember that reinforcement and fillers only modify a polymer; they do not change or impart properties that are not basically present in the resinous material. In addition, compounding can have a reverse effect on other resins properties. Thus, while a formulation may improve mechanical properties of a polymer system, it may at the same time adversely affect the electrical properties. The proper formulation will enhance the most important properties for the application, and have a minimum negative effect on associated factors.

ALKYDS

123. General. The initial reaction in the formation of alkyd (term derived from alcohol and acid) resins is the condensation of a dibasic acid or anhydride with a polyhydric alcohol, to form a partial condensation polymer. The two most commonly used components are phthalic anhydride and glycerin. Solubility in aromatic or aliphatic solvents is developed by introducing into the resin molecule a monobasic acid, usually a long-chain fatty acid. When a fatty acid with a low degree of unsaturation is used (such as coconut fatty acid), a non-drying alkyd resin is obtained; on the other hand, unsaturated fatty acids, such as linseed or soya, give a drying type of alkyd resin. Generally, the fatty acid is introduced by first reacting an oil with glycerin to form a monoglyceride, and then reacting the latter with phthalic anhydride plus more glycerin if required. The formulations for alkyd resins can be extensively varied by the introduction of different polyhydric alcohols and anhydrides. As a result of their excellent weatherability, toughness, adhesion, flexibility, and ease of application, alkyd resins have become the major synthetic resin for use in surface coatings.

Structurally, alkyd resins are modified polyesters, but the latter term is now used almost exclusively for linear polyesters derived from dihydric alcohols and dibasic acids.

Alkyd molding compounds use an unsaturated polymerizable alkyd as their base resin. The unsaturation is obtained by substituting malic anhydride or fumaric acid for phthalic anhydride. This resin is combined with glass fibers, synthetic fibers or minerals to impart desired characteristics. This combination determines physical and electrical properties that alkyd molding compounds cure at high speed, with no water condensation in the cure cycle. In addition, they require low molding pressures. High production rates on lightweight, high-speed presses are achieved.

124. Engineering Properties.

(1) Excellent dielectric strength, arc and dry insulation resistance. At elevated temperatures in combination with high humidities, properties should drop off somewhat.
(2) Low dielectric constant, power factor and capacitance drift (change in dielectric constant with temperature-humidity variations).
(3) Dimensional stability is excellent. Shrinkage, even at elevated temperatures, is negligible.
(4) Suitable for use at 400^{o} without degradation. Some properties will change when tested at elevated temperatures. However, property change is negligible when parts are returned to ambient temperature after long-term elevated temperature exposure.
(5) Molded alkyds resist attack by most organic solvent, but are attacked readily by strong acids and bases.
(6) Excellent fungus resistance.
(7) Chief disadvantages aside from cost are very low impact strength and some difficulty in mass production molding to close tolerances. Alkyds can be formulated with fillers that improve impacts, and with proper mold design mass production of molded parts can be made to close tolerances.

125. Available Forms.

Flakes – These materials contain long glass fibers up to ½ inch in length. The bulk factor is high (5 to 7), and conventional preforming or volumetric-loading cannot be used. Molded fiberglass reinforced materials display high impact strength (up to 12 ft-lb per inch of notch).

Ropes, Slugs and Sheets – Materials are available in rope form of various diameters, coiled in spools, or in straight lengths. Similar materials are available in precut slugs of uniform nominal weight and in rough sheet form. Most of these materials contain sufficient glass fiber to give impact strength to 1 to 3 ft-lb.

Granular Powder – These materials are granular thermosetting molding compounds and can be used on automatic preform machines or automatic molding presses. Their impact strength is generally 0.3 to 0.5 ft-lb.

Putty – These materials are available for encapsulation of electronic components.

126. Typical Applications. Alkyds are used in electrical insulation, vacuum tube bases, automobile ignition systems, radio and television components, transformer components, transformer boards, small switch gear, computer components, circuit breakers, signal light and fuse holders, rocker, blower housings, automotive bodies and boat bodies.

ALLYLICS

127. General. These polyesters are based on the unsaturated allyl alcohol $CH_2 = CH\text{-}CH_2\text{-}OH$. Diallyl phthalates and isophthalates are the most commercially-available allylics. Because of the difunctionality of the acid involved, these materials are all thermosetting resins when fully cured. Allylic resins are normally polymerized by a free radical addition mechanism. Generally, low pressure is adequate for their molding and curing, because no water or other volatiles are formed during their polymerization.

128. Engineering Properties.

(1) Exhibit very low mold and post mold shrinkage, and can be used where exacting dimensional requirements are important.
(2) Moisture resistance is greater than any of the other thermosets. Even when combined with hydrophilic fillers such as glass, the moisture absorption is low.
(3) Insulation resistance is excellent; volume and surface-resistivity of the material surpasses that of any other thermoset. High dielectric strength, good arc resistance, and low dissipation factor are maintained, even under high humidity and elevated temperature conditions.
(4) Heat resistance in continuous service is outstanding; up to 350^{o}F. for diallyl phthalates, and up to 450^{o}F. for diallyl isophthalate.
(5) Isophthalates offer special molding advantages because of good flow and high "hot" strength characteristics.
(6) Excellent color stability up to 350^{o}F.
(7) Resin is completely inert in the presence of metals.
(8) Excellent resistance to corrosion, fungus, and chemicals.
(9) Good resistance to creep at room and elevated temperatures.
(10) With appropriate flame retardance, compounding with diallyl chlorendate can yield a self-extinguishing material.
(11) Good optical clarity.
(12) Glass-fiber-filled types offer highest physical strength of all fillers. Impact strengths reach as high as 18 ft-lb/inch of notch, depending on fiber length. Such compounds are the most dimensionally stable and have excellent properties. Diallyl phthalate compounds filled with "Dacron" synthetic fiber are highly shock resistant and offer excellent moisture resistance. "Orlon-filled" material is similar to the "Dacron" type, except for slightly lower physical properties and heat resistance. "Nylon" filler normally increases shock and wear characteristics at slight sacrifice to moisture-absorption properties. Asbestos filled compounds have good electrical properties and dimensional stability, and are the most economical.
(13) Diallyl phthalate costs about $0.85 per pound, and isophthalate costs about $1.75 per pound. Compound prices made with these materials range from $0.95 to $3.25 per pound. Therefore, the use of this material is restricted to specialized applications where its unusual combinations of properties offset cost considerations.
(14) Diallyl phthalate prepolymer is stable at ambient storage temperatures, even when mixed with catalyst. At molding temperatures, however, polymerization (cure) is normal and rapid. Thus, storage stability of compounded molding materials, prepregs for reinforced structures, or impregnated papers for decorative laminates is almost indefinite. Samples held for as long as five years have remained unchanged, and proved to be as reactive to heat and pressure as before storage.

129. Available Forms. Compression and transfer molding compounds are available in a full range of colors, including pastel shades. Prepregs suitable for bag and compression molding are also available. Allylic monomers are also available for use as crosslinking agents for unsaturated polyesters.

130. Typical Applications. Allylics are used in electrical multi-prong connectors, encapsulating shells insulators, plug-boards, housings, decorative laminates, industrial laminates, heat resistant handles, protective insulating coatings, and air ducts.

AMINO RESINS

131. General. Amino plastics are thermosetting resins obtained by a condensation reaction between formaldehyde and such compounds as urea, melamine, dicyandiamide, ethylene urea and sulfonamide. Since the urea and melamine amino compounds are the most widely used, this section is restricted to a discussion of these two materials.

The properties and end uses of these resins depend to some extent on the ratio of formaldehyde content to urea or melamine. Resins with lowest formaldehyde content are in molding compound production, immediate ratios in bonding applications, and the higher ratio in textile and other fields. The basic resins are usually clear water-white syrups or white powdered materials. The dry materials are usually dispersible in water to colorless syrups. In the case of ureas, the presence of acids is necessary to convert the resins to the insoluble or infusible stage. The acidity is often derived by the addition of materials that liberate acid by reaction with formaldhyde or by dissociation at elevated temperatures; the use of these latent catalysts gives a curable product without sacrificing low-temperature stability.

In most commercial applications, the resin is cured at elevated temperatures. However, certain urea formulations, particularly those used as adhesives, can be cured at room temperature by the use of an appropriate catalyst. The cure of melamines is accelerated by acids but, in contrast to the ureas, the cure of the unalkylated melamines can be accomplished by heat alone, under neutral or even slightly alkaline conditions. The alkylated melamine resins cure only under acidic conditions, but are generally formulated for use in surface coatings with a high proportion of alkyd resins; the residual free carboxyl hydrogen is sufficient for cure at baking oven temperatures.

132. Engineering Properties.

(1) Unlimited range of light stable colors.
(2) Excellent insulation characteristics and high arc resistance.
(3) The ureas and melamines are unaffected in contact with organic solvents such as acetone, carbon tetrachloride, ethyl alcohol, ketones, isopropyl alcohol, petroleum products, fluorinated hydrocarbons, citric, and boric and lactic acid. Detergents (dilute or concentrated) and cleaning agents such as naptha have no effect on the melamines. Melamine-formaldehyde molded products also resist deterioration by boiling water.
(4) Alpha cellulose-filled melamines and ureas are among the hardest plastics available. Hardness, combined with rigidity and abrasion resistance, allows continuous handling of molded products with no apparent effect on physical properties or appearance.
(5) High compressive strengths permit high resistance to deformation under load.
(6) Physical properties of alpha cellulose-filled melamine formaldehydes are relatively unaffected between -70°F. to 210°F. Products show excellent heat insulation and temperatures up to the destruction point and will not cause parts to lose shape. Maximum extended-use temperature for the ureas is 170°F. Below -70°F., urea formaldehyde moldings are more subject to embrittlement and possible breakage. Low temperatures have little effect on electrical properties.
(7) Melamines and ureas show little cold flow, but do expand and contract because of moisture absorption and drying.
(8) Asbestos filled melamines show less humidity shrinkage than alpha and modified alpha cellulose-filled melamines.
(9) Melamines and ureas are subject to initial mold and after shrinkages.
(10) Alpha cellulose-filled melamines have proven satisfactory for outdoor usage. However, the urea formaldehydes are not satisfactory.
(11) Melamine products undergo color changes at temperatures in excess of 210°F., whereas the ureas will change colors at temperatures in excess of 170°F. As temperature is raised to 300°F., pronounced color change and blistering may occur after only ½ to 1 hour. Corrosive effects are more marked in ureas than in melamines.
(12) All ureas and melamines are classed as self-extinguishing.

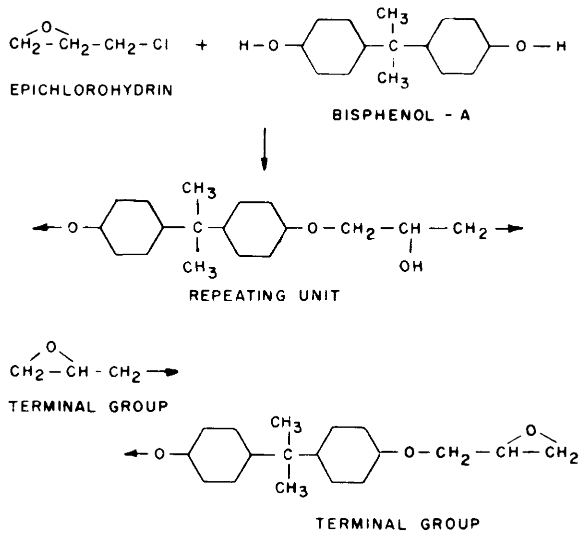
133. Available Forms. The molding compounds are available in a range of plasticities, and the rate of cure can be controlled during manufacture. Thus, the molder can select a grade of material suitable for his particular purpose. Practically all commercial urea molding compounds are cellulose-filled, either alpha-cellulose or wood flour. However, the melamines although predominantly cellulose-filled, are available with an extensive variety of fillers. Urea, melamine and urea-melamine formaldehyde adhesives are available for plywood bonding and the production of pressed boards from sawdust. There are resins also available for the treatment of textiles, papers and surface coatings.

134. Typical Applications. Amino resins are used in closures for glass, metal, and plastic containers, electrical wiring devices, buttons, appliance knobs, dials, handles, light diffusers, toaster bases and end plates,

slide projector parts, dinnerware, food service trays, electrical housings, aircraft, truck and tractor ignition parts, terminal strips, sockets, switch housing, and heavy-duty switch gears.

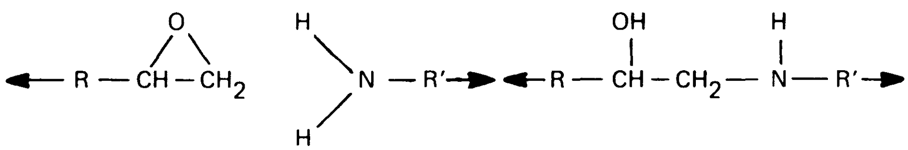
EPOXY RESINS

135. General. The epoxy (ethoxyline) resins are those which contain an epoxide $-CH_2-CH_2-$group. Epoxy resins are generally produced from bisphenol-A and epichlorohydrin as shown below:



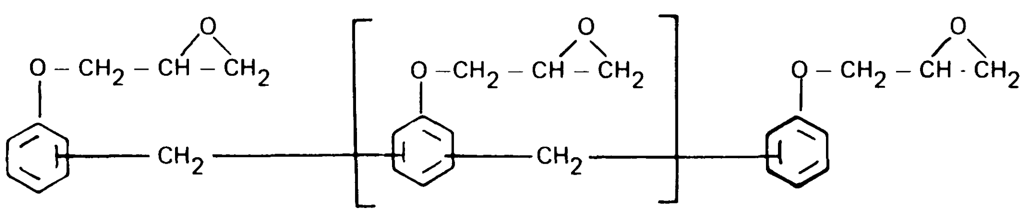
A wide range of these thermosetting resins is now available and varies from a low molecular-weight liquid diglycidyl ethers of bisphenol -A, to hard, tough, high-melting solids.

Each terminal group contains an epoxide linkage, and the repeating units contain secondary alcohols; and it is through these that curing (crosslinkage) of the resin takes place. There are many possible types of curing agents, among them the amines, diamines, and the anhydrides. These enter into the molecular structure as illustrated for an amine, and thus they influence the properties of cured material. These linkages form without any by-products; hence, counter-pressure is not necessary during the cure. Curing is exothermic and can be triggered off by warming or, in some cases, by simple addition of the curing agent.



TERMINAL EPOXY GROUP — AMINE-TYPE CURING AGENT — LINKAGE STRUCTURE

Other epichlorohydrin derived resins are epoxidized novolaks, ρ-aminophenol epoxies and glycidyl esters. Epoxidized novolaks are the most important of this group. Their idealized structure is



Manufacture of the epoxidized novolaks is similar to that of the bisphenol A epichlorohydrin resins with the exception that phenol-formaldehyde novolaks are substituted for bisphenol A. Epoxidized novolaks, however, have a higher functionality, and are characterized by superior heat resistance and high reactivity with hardeners. They find application where performance at elevated temperatures is important.

Although relatively new, cycloaliphatic eposides are becoming very important. Compared to conventional epoxies, the cycloaliphatics have the superior arc track and weathering resistance necessary for exterior high-voltage electrical insulator applications. Because of their high purity, cycloaliphatic epoxy resins also find application in electronic encapsulation systems. Since epichlorohydrin is not used in their manufacture, they do not contain chloride or sodium to contribute to extractable ions. The structure of a popular liquid cycloaliphatic resin is shown in Fig. 3.

Bis (2,3-epoxy cyclopentyl) ether, a cycloaliphatic epoxy that does not contain ester linkages, finds application in the aerospace and hydrospace industries (particularly in graphite and boron composites) because of its high strength.

136. Engineering Properties.

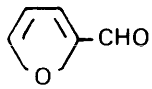
(1) Epoxies have extremely broad capability for blending properties through resin systems, fillers and additives. Formulations can be soft and flexible, or rigid and tough. They are available as solids and liquids in a wide range of viscosities. Systems are available to cure at room and intermediate temperatures. Others require extreme heat for optimum properties. This versatility leads to wide acceptance of epoxies in many diversified applications.
(2) High dimensional stability over long periods of time and humidity, low shrinkage during cure (often less than 1 percent), and subsequent resistance to most environments are characteristics of epoxies.
(3) Epoxies have excellent mechanical and thermal shock resistance.
(4) Most epoxy systems are used up to approximately 275°F., continuous. Some systems retain their properties at continuously elevated temperatures up to 500°F.
(5) Epoxy molding and casting compounds can bond to all metals, most plastics, glass, ceramics, wood, and paper. Epoxies have excellent wettability for adhesion. Adhesive strength of epoxies to a substrate is usually stronger than the internal strength of the resin itself. Adhesion is stable under a wide range of humidity, temperature and chemicals.
(6) Overall physical properties such as tensile, flexural and compressive strengths, are excellent.
(7) Excellent electrical properties, including good dielectric strength, low loss and dielectric constant, and good volume resistivity.
(8) Low temperature properties of epoxies have widespread applications down to -85°F., with minimal shrinkage and cracking.
(9) Chemical resistance is excellent, based on mechanical properties.
(10) Weatherability is good.
(11) Stability under vacuum facilitates impregnation of other materials.
(12) Good wicking action assures thorough encapsulation.
(13) Special compounding can provide fire-retardant formulations.
(14) Improvements have been made on the epoxidized novolaks providing higher heat resistance, improved flow, faster curing and lower cost.
(15) Considerable work is being done to reduce ionic contamination. Some contaminants, such as chlorine and solium can adversely affect the performance of parts in service.
(16) A relatively new form of epoxy, the liquid cycloaliphatics, have superior arc track and weatherability along with the usual epoxy characteristics.

137. Available Forms. Laminating system are derived from liquid, solid and semi solid resins. They are used in solvent or hot melt preimpregnation of reinforcements and produce dry, dust-free, easily handled ready-to-mold stock. Reinforcements include glass asbestos, cotton, paper, synthetic fibers and metal foils.

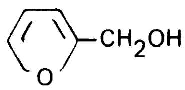
138. Typical Applications. Epoxy resins are used in filament-wound structures including pipes, pressure bottles, oil storage tanks and rocket motor cases; electrical terminals and printed circuit boards, automobile and boat bodies, radomes, aircraft skins, encapsulation and potting of electrical and electronic components, structural adhesives, body solders and sealers, surface coatings,foam thermal and acoustic materials.

FURAN POLYMERS

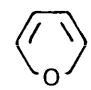
139. General. The terms "furan polymers" and "furan resins" are often used in referring to condensation products in which furfural (1) or furfuryl alcohol (2) is one of the starting monomers. This can be misleading because furan is a specific chemical compound (3).



(1)



(2)



(3)

It is more meaningful to use the correct name of the nomomer employed (e.g., furfural-phenol resin of furfuryl alcohol resin).

The more important furan type polymers are phenol-furfuryl, furfuryl alcohol condensation polymers, urea formaldehyde modified furfuryl alcohol resins, and formaldehyde furfuryl alcohol resins.

140. Engineering Properties.

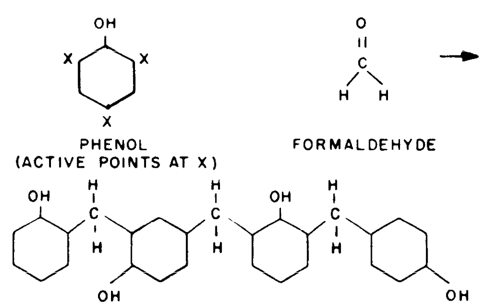
(1) Excellent chemical resistance against acids, alkalies and solvents.
(2) Good wetting properties.
(3) Low viscosity permits high filler loading.
(4) Low viscosity resins penetrate semi porous products to add strength, weatherability and heat resistance.
(5) Relatively inexpensive.

141. Typical Applications. Furan resins are used for adhesives, foundry sand cores, shell molding and for corrosion resistant materials for construction.

PHENOLICS

142. General. The phenolics are the oldest and least expensive of the thermosetting plastics. The average price of general purpose material is in the order of \$0.20 to \$0.25 per pound.

The manufacture of a phenolic plastic part first involves the preparation of the pure resin, which is then blended with dye, filler, and other material to provide the molding powder. The pure resin is manufactured by a reaction between phenol C_6H_5OH, and formaldehyde, HCHO. This condensation reaction is illustrated by accompanying formulas showing production of a typical intermediate resin. Ordinarily, the reaction gives many different products with a range of molecular size and with various types of attachment points and branching chain.



TYPICAL (INTERMEDIATE) CONDENSATION PRODUCT

As can be seen in the above illustration, the formaldehyde and phenol molecules react and produce CH_2 - linkages (methylene bridges) between the phenol molecules. The molecular ratio of formaldehyde-to-phenol in a typical intermediate is somewhat less than 1-to-1. In the formula of the illustration, it is 3-to-4 or 0.75-1. The ratio increases as molecular size increases and approaches 1-to-1, as chain length and formula mass of the intermediate become infinite. As a ratio greater than 1-to-1, the formaldehyde can no longer serve to increase molecular size, but may form bridges between various parts of a giant molecule. This, in a sense, replaces weak secondary forces of molecular attraction with strong primary chemical bonds. These chemical crosslinks hold the parts of the molecule firmly together and render it hard, infusible and immune to attack by solvents. The problem in the chemistry of phenolic plastics is to control the formaldehyde-to-phenol-combination so that the material is soft and moldable when it goes into the mold, yet is hard, infusible, and serviceable as it leaves.

Commercial production, in which this control is achieved, may be either by a "two-step" or a "one-step" process. In the two-step process, the condensation between phenol and formaldehyde is started in the presence of an acid catalyst. The initial ratio of formaldehyde added to the phenol is carefully fixed at perhaps 0.9, so that infusible crosslinked material does not form. The reaction is exothermic and, after the mixture is warmed initially, it proceeds without further heating. When all the formaldehyde supplied has reacted, water formed in the reaction, as well as that carried in with the reactants, is removed by vacuum distillation. The molten resin is then poured from the kettle, allowed to cool and solidify, and broken into lumps for further processing. It is an amber-colored, brittle material called "A-stage" resin or a "novolak". The product is fusible, thermoplastic, soluble in alcohol and ketones, and can be used not only for the production of phenolic plastics but also as a resin for a synthetic varnish of high quality.

To convert this A-stage resin into a molding powder, it is first ground into a fine powder. It is then intimately mixed with reinforcing material (called a filler), a pigment or dye for color, a mold lubricant such as aluminum stearate, and the hexamethylenetetramine $C_6H_{12}N_4$ called "hexa", which decomposes into formaldehyde and ammonia. The mixing (compounding) is best accomplished on heated differential-speed rolls on which the resin melts and is absorbed by the filler. On cooling, the mixture takes the form of coarse granules and is referred to as a molding powder. Powders such as these are molded for 2 minutes at 325°F. and 1500 p.s.i. pressure. As the granules are warmed by the hot mold, the resin melts, and the material flows and fills the cavity. The "hexa" decomposes into formaldehyde and ammonia. The ammonia released then acts as a catalyst for crosslink formation, and formaldehyde begins to react and to form a complex three-dimensional network. The resin first gels and becomes rubbery (the B-stage), and with further crosslinking becomes hard and infusible (the C-stage), after which it can be removed from the mold. The pressure required for molding not only causes the melt to run and fill the cavity, but is also required to overcome the effect of water formed chemically in the crosslinking process. This water is above its normal boiling temperature and would ordinarily be in the form of stream which, because of its large volume, would cause bubbles, voids and porosity. Use of counterpressure prevents stream formation until sufficient crosslinks are established to overcome its effect. The keys to success in molding phenolic plastics are the use of counterpressure to obtain sound moldings, and of "hexa" to control crosslink formation.

In the one-step process, alkali is used as a catalyst, and about 1.2 moles of formaldehyde per mole of phenol is introduced at the beginning. Condensation proceeds more slowly, and is precisely controlled by the heating cycle. The reaction can be stopped at any time by cooling the mixture. To produce a molding resin, the reaction is stopped at the early B-stage and the intermediate is dried and recovered. It is then mixed on the rolls with the filler, color and lubricant. During molding of this mixture, the condensation and crosslink formation is completed and the C-stage produced. The one-step process for the manufacture of the phenolic materials is becoming more widely used because, although careful control is required, it has rate of production advantages with corresponding reduced (unit) overhead costs. The one-step resins usually contain somewhat less residual phenol, catalyst, etc., and so may give less tarnish on inserts and impart less odor or taste. These characteristics may be preferred in some electrical or other applications.

Fillers used in typical phenolic molding powders are fibrous in nature, and their interlocking fibers act to reduce brittleness of the resin and to give pronounced reinforcing effects. Wood flour, ground to 100 mesh, is the most commonly used filler for general purpose molding powders. Asbestos and graphite fillers give the conventional "heat resistant" plastics. Paper and fabric fillers are utilized for high-impact or shock-resistant phenolics. Phenolics can be blended with synthetic rubber based on styrene and acrylonitrile. Phenolic-rubber blends show reduced strength, but will withstand greater deformation without failure. Because of their comparative softness, they are difficult to mold to close tolerances, but this softness makes them useful for complicated shapes with large metal inserts.

The term "phenolic plastics" also includes laminated material where wood, paper, asbestos felt, glass fibers etc., may be impregnated and bonded together at pressures in excess of 1000 p.s.i.

Foamed phenolics are made from liquid resin by a chemical blowing process. Large quantities of liberated gas, such as that between an acid and sodium bicarbonate, make a froth of the resin. The heat release of the reaction brings the resin to cure temperature, while the water produced in the curing process is released in the form of steam; the steam also contributes to the volume of froth.

Furfural resins are based on furfuraldehyde C_4H_4O - CHO, rather than on formaldehyde, and have the unique molding property of having their cure going almost directly from the A-stage to the C-stage without the intermediate gel or rubber-like material. Thus, they flow and fill a mold readily, then congeal rapidly on reaching cure temperature. This is an important advantage in molding complicated objects with metal inserts which must not be deformed or disturbed, as in the molding of large radio cabinets.

143. Engineering Properties.

(1) Among the lowest in cost of thermosetting materials.
(2) Ease of handling and short cure-time assures low processing cost.
(3) Can be molded into final dimensional shape, with little or no finishing operations.
(4) Dimensional retention is excellent over long periods of time at normal atmospheric conditions.
(5) High resistance to deformation under load.
(6) Most phenolics can operate at temperatures up to 300°F.; some special materials are usable to 500°F.
(7) Excellent electrical properties and special filler formulations can be used for electronic applications over wide ranges of temperature and humidity.
(8) Decomposition products at high temperatures are non-corrosive to metals.
(9) Thermal conductivity is low.
(10) Exhibit good impact strength and high flexural modulus.
(11) Weathering resistance is excellent.
(12) Chemical-resistant phenolics are inert to nearly all organic solvents, weak acids and bases.
(13) Most phenolic compounds have no limitation on shelf life.
(14) Colors are limited to black, brown tans, and some other dark pigmented shades.

144. Available Forms. Phenolics resins are available as molding compounds, bonding resins and coating resins. The molding resins are available under six general headings: general purpose, nonbleeding, heat resistant, impact, electrical, and special purpose.

145. Typical Applications.

a. General Purpose

Compound A – Available in brown, and is used for house-wiring devices, camera cases, industrial electrical parts and electrical appliances.

Compound B – Supplied in black, and is considered the most versatile phenolic material. Used for house-wiring devices, automotive electrical components, radio and television sockets, and electrical appliances.

Compound C – Higher specific gravity, and better dimensional stability and rigidity than compounds A or B. Applications include radio tube bases, fuse blocks, and camera cases.

Compound D – Higher impact compound than preceding grades.

Compound E – Formulated for fast-curing cycles in semi-automatic and automatic molding equipment for electrical component parts.

Compound F – One-stage resin type with ammonia free characteristics. Used for instrument cases, particularly where units are hermetically sealed. The ammonia free characteristics of this material eliminate danger of corrosion of metal component parts.

b. Nonbleeding

Compounds G and H – One-stage resin types with very little odor or taste, and used as bottle cap-closures for liquor, cosmetics, and prescriptions.

c. Heat Resistant – These are two-stage resins containing a mineral filler.

Compound I – For applications at approximately 300°F. Used for heater plugs, utensile handles, and toaster handles and bases.

Compound J – For service applications to 500°F.

d. Impact

Compound K – Used for many electrical applications requiring strength, and for housing on small electrical tools.

Compound L – Glass-filled materials with exceptionally high impact strength. Used for missile insulations, soldering gun handles, instrument housings, automotive-transmission pump gears.

Compound M – Two-stage resin designed to meet military specification MIL-M-14 F, Grade CF1-5. Used in small motor housings, sander frames and heavy duty electrical components parts.

Compound N – Two-stage resin formulated to meet military specification MIL-M-14 F Grade CFI-10.

e. Electrical.

Compound O – Two-stage resin type, crack-resistant. Used around metal inserts in automotive ignition systems. Widely used for distribution caps, coil tops and rotors.

Compound P – Two-stage electrical type containing mineral filler. Used in electrical component parts of computers, aircraft, guided missiles and communications instruments, where exceptionally low electrical-loss characteristics are desired.

Compound Q – Two-stage type with good impact properties and exceptional crack resistance. Used in tool housing, automotive ignition system, computers and electronic parts.

Compounds R and S – Diallyphthalate resin modified phenolics. Compound R contains orlon filler, and S a mineral type filler. Used for absolute reliability of insulation in hot, cold, wet or dry conditions. Used for electrical instrumentation, computers, missiles, television and underwater cable systems.

f. Special Purpose.

Compound T – One-stage resin type resistant to soap, detergents, and mild chemicals. Applications include, rayon processing equipment, vaporizer parts, ink wells, and soap dispensers.

Compound U – One-stage resin type with high impact resistance and good chemical resistance. For applications such as pump housings, kitchen-sink sprays, and shower heads.

Compound V – Two-stage resin type with exceptional resistance to chemicals and water. For applications such as washing machine agitators, automotive pump impellers and washing machine pump impellers.

POLYESTERS

146. General. The polyester resins are those with ester $(- \overset{O}{\overset{\|}{C}} - O -)$ groupings as the key links in their molecular chains. They are made by the condensation reaction with a dialcohol and a diacid as starting materials. These resins are classified into three general types: unsaturated polyester, high temperature aromatic polyester and thermoplastic aromatic polyesters.

147. Unsaturated Polyester. This linear polyester is produced from an unsaturated dibasic acid and a glycol. Usually a saturated dibasic acid is employed with an unsaturated dibasic acid to modify the degree of unsaturation and thereby the reactivity of the resulting resin. The unsaturated intermediates are commonly maleic anhydride and fumaric acid; the saturated acids are phthalic anhydride, isophthalic acid and adipic acid; the glycols are propylene glycol, ethylene glycol, diethylene glycol dipropylene glycol.

The usual crosslinking agents are styrene, vinyl toluene, methyl methacrylate, α - methyl styrene, and diallyl phthalate. Conventional inhibitors are hydroquinone and t - butyl catechol.

a. Engineering Properties.

(1) Resins can be formulated to have a wide range of physical properties.
(2) Resins can be brittle and hard, tough and resilient or soft and flexible.
(3) Viscosity at room temperature may range from 50 to 25,000 cps.
(4) Fire retardance can be achieved.
(5) Good chemical resistance.
(6) Good resistance to weathering.
(7) Added polymers can eliminate shrinkage.

b. Available Forms. Unsaturated polyesters can be used in many techniques such as open mold casting, hand layup, sprayup, vacuum bag molding, matched metal die molding filament winding and injection molding.

c. Typical Applications. Used extensively in furniture applications. Finished product looks like wood. Used for bowling balls, simulated marble shirt buttons, boats of all kinds, auto bodies, motor homes and playground equipment.

148. High Temperature Aromatic Polyester. The high temperature aromatic polyester shows excellent stability to air at over 600^{o}F and has the potential of being fabricated by rapid forming metallurgical-type processes. The structure is characterized by a linear repeating chain of p-oxybenzoyl units.

a. Engineering Properties.

(1) Polymer has self lubricating characteristics.
(2) Good thermal conductivity.
(3) Good electrical insulating properties.
(4) Good solvent resistance.
(5) Material undergoes a crystal-crystal transition at 325 to 360^{o}C.
(6) Machinability of molded shapes is excellent.
(7) Thermal stress reduced by adding 18% Al_2O_3.

b. Typical Applications. This polymer is used for self lubricating bearings, seals rotors or vanes of processing pumps where wear resistance and corrosion resistance are critical. Useful for electrical insulation and handles and slip-free coatings for frying pans and piston rings for automobile engines.

149. Thermoplastic Aromatic Polyesters. The thermoplastic polyesters currently available are products of terephthalic and isophthalic acids and a glycol. Poly(ethylene terephthalate) is used almost exclusively for film and fibers. The product of terephthalic acid and 1,4-butanediol is a readily moldable, translucent, crystalline material. A polymer of terephthalic and isophthalic acids and 1,4-cyclohexylene dimethanol, also readily moldable, is noncrystalline and transparent.

a. Engineering Properties.

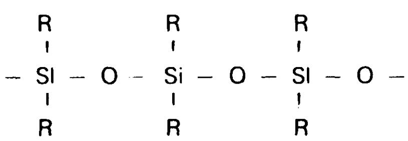
(1) Crystalline polymer useful under light loadings up to 300°F. or higher. Glass-fiber-reinforced variations useful above 400°F. for short periods.
(2) Both crystalline and noncrystalline polymers are tough even at low temperatures.
(3) Surface hardness, lubricity, and abrasion resistance of crystalline polymer are outstanding.
(4) Crystalline polymer has excellent resistance to water and most chemicals.
(5) Dimensional stability of both types of polymer is excellent.
(6) Noncrystalline polymer has negligible color and excellent clarity.
(7) Crystalline polymer has excellent strength, stiffness, and creep resistance.
(8) Both types of polymer have good dielectric properties at power-line frequencies.
(9) Sheets of noncrystalline polymer can be thermoformed readily.
(10) Crystalline polymer has glass-transition temperature near 110°F., melting point near 435°F.
(11) Noncrystalline polymer has glass-transition temperature near 180°F.
(12) Noncrystalline polymer is lawful for use in contact with food under USFDA regulations and is very resistant to high-energy radiation.
(13) Available in formulations classified by Underwriters' Laboratories, Subject 94, 94VE-O (formerly SE-O by UL Sub. 94).

b. Available forms. Thermoplastic polyesters are produced in pellet form for injection molding, general-purpose extrusion, film extrusion, and extrusion coating. The noncrystalline polymer is also available as powder for electrostatic-spray coatings, where it offers good adhesion to properly prepared metal without a primer. The crystalline material is offered reinforced with glass fibers for extra strength and short-term, high temperature resistance. The crystalline material also available in grades with special flammability characteristics. Available color range is very wide.

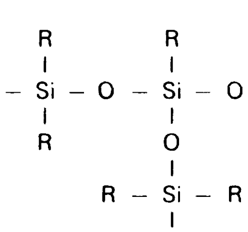
c. Typical Applications. Pump components, gears, spray nozzles, battery clamps, electrical tools, alternator components, electronic equipment, control knobs, sunglass lenses, medical apparatus, and others.

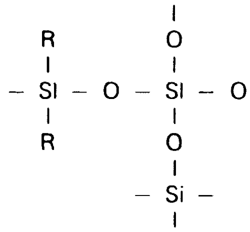
SILICONES

150. General. Probably no class of synthetic materials have found so many diverse and seemingly unrelated applications as the silicones. Chemically, the silicones are organopolysiloxanes. The alternating silicon and oxygen atoms which are located in the backbone (below)



of the molecule, are common to many minerals such as quartz and mica. The pendant R groups attached to the silicon atoms are usually simple hydrocarbon radicals such as methyl, phenyl, or vinyl; recently, more complex groups such as cyanoethyl and fluoroalkyl have also been introduced. The length of the chain, and thus the molecular weight, can be varied from only a few to several thousand atoms, producing a variety of materials ranging from low viscosity fluids to semi-solids. It is also possible to vary the molecular architecture by producing branched polymers shown below.





Chain stopping groups, which were omitted in these structures, are most commonly $(CH_3)_3$ SiO- and HO-. The latter functional group can be utilized for subsequent crosslinking reactions.

A variety of ingredients may be added to such polymers, to further modify their physical form and properties. The fluids may be emulsified; or soaps or inert fillers may be added to form greases. Pigments, fillers and fibers may be added to form resin compounds. Vulcanizing agents and reinforcing fillers are added to very high molecular weight fluids to prepare rubber stocks.

151. Engineering Properties.

(1) Most silicone-rubber molded parts remain useful from -70°F. to 500°F.; many are serviceable from -140°F. to 600°F., continuously, and up to 700°F. for intermittent use. Silicone rubber materials are used at much higher temperatures for brief periods for ablative service. The silicone rubbers are especially useful for low-temperature service because they do not employ plasticizers to maintain rubberiness. Thus, they are not limited by the leaching of plasticizers in solvents or oils, or by separation of plasticizers in long-term and cold weather service. General purpose compounds can be used for long periods at -75°F. Special low-temperature compounds exhibit brittle points below -150°F., and are generally serviceable at -120°F. to -130°F.

(2) Long-term stability and resistance of silicone rubber to tough environmental conditions are without equal among elastomers. They are highly resistant to oxidation and deterioration caused by heat aging, in addition to their serviceability at very low and very high temperatures. They have excellent resistance to oils and chemicals, superior long-term stability against weathering effects, good radiation resistance as compared to other elastomers, and excellent resistance to water and steam.

(3) Silicone rubbers are characterized by high dielectric strength, low dissipation factor and dielectric constant in the 2.9 to 3.6 range. These properties show little change with thermal aging, and with frequency and temperature variations. Silicones also resist moisture, ozone and corona; these are common causes of insulation failure at high voltages and/or high altitudes. Silicone rubber insulation, unlike organic insulation, shows little tendency to form conductive paths when subjected to arcing.

(4) Most silicone rubbers show low compression set over useful temperature range.

(5) Silicone rubbers are available in durometer hardness ratings from 25 to 80, tensile strengths to 1500 p.s.i., and elongations to 800 percent.

(6) Parts, tubing and cable jackets can be shrunk into place by heating briefly at 300°F. This heat-shrinkable rubber has good ablative properties.

(7) Silicones are easily bonded to metals, ceramics, and plastic substrates, as well as to each other. The bonds remain tough and flexible up to 500°F.

(8) Silicones are physiologically inert, odorless, tasteless, and non-toxic.

(9) Solvents such as benzene, toluene, gasoline, and carbon tetrachloride cause excessive swelling of silicone rubber compounds.

(10) Gas permeability is higher than other organic rubbers, but is subject to less change with temperature variations.

152. Available Forms. Silicones come in a variety of forms, some of which are listed below:

(1) Rigid thermosetting, laminating and molding resins.

(2) Foaming powders and liquids.

(3) Encapsulating resins range from non-flowing gels to rigid, dimensionally stable structures.

(4) Sheets.
(5) Adhesives.
(6) Greases.
(7) Emulsions.
(8) Resin solutions.
(9) Sealants.
(10) Coupling agents.
(11) Oils.
(12) Rubber tubes and shapes.
(13) Room temperature vulcanizing compounds.

153. Typical Applications. Silicons are used in bonding, sealing and pressure sensitive adhesives; waterproofing of brick and masonry, glass fiber finishes, liquid springs, cosmetics, damping fluids, defoaming agents, dielectric oil and greases, insulating varnishes, potting and embedding compounds, fluidized bed coatings, fabricated parts including glass laminates, rigid and rubber molded parts, diffusion pump fluids, electrical insulation of all types, foams, O-rings, jet fuel hose, gaskets, seals, heat transfer fluids, lubricants, polish ingredients, paper coating, protective coatings, paint additives, release agents, tapes, flexible molds, textile finishes, leather treatments, laminates for glass in supersonic aircraft, radomes, and shrink type insulation for cable and wire harnesses.

URETHANES

154. General. The basis of urethane chemistry is the reaction of an isocyanate group with the hydrogen of an hydroxyl group, whereby the reactants join through the formation of urethane linkages as depicted below:

$$-OH \quad + \quad O=C=N \quad \longrightarrow \quad -O-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle H}{|}}{N}-$$

HYDROXYL GROUP	+ ISOCYANATE	→	URETHANE LINKAGE

Depending on the type of raw materials chosen and in the manner in which they are combined, the products created can take the form of elastomers, foams and coating resins.

155. Foams. (see also par. 254) Generally, flexible urethane foams are prepared commercially from polyether or polyester resins, diisocyanates and water in the presence of catalysts. The reaction between water and the isocyanates liberates carbon dioxide which functions as the blowing agent to create an open cellular structure.

Rigid foams are manufactured by incorporating fluorocarbon flowing agents (e.g., monofluorochloromethane, difluorochloromethane, etc.) with the reactive polyol and isocyanate combination. The exothermic heat-of-reaction causes the high molecular-weight fluorocarbon gases to boil, and the resulting vapor creates a closed cell foam structure.

By juggling reactants, catalysts, and emulsifiers, either rigid or flexible foams with a wide range of properties can be created.

Resins used with the polyisocyanate may be classified as: (1) polyether urethane foams (based on polyfunctional propylene ether glycols); (2) polyester urethane foams (based on chemically saturated polyesters); and (3) castor-oil urethane foams (based on castor-oil derivatives).

The manufacturing process may be classified as: (1) one-shot forms (all raw material combined in one step); (2) prepolymer foams (isocyanate combined with polyester or polyether, then foamed by the addition of catalysts and blowing agents); and (3) semi-prepolymer foams (isocyanate first combined with part of the resin then mixed with the remaining resin and foamed).

a. Engineering Properties of Flexible Foams.

(1) Cell structure is open or closed, and ranges from 0.015 to 0.25 inches.
(2) Poor absorbers of moisture, but may hold water mechanically.
(3) The polyether type is more flammable than the polyester type; but both are made self-extinguishing by the addition of flame retardants.
(4) Can be pigmented to produce any color, but all colors are yellow when exposed to air and light.
(5) Solvents and corrosive solutions decrease tear and tensile strength, and increase swelling. Swelling is not permanent if foam is dried by evaporation of solvent. Strong oxidizing acid and bases completely destroy the foams.
(6) Accelerated hydrolysis, drying, and high temperature aging have no serious effect on urethane foams. Ultraviolet light will make foam surface friable, but tensile strengths are not appreciably changed.
(7) The fine pore and open cell structure make the flexible urethane foams effective sound absorbers in thickness greater than one inch.
(8) Flexible foams are good energy absorbers, and therefore have good cushioning properties.

b. Engineering Properties of Rigid Foams.

(1) Cell structure is similar in size and uniformity to flexible foams, but the cells are approximately 90 percent closed. Therefore, water absorption is low.
(2) Can be made to be self-extinguishing.
(3) Excellent low temperature and high temperature insulating characteristics.
(4) High strength and low density.
(5) Good dimensional stability.
(6) Limited swelling in organic solvents, but recovers after removal from solvent and drying.
(7) Attacked by strong acids and bases.
(8) The rigid fluorocarbon blown foams have unusually low thermal conductivity. Aging increases the thermal conductivity; however, this increase can be eliminated by protecting the exterior with an impervious finishing material.
(9) Good electrical properties.
(10) Good adhesive properties to other materials.

c. Available Forms.

Slab Stock – Produced in large buns up to 80 in. by 30 in. by 40 ft. These are converted into sheets or other forms, or are fabricated directly into almost any shape.

Molded Foam – These foams are molded directly into desired shape.

Foam-in-Place – The reactants are mixed, poured in odd-shaped or hard-to-reach areas and allowed to foam. This places the foam where needed, forms a strong adhesive bond between foam and container, and eliminates further fabrication. Foaming-in-place and molding are limited by cavity size that can be filled with one pour. Molds withstanding up to 4 p.s.i. surface pressure are usually required.

Spray – Rigid foam reactant mixtures are effectively sprayed by two-component spray units to coat odd-shaped but open areas. This gives physical strength as well as insulation.

Froth – Liquid foam reactants are combined under pressure with a liquid which will vaporize when the pressure is lowered. This produces a stable froth which can be moved, molded, or further expanded before gelation into a permanent structure. Frothing has low exothermic, requires low internal pressure during molding, and produces fewer flow patterns than section molding.

d. Typical Applications. Foams are used in cushions, upholstery, padding, clothing, interlining, gaskets, toys, sponges, acoustic insulation, cavity filling in radomes, ailerons, rudders, elevators, wing tabs, and insulation of cabin ventilating systems; non-sinkable boats and pontoons, and refrigerator insulation.

156. Elastomers. Urethane elastomers are usually prepared from diisocyanates and a linear polyester or polyether resin, and a low molecular weight curing agent such as glycol or diamine. Common types or urethane elastomers are casting elastomers, millable gums and thermoplastic.

The casting elastimers utilize a technique of reacting the diisocyanate and the resin to give an isocyanate terminated "prepolymer"; this may then be mixed with the glycol or diamine curing agent and poured into a mold, where polymerization takes place. Mold times are usually 20 to 30 minutes, but heat curing is often needed after removing the part from the mold.

Increasing the isocyanate and glycol or diamine content of the system, generally increases the elastomer hardness and modulus. The use of glycol-cured polyether systems or of systems based on castor oil or its derivatives, usually provide a route to the very soft urethane elastomers.

The millable gums are made by mixing the resin, diisocyanate and other desired reactants in such proportions so as to give a moderately high molecular-weight elastomeric polymer which can be milled, filled, and otherwise handled on standard rubber machinery. This process has been limited primarily to relatively soft types of urethane elastomers; e.g., about 60 to 80 Shore A hardness.

Of special interest to the plastic industry are the two types of thermoplastic urethane elastomers which are processable on standard extrusion: injection molding and transfer molding equipment. One type needs no crosslinking or curing steps and behaves like a thermoplastic. The other type is processed like a thermoplastic and can even be reworked prior to curing at elevated temperatures, when it takes on the properties of a thermosetting material.

a. Engineering Properties.

(1) Highest abrasion resistance of all elastomers.
(2) High hardness combined with high resilience over a wide low- and high-temperature range.
(3) Higher load bearing capacity than other elastomers of comparable hardness.
(4) Better solvent resistance than especially compounded solvent-resistance rubber formulations.
(5) Exceptionally high tear strength and resistance to peeling.
(6) Excellent resistance to oxygen and ozone, and can be formulated for good weatherability.
(7) Low temperature properties are excellent. Material stiffens between -4°F. and -30°F., but does not become brittle until about -40°F. to 130°F.
(8) Limited to continuous duty at 180°F. maximum, and intermittent duty at 285°F. maximum. In oil, approximately 250°F. is satisfactory for continuous duty.
(9) Good vibration damping characteristics.
(10) Good electrical properties.
(11) Resistance is generally poor to strong oxidizing agents, acids, bases and hot water.
(12) Good torsional and shock loading strength.

b. Available Forms. Prepolymer viscous liquid or low melting amorphous solids are supplied. Cubes and pellets can be furnished for injection, extrusion, compression, and transfer molding. Millable gums for processing on standard rubbery equipment is also available.

c. Typical Applications. Elastomers are used in the materials shown in figure 12.

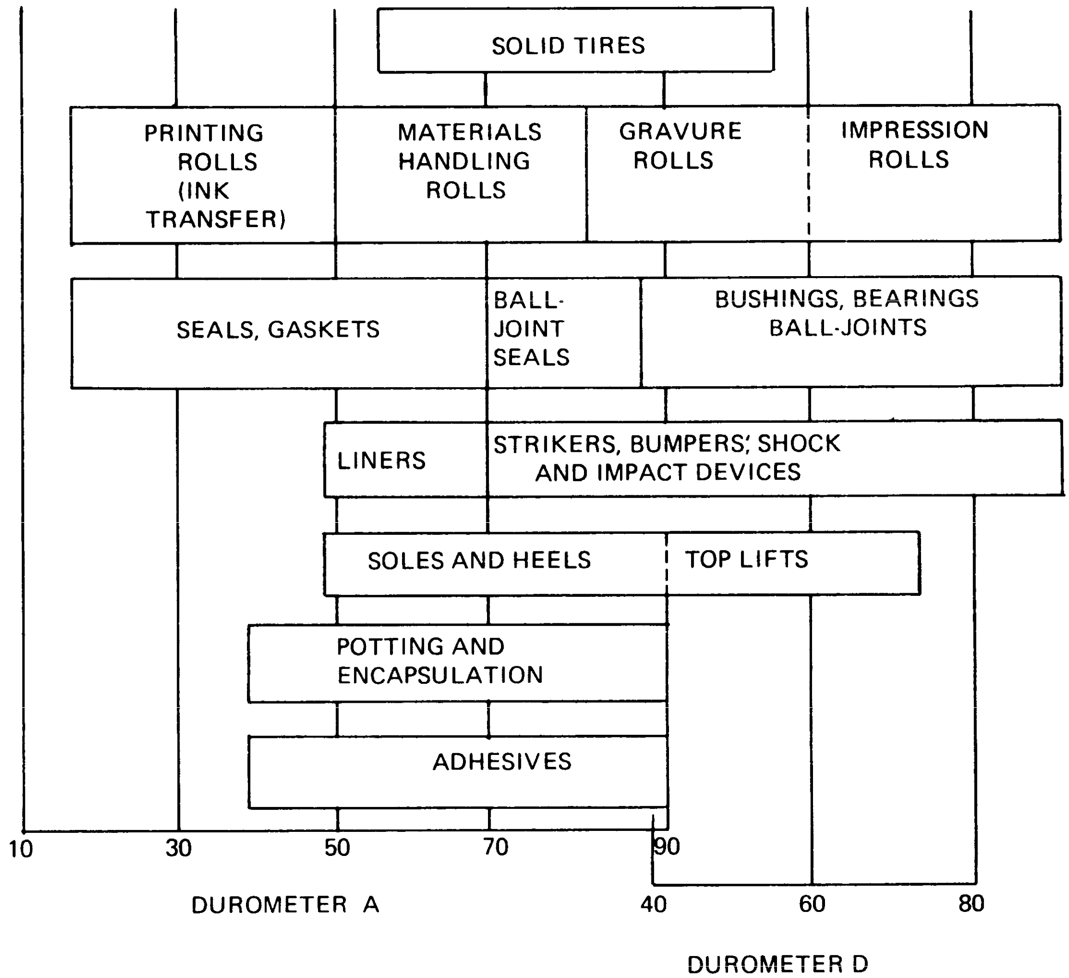


FIGURE 12. Applications of Urethane Elastomers and their Relation to Elastomer Hardness

157. Coatings. Urethane coatings can be tailored to meet the most demanding requirements of a customer. They are produced in six classifications. They are oil modified, moisture cure, blocked isocyanate, catalyzed prepolymers, polyolprepolymer cure and thermoplastic. The last unlike the other five types does not depend upon an isocyanate curing reaction, but rather on hydrogen bonding. These thermoplastic polyurethanes can be processed like any other thermoplastic and can be dissolved, heat sealed, calendered or extruded. They find wide use as adhesives, fabric coatings elastomer overcoatings and industrial films. In addition polyurethane coatings have found commercial uses as light stable isocyanates, fire retarding coatings, improved hydrolytic stability coatings, solventless coatings and emulsion and water soluble lacquers.

TABLE II. PLASTICS PROPERTIES CHART

	Plastics properties chart	ASTM test method	ABS (acrylonitrile-butadiene-styrene (see also next page)					
				Molding grades				
			Extrusion grades	High impact	High heat resistant	Medium impact	Flame retardant	20 to 40% glass filled
PROCESSING	1. Molding qualities	—	—	Good to excellent			Good	Fair to good
	2. Compression molding temp. °F.	—	325-450	325-450	325-500	325-350		—
	3. Comp. molding pressure, p.s.i.	—	—	1000 to 8000				—
	4. Injection molding temp., °F.	—	—	380-525	475-550	400-525	380-500	500-550
	5. Injection molding pressure, p.s.i.	—	—	8000 to 25000				15000-40000
	6. Compression ratio	—	—	1.1 to 2.0				
	7. Mold (linear) shrinkage, in./in.	—	N.A.	0.004-0.009			0.004-0.008	0.0010-0.0020
	8. Specific gravity (density)	D792	1.02-1.06	1.01-1.04	1.05-1.08	1.03-1.06	1.16-1.21	1.23-1.36
	9. Specific volume, cu. in./lb.	D792	28.0	27.0-26.0	28.0	28.0-27.0		22.5-20.4
	10. Machining qualities	—	Good to excellent					Good
MECHANICAL	11. Tensile strength, p.s.i.	D638	4000-7000	4400-7500	6500-8000	6500-7500	5000-8000	8500-19000
	12. Elongation, %	D638	20.0-110.0	5.0-70.0	3.0-20.0	5.0-25.0	5.0-25.0	2.5-3.0
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	2.3-3.8	2.3-3.3	2.9-4.2	3.0-4.5	2.2-4.0	5.9-10.3
	14. Compressive strength, p.s.i.	D695	5200-10200	4500-8000	7200-10000	1800-12500	6500-7500	12000-22000
	15. Flexural yield strength, p.s.i.	D790	4000-14000	6000-11000	10000-14500	11000-13000	8000-14000	16000-27000
	16. Impact strength, ft. lb./in. of notch (½ x ½ in. notched bar, Izod test)	D256	2.5-12.0 @ 73° 0.6-4.0 @ -40° (1/8 x 1/2 in. bar)	5.0-12.0 @ 73° 1.5-6.0 @ -40° (1/8 x 1/2 in. bar)	2.0-6.5 @ 73° 0.7-1.6 @ -40° (1/8 x 1/2 in. bar)	2.0-6.0 @ 73° 1.0-2.4 @ -40° (1/8 x 1/2 in. bar)	1.6-12.0 @ 73° 1/8 x 1/2 in. bar)	1.0-2.4
	17. Hardness, Rockwell	D785	R75-115	R85-105	R100-115	R107-115	R90-120	M65-100
	18. Flexural elastic modulus, p.s.i. x 10^5	D790	1.3-4.8	2.0-3.9	3.4-4.2	3.0-4.6	2.5-4.0	9.0-13.0
	19. Compressive modulus, p.s.i. x 10^5	D695	1.5-3.9	1.4-3.0	1.9-4.4	2.0-4.5	1.3-3.1	—
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq.cm./1(°C./cm.)	C177	4.5-8.0					—
	21. Specific heat, cal./°C./gm.	—	0.3 to 0.4					—
	22. Thermal expansion, 10^{-5} in./in./°C.	D696	6.0-13.0	9.5-13.0	6.0-9.3	8.0-10.0	6.5-9.5	2.9-3.6
	23. Resistance to heat, °F. (continuous)	—	140-200	140-210	190-230	160-200	130-180	200-230
	24. Deflection temp., °F. @ 264 p.s.i. fiber stress	D648	(annealed) 170-225	(annealed) 200-218	(annealed) 215-245	(annealed) 199-221	(annealed) 186-225	210-240
	@ 66 p.s.i. fiber stress		170-245	210-225	225-252	210-227	199-245	220-250
ELECTRICAL	25. Volume resistivity, ohm-cm. (50% RH and 23°C.)	D257	$1.0\text{-}4.8 \times 10^{16}$	$1.0\text{-}4.8 \times 10^{16}$	$1.0\text{-}5.0 \times 10^{16}$	2.7×10^{16}	1.69×10^{15}	$7.2\text{-}16.0 \times 10^4$
	26. Dielectric strength, short-time 1/8-in. thickness, volts/mil	D149	350 to 500					—
	27. Dielectric strength, step-by-step 1/8-in. thickness, volts/mil	D149	350-460	350-450	360-400	370-400	345	—
	28. Dielectric constant, 60 cyc.	D150	2.4 to 5.0					—
	29. Dielectric constant, 10^3 cyc.	D150	2.4 to 4.5					—
	30. Dielectric constant, 10^6 cyc.	D150	2.4 to 3.8					—
	31. Dissipation (power) factor, 60 cyc.	D150	0.003 to 0.008					—
	32. Dissipation (power) factor, 10^3 cyc.	D150	0.004 to 0.007					—
	33. Dissipation (power) factor, 10^6 cyc.	D150	0.007 to 0.015					—
	34. Arc resistance, sec.	D495	50 to 85				25-95	—
OPTICAL	35. Refractive index, n_D	D542	—	—	—	—	—	—
	36. Clarity	—	Translucent in thin sections to opaque					
	37. Transmittance, %	—	33.3	28.0	33.3	33.3	—	—
	38. Haze, %		100	100	100	100	—	—
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8-in. thick., %	D570	0.20 to 0.45				0.2-0.6	0.18-0.40
	40. Flammability[a] Burning rate, in./min. AEB, in./ATB, sec[b]	D635	0.6-1.0 —				—	—
	41. Effect of sunlight	—	None to yellows slightly plus some embrittlement					
	42. Effect of weak acids	D543	None					
	43. Effect of strong acids	D543	Attacked by concentrated oxidizing acids					
	44. Effect of weak alkalies	D543	None					
	45. Effect of strong alkalies	D543	None					
	46. Effect of organic solvents	D543	Soluble in ketones, esters and some chlorinated hydrocarbons					

a This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.
b AEB = Avg. extent of burning in inches; ATB = Avg. time of burning in seconds.

	ABS (Cont'd)		ACETALS				
	Clear	ASA (acrylonitrile-styrene-acrylic elastomer)	Homopolymer	Copolymer	20% glass filled homopolymer	25% glass coupled copolymer	TFE-fiber reinforced
1	Good to excellent	Good to excellent	Excellent	Excellent	Good to excellent	Good to excellent	Excellent
2	300-350	400-500	—	340-400	—	—	—
3	1000-5000	4000-5000	—	1000-5000	—	—	—
4	400-450	450-500	380-470	360-480	350-480	380-480	370-410
5	10000-20000	8000-20000	10000-20000	10000-20000	10000-20000	10000-20000	10000-20000
6	1.1-1.2	1.1-1.2	—	3.0-4.0	—	3.0-4.0	—
7	0.006-0.008	0.004-0.008	0.020-0.025	0.020-(Avg)	.009-.012	0.004 (flow) 0.018 (trans.)	0.02-0.025
8	1.07	1.07	1.42	1.41	1.56	1.61	1.54
9	26.0	27.0	19.6	19.7	18.7	17.4	18.9
10	Good to excellent	Good to excellent	Excellent		Good to fair	Good to fair	Excellent
11	5600-5800	6000-8000	10000	8800	8500-11000	18500	6900 (73° F.)
12		20-60	25.0-75.0	40-75	2-7	3	12.0 (73° F.)
13	2.9-3.1	3.3-3.7	5.2	4.1	10.0	12.5	—
14	7000	9500-21500	18000 (10% defl.)	16000 (10% defl.)	18000 (10% defl.)	17000 (10% defl.)	11000 (10% defl.)
15	9900-9950	10000-12000	14100	13000	15000 (5%)	28000	—
16	5.0 (1/8 x 1/2 in. bar)	6.0-8.0 (1/2 x 1/8 in. bar)	1.4 (Inj.) 2.3 (Ext.)	1.0-1.5 (1/8 x 1/2 in. bar)	0.8	1.8 (1/8 x 1/2 in. bar)	0.7
17	R 100	R102-108	M94, R120	M78-M80	M75-M90	M-79	M78, R118
18	3.0	3.3-3.7	4.1	3.75	8.8	11.0	4.0
19	1.9-2.9	1.5-2.5	6.7	4.5	—	—	—
20		4.5-8.0	5.5	5.5	—	—	—
21	—	0.3-0.4	0.35	0.35	—	—	—
22	8.3-9.0	6.0-10.0	8.1	8.5	3.6-8.1	—	7.5
23		160-200	195 (8800 hr.)	220	185-220	220	195 (8800 hr.)
24	170-185	215-225 (annealed)	255	230	315	325	212
	180-200	225-230 (annealed)	338	316	345	331	329
25		1.0-5.0 x 10^{16}	1.0 x 10^{15}	1.0 x 10^{14}	1.2 x 10^{14}	1.2 x 10^{14}	—
26		350-500	380	500 (90 mil)	580	580	—
27		360-400	320	—	—	—	—
28		3.0-4.0	—	3.7	3.97	3.9	—
29	—	3.0-3.8	3.7	3.7	3.97	3.9	—
30	—	3.0-3.5	3.7	3.7	3.97	3.9	
31	—	0.02-0.05	—	—	—	—	—
32	—	0.02-0.04	0.0048	0.0010 (40 mil)	0.0036	0.0025	—
33	—	0.02-0.03	0.0048	0.006	0.005	0.0062	—
34	—	—	129 on 15 mil spec.	240 (burns)	136	136	—
35	1.538	—	1.48	—	—	—	—
36	Transparent translucent, opaque	Translucent in thin sections to opaque	Translucent to opaque		Opaque	Opaque	Brown Opaque
37	80-85	—	—	—	—	—	—
38	6.0-12.0	—	—	—	—	—	—
39		0.5	0.25	0.22	0.25-0.29	0.29	0.20
40		—	1.0-1.1		0.8-1.0	1.0	0.8
	—	—					
41	None to sl. yellow, some embrittlement	Good resistance to prolonged exposure	Chalks slightly		Chalks slightly	Chalks slightly	Chalks slightly
42	Nil	None	Resists some		Resists some	Resists some	Resists some
43	Attacked by concentrated oxidizing acids	Attacked by concentrated oxidizing acids	Attacked		Attacked	Attacked	Attacked
44	Nil	None	Resists some	None	Copolymer resists some	None	Resists some
45		None	Not recom.	None	Copolymer resists some	None	Not recom.
46	Soluble in ketones, esters, aromatics, and chlorinated hydrocarbons	Soluble in ketones, ester and some chlorinated hydrocarbons	Excellent resistance		Excellent resistance	Excellent resistance	Excellent resistance

PLASTICS PROPERTIES CHART (Cont'd)		ASTM test method	ACRYLICS (see also next page) Cast flame retardant	High impact cast sheet	Cast[a]	Molding	MMA styrene copolymer	Coated sheet
PROCESSING	1. Molding qualities	—	—	—	—	Excellent	Excellent	—
	2. Compression molding temp., °F.	—	—	—	—	300-425	300-400	—
	3. Comp. molding pressure, p.s.i.	—	—	—	—	2000-10000	1000-8000	—
	4. Injection molding temp., °F.	—	—	—	—	325-500	330-500	—
	5. Injection molding pressure, p.s.i.	—	—	—	—	10000-20000	10000-30000	—
	6. Compression ratio	—	—	—	—	1.6-2.0	—	—
	7. Mold (linear) shrinkage, in./in.	—	—	—	—	0.001-0.004 (C) 0.002-0.008 (I)	0.002-0.006	—
	8. Specific gravity (density)	D792	1.21-1.28	—	1.17-1.20	1.17-1.20	1.09	1.19
	9. Specific volume, cu. in./lb.	D792	22.8-21.6	—	23.7-23.1	23.7-23.1	25.2	23.4
	10. Machining qualities	—	Good to Excellent	Good to Excellent	Good to Excellent	Good to Excellent	Good to Excellent	Good to Excellent
MECHANICAL	11. Tensile strength, p.s.i.	D638	8000-12500	6500	8000-11000	7000-11000	10000	10500
	12. Elongation, %	D638	3.8-5.1	40-143	2.0-7.0	2.0-10.0	3.0	3%
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	3.5-4.8	2.65	3.5-4.5	3.8-4.5	4.3	4.50
	14. Compressive strength, p.s.i.	D695	11000-12000	—	11000-19000	12000-18000	11000-15000	18000
	15. Flexural yield strength, p.s.i.	D790	12000-18000	8900	12000-17000	13000-19000	16000-19000	16000
	16. Impact strength, ft. lb./in. of notch (½ x ½ in. notched bar, Izod test)	D256	0.3-0.4	1.4	0.3-0.4	0.3-0.5	0.3	0.4
	17. Hardness, Rockwell	D785	M61-M100	M-61	M80-M100	M85-M105	M-75	M-100
	18. Flexural elastic modulus, p.s.i. x 10^5	D790	3.5-4.5	3.0	3.90-4.75	4.2-4.6	2.6-3.8	4.50
	19. Compressive modulus, p.s.i. x 10^5	D695	4.5	—	3.90-4.75	3.7-4.6	2.4-3.7	4.50
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq.Cm.,/1(°C./cm.)	C177	4.0-6.0	—	4.0-6.0	4.0-6.0	4.0-5.0	5.0
	21. Sepcific heat, cal./°C./gm.	—	0.35	—	0.35	0.35	0.34	0.35
	22. Thermal expansion, 10^{-5} in./in./°C.	D696	7.7	—	5.0-9.0	5.0-9.0	6.0-8.0	5.2
	23. Resistance to heat, °F. (continuous)	—	125-200	—	140-200	140-200	180-200	180-200
	24. Deflection temp., °F. @ 264 p.s.i. fiber stress	D648	155-205	172	160-215	165-210	205-212	205
	@ 66 p.s.i. fiber stress		170-200	195	165-235	175-225	—	225
ELECTRICAL	25. Volume resistivity, ohm-cm (50% RH and 23°C.)	D257	$\cdot 10^{16}$	—	$\cdot 10^{15}$	$\cdot 10^{14}$	10^{15}	10^{15}
	26. Dielectric strength, short-time, 1/8-in. thickness, volts/mil	D149	400-440	—	450-550	400-500	450	500
	27. Dielectric strength, step-by-step, 1/8-in. thickness, volts/mil	D149	—	—	431	350-400	450	430
	28. Dielectric constant, 60 cyc.	D150	3.5-5.1	—	3.3-4.5	3.3-3.9	3.4	3.7
	29. Dielectric constant, 10^3 cyc.	D150	3.1-4.3	—	3.0-3.5	3.0-3.6	—	3.3
	30. Dielectric constant, 10^6 cyc.	D150	3.0-3.7	—	2.1-3.2	2.2-3.2	2.9	2.5
	31. Dissipation (power) factor, 60 cyc.	D150	0.04-0.09	—	0.05-0.06	0.04-0.06	.006	.05
	32. Dissipation (power) factor, 10^3 cyc.	D150	0.03-0.06	—	0.04-0.06	0.03-0.05	—	.04
	33. Dissipation (power) factor, 10^6 cyc.	D150	0.02-2.05	—	0.015-0.03	0.02-0.03	.013	.03
	34. Arc resistance, sec.	D495	No track	—	No track	No track	150	No track
OPTICAL	35. Refractive index, n_D	D542	1.50	1.50	1.48-1.50	1.49	1.567	1.49
	36. Clarity	—	Transparent, translucent and opaque				Transparent	Transparent
	37. Transmittance, %	D1003	92	92	92	92	90	93-94
	38. Haze, %	—	1	—	1	<3	—	<1
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8-in. thick., %	D570	0.3-0.4	—	0.2-0.4	0.1-0.4	.15	<0.4
	40. Flammability[b] Burning rate, in./min. AEB, in./ATB, sec.[c]	D635	—	1.2 —	0.9-1.3 —	0.6-1.2 —	—	1.1 —
	41. Effect of sunlight	—	Darkens	Slight	Nil	Nil	Nil	Nil
	42. Effect of weak acids	D543	—	Nil	Nil	Nil	None	None
	43. Effect of strong acids	D543	—	Attacked only by high concentration oxidizing acids				None, except attacked by HF
	44. Effect of weak alkalies	D543	—	Nil	Nil	Nil	None	Slow attack
	45. Effect of strong alkalies	D543	—	Attacked	None except by liquid ammonia (NH_3)	Attacked	None	Attacked
	46. Effect of organic solvents	D543	Soluble in ketones, esters, aromatic and chlorinated hydrocarbons					None

a The data for cast acrylic sheet should be regarded as a guide only since the materials produced by the various manufacturers differ considerably from the charts and from each other.

b This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.

c AEB = Avg. extent of burning in inches, ATB = Avg. time of burning in seconds

ACRYLICS (Cont'd)					ALLYL RESINS AND MONOMERS				BUTADIENE STYRENE
						DAP molding compounds			
	Impact acrylic	MMA alpha-	Acrylic	Acrylic	Cast				Injection, blow molding and

	PLASTICS PROPERTIES CHART (Cont'd)	ASTM test method	CELLULOSIC MOLDING COMPOUNDS AND SHEET (see also next page)				
			Ethyl cellulose molding compounds and sheet	Cellulose acetate		Cellulose propionate molding compound	Cellulose acetate butyrate sheet
				Sheet	Molding		
PROCESSING	1. Molding qualities	—	Excellent	Excellent	Excellent	Excellent	Excellent
	2. Compression molding temp., °F	—	250-390	—	260-420	265-400	—
	3. Comp. molding pressure, p.s.i.	—	500-5000	—	100-5000	100-5000	—
	4. Injection molding temp., °F	—	350-500	—	335-490	335-515	—
	5. Injection molding pressure, p.s.i.	—	8000-32000	—	8000-32000	8000-32000	—
	6. Compression ratio	—	1.8-2.4	—	1.8-2.6	1.8-2.4	—
	7. Mold (linear) shrinkage, in./in.	—	0.005-0.009	—	0.003-0.010(C) 0.003-0.008(I)	0.003-0.009(C) 0.003-0.006(I)	—
	8. Specific gravity (density)	D792	1.09-1.17	1.28-1.32	1.22-1.34	1.17-1.24	1.15-1.22
	9. Specific volume, cu. in./lb.	D792	25.5-23.6	21.7-21.0	22.7-20.6	23.4-22.4	24.1-22.7
	10. Machining qualities	—	Good	Excellent	Excellent	Excellent	Excellent
MECHANICAL	11. Tensile strength, p.s.i.	D638	2000-8000	4500-8000	1900-9000	2000-7800	2600-6900
	12. Elongation, %	D638	5.0-40.0	20.0-50.0	6.0-70.0	29.0-100.0	50.0-100.0
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	1.0-3.0	3.0-6.0	0.65-4.0	0.6-2.15	2.0-2.5
	14. Compressive strength, p.s.i.	D695	10000-35000	—	2000-36000	2400-22000	—
	15. Flexural yield strength, p.s.i.	D790	4000-12000	6000-10000	2000-16000	2900-11400	4000-9000
	16. Impact strength, ft. lb./in. of notch (½ × ½ in. notched bar, Izod test)	D256	2.0-8.5 0.3-1.7 @ -40°F	—	0.4-5.2	0.5-11.5	
	17. Hardness, Rockwell	D785	R50-R115	R85-R120	R34-R125	R10-R122	R30-R115
	18. Flexural elastic modulus, p.s.i. × 10^5	D790	—	—	—	1.5-3.4	—
	19. Compressive modulus, p.s.i. × 10^5	D695	—	—	—	—	—
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq. cm./1(°C./cm.)	C177	3.8-7.0	4.0-8.0	4.0-8.0	4.0-8.0	4.0-8.0
	21. Specific heat, cal./°C./gm.	—	0.3-0.75	0.3-0.5	0.3-0.42	0.30-0.40	0.3-0.4
	22. Thermal expansion, 10^{-5} in./in./°C.	D696	10-20	10-15	8-18	11-17	11-17
	23. Resistance to heat, °F (continuous)	—	115-185	140-220	140-220	155-220	140-220
	24. Deflection temp., °F @ 264 p.s.i. fiber stress	D648	115-190	—	111-195	111-228	—
	@ 66 p.s.i. fiber stress		—	—	120-209	147-250	—
ELECTRICAL	25. Volume resistivity, ohm-cm. (50% RH and 23°C.)	D257	10^{12}-10^{14}	10^{11}-10^{15}	10^{10}-10^{14}	10^{12}-10^{16}	10^{11}-10^{15}
	26. Dielectric strength, short-time, 1/8-in. thickness, volta/mil	D149	350-500	250-600	250-600	300-450	250-400
	27. Dielectric strength, step-by-step, 1/8-in. thickness, volta/mil	D149	300-500	200-520	200-520	230-385	225-320
	28. Dielectric constant, 60 cyc.	D150	3.0-4.2	4.0-5.0	3.5-7.5	3.7-4.3	4.0-5.0
	29. Dielectric constant, 10^3 cyc.	D150	3.0-4.1	4.0-5.0	3.4-7.0	3.6-4.3	4.0-5.0
	30. Dielectric constant, 10^6 cyc.	D150	2.8-3.9	4.0-5.0	3.2-7.0	3.3-3.8	4.0-5.0
	31. Dissipation (power) factor, 60 cyc.	D150	0.005-0.020	0.01-0.02	0.01-0.06	0.01-0.04	0.01-0.02
	32. Dissipation (power) factor, 10^3 cyc.	D150	0.002-0.020	0.01-0.03	0.01-0.07	0.01-0.04	0.01-0.03
	33. Dissipation (power) factor, 10^6 cyc.	D150	0.010-0.060	0.03-0.04	0.01-0.10	0.01-0.05	0.02-0.04
	34. Arc resistance, sec.	D495	60-80	180-200	50-310	175-190	—
OPTICAL	35. Refractive index, n_D	D542	1.47	1.49-1.50	1.46-1.50	1.46-1.49	1.46-1.49
	36. Clarity		Transparent, translucent, opaque				
	37. Transmittance, %	—	—	88 (1/8-in. thick)	—	88 (1/8-in. thick)	88 (1/8-in. thick)
	38. Haze, %	—	—	< 1 (film, thin sheet)	—	< 1 (film, thin sheet	< 1 (film, thin sheet)
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8-in.thick %	D570	0.8-1.8	2.0-7.0	1.7-6.5	1.2-2.8	0.9-2.2
	40. Flammability[b] Burning rate, in./min. AEB, in.%ATB, sec.[c]	D635	— —	— —	— —	1.0-1.3 —	— —
	41. Effect of sunlight	—	Slight when properly stabilized	Slight	Slight	Slight	Slight
	42. Effect of weak acids	D543	Slight	Slight	Slight	Slight	Slight
	43. Effect of strong acids	D543	Decomposes	Decomposes	Decomposes	Decomposes	Decomposes
	44. Effect of weak alkalies	D543	None	Slight	Slight	Slight	Slight
	45. Effect of strong alkalies	D543	Slight	Swells	Decomposes	Decomposes	Decomposes
	46. Effect of organic solvents	D543	Widely soluble	Soluble in liquid ketones and esters of lower alcohols; softened or dissolved by chlorinated hydrocarbons and aromatic hydrocarbons; little affected by aliphatic hydrocarbons			

a Filled with Microballoons or other hollow spheres.
b This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.
c AEB = Avg. extent of burning in inches; ATB = Avg. time of burning in seconds.

	CELLULOSIC MOLDING COMPOUNDS AND SHEET (Cont'd)		EPOXY RESINS (see also next page)						
			Cast Resins		Cast Resins		Molding compounds		
	Cellulose butyrate acetate molding	Cellulose nitrate	No filler	Silica filled	Aluminum filled	Flexibilized	Glass fiber filled	Mineral filled	Low density[a]
1	Excellent	Good	—	—	—	—	Excellent	Excellent	Good
2	265-390	185-250	—	—	—	—	300-330	250-330	250-320
3	100-5000	2000-5000	—	—	—	—	300-5000	100-3000	100-2000
4	335-480	—	—	—	—	—	—	—	250-300
5	8000-32000	—	—	—	—	—	—	—	100-1500
6	1.8-2.4	—	—	—	—	—	3.0-7.0	2.0-3.0	3.0-7.0
7	0.003-0.009(C) 0.003-0.006(I)	—	0.001-0.01	0.0005-0.008	0.001-0.005	0.001-0.01	0.001-0.005	0.002-0.008	0.006-0.010
8	1.15-1.22	1.35-1.40	1.11-1.40	1.6-2.0	1.4-1.8	1.05-1.35	1.6-2.0	1.6-2.0	0.75-1.00
9	24.1-22.7	20.5-19.8	24.9-20.0	17.3-13.9	—	20.5	15.4-14.0	14.2-13.4	—
10	Excellent	Excellent	Good	Poor	Excellent	Good	Fair	Fair	Good
11	2600-6900	7000-8000	4000-13000	7000-13000	7000-12000	2000-10000	10000-20000	5000-10000	2500-4000
12	40.0-88.0	40.0-45.0	3.0-6.0	1.0-3.0	0.5-3.0	20.0-70.0	4	—	—
13	0.5-2.0	1.9-2.2	3.5	—	—	0.01-3.5	30.4	—	—
14	2100-22000	22000-35000	15000-25000	15000-35000	15000-33000	1000-14000	25000-40000	18000-40000	10000-15000
15	1800-9300	9000-11000	13300-21000	8000-14000	8500-24000	1000-13000	10000-60000	8000-15000	5000-7000
16	0.8-6.3	5.0-7.0	0.2-1.0	0.3-0.45	0.4-1.6	3.5-5.0	2.0-30.0	0.3-0.4	0.15-0.25
17	R31-R116	R95-R115	M80-M110	M85-M120	M55-M85	—	M100-M110	M100-M110	—
18	—	—	—	—	—	—	$2.5\text{-}4.5 \times 10^6$	$1.4\text{-}2.2 \times 10^6$	$5.0\text{-}7.5 \times 10^5$
19	—	—	—	—	—	—	—	—	—
20	4.0-8.0	5.5	4.0-5.0	10.0-20.0	15-25	—	4.0-10.0	4.0-30.0	4.0-6.0
21	0.3-0.4	0.3-0.4	0.25	0.20-0.27	—	—	0.19	—	—
22	11-17	8-12	4.5-6.5	2.0-4.0	5.5×10^{-6}	2.0-10.0	1.1-3.5	2.0-5.0	—
23	140-220	ca. 140	250-550	250-550	200-500	250-300	300-500	300-500	—
24	113-202	140-160	115-550	160-550	190-600	RT-250	250-500	250-500	200-250
	130-227	—	—	—	—	—	—	—	—
25	$10^{11}\text{-}10^{15}$	$10\text{-}15 \times 10^{10}$	$10^{12}\text{-}10^{17}$	$10^{13}\text{-}10^{16}$	· 10	$1.3\text{-}15.0 \times 10^{14}$	$>10^{14}$	$>10^{14}$	$10^{13}\text{-}10^{14}$
26	250-400	300-600	300-500	300-550	—	235-400	300-400	300-400	380-420
27	225-320	250-550	380	—	10-200	235-400	300-400	300-400	375-400
28	3.5-6.4	7.0-7.5	3.5-5.0	3.2-4.5	·8	3.0-6.0	3.5-5.0	3.5-5.0	—
29	3.4-6.4	7.0	3.5-4.5	3.2-4.0	—	3.0-5.0	3.5-5.0	3.5-5.0	—
30	3.2-6.2	6.4	3.3-4.0	3.0-3.8	—	3.0-6.0	3.5-5.0	3.5-5.0	2.0-3.0
31	0.01-0.04	0.09-0.12	0.002-0.010	0.008-0.03	·0.1	0.010-0.040	0.01	0.01	—
32	0.01-0.04	0.03	0.002-0.02	0.008-0.03	—	0.012-0.050	0.01	0.01	—
33	0.01-0.04	0.06-0.09	0.030-0.050	0.02-0.04	—	0.018-0.090	0.01	0.01	0.005-0.012
34	—	—	45-120	150-300	—	50-180	120-180	150-190	120-150
35	1.46-1.49	1.49-1.51	1.55-1.61	—	—	—	—	—	—
36	—	—	Transp.	Opaque	Opaque	Transp.	Opaque	Opaque	Opaque
37	—	—	—	—	—	—	—	—	—
38		—	—	—	—	—	—	—	—
39	0.9-2.2	1.0-2.0	0.08-0.15	0.04-0.10	0.1-4.0	0.27-0.50	0.05-0.20	0.04	0.2-1.0
40	—	—	—	—	—	—	—	0.16 (FR gr.)	—
41	Slight	Discolors and becomes brittle	None	None	None	None	Slight	Slight	None
42	Slight	Slight	None	None	None	None	None	None	None
43	Decomposes	Decomposes	Attacked by some	Attacked by some	Attacked by some	Attacked by some	Negligible	None	Slight
44	Slight	Slight	None	None	None	None	None	None	Slight
45	Decomposes	Decomposes	Slight	Slight	Some	Slight	None	Slight	Slight to attacked
46	—	Widely soluble	Generally resistant	Generally resistant	Chlorinated affects	Generally resistant	None	None	Slight

PLASTICS PROPERTIES CHART (Cont'd)		ASTM test method	EPOXY RESINS (Cont'd) Encapsulating grades: Mineral filled	EPOXY RESINS (Cont'd) Encapsulating grades: Glass filled	Phenol novolac epoxy resins	Cycloaliphatic epoxy resins	Ortho cresol novolac epoxy resins	FLUOROPLASTICS (see also next page): Polychlorotrifluoroethylene
PROCESSING	1. Molding qualities	—	Good to excel.	Good	Good	—	Good	Excellent
	2. Compression molding temp., °F.	—	250-330 (Transf.)	280-330 (Transf.)	250-330	—	250-330	460-550
	3. Comp. molding pressure, p.s.i.	—	50-1000 (Transf.)	50-1000 (Transf.)	100-800	—	100-800	500-15000
	4. Injection molding temp., °F.	—	—	—	—	—	—	500-600
	5. Injection molding pressure, p.s.i.	—	—	—	—	—	—	20000-60000
	6. Compression ratio	—	2.0	3.0	—	—	—	2.0
	7. Mold (linear) shrinkage, in./in.	—	0.004-0.010	0.004-0.008	—	—	—	0.010-0.015
	8. Specific gravity (density)	D792	1.7-2.1	1.7-2.0	1.16-1.21	1.16-1.21	1.16-1.21	2.1-2.2
	9. Specific volume, cu. in./lb.	D792	14.0	14.0	—	—	—	13.2-12.7
	10. Machining qualities	—	Fair	Fair	Good	Good	Good	Excellent
MECHANICAL	11. Tensile strength, p.s.i.	D638	4000-10000	5000-15000	6000-12000	8000-12000	—	4500-6000
	12. Elongation, %	D638	—	—	2.0-6.0	2.0-10.0	—	80.0-250.0
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	—	—	—	—	—	1.5-3.0
	14. Compressive strength, p.s.i.	D695	18000-30000	18000-30000	—	15000-20000	—	4600-7400
	15. *Flexural yield strength*, p.s.i.	D790	6000-15000	8000-20000	—	10000-13000	—	7400-9300
	16. Impact strength, ft. lb./in. of notch (½ x ½ in. notched bar, Izod test)	D256	0.3-0.45	0.5-2.0	—	—	—	2.5-2.7
	17. Hardness, Rockwell	D785	M100-M112	M100-M112	—	—	—	R75-R95
	18. Flexural elastic modulus, p.s.i. x 10^5	D790	—	—	—	—	—	—
	19. Compressive modulus, p.s.i. x 10^5	D695	—	—	—	—	—	—
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq.Cm.,/°C./cm.)	C117	4.0-10.0	4.0-10.0	—	—	—	4.7-5.3
	21. Specific heat, cal./°C./gm.	—	—	—	—	—	—	0.22
	22. Thermal expansion, 10^{-5} in./in./°C.	D696	3.0-6.0	3.0-5.0	—	—	—	4.5-7.0
	23. Resistance to heat, °F. (continuous)	—	300-450	300-450	—	—	—	350-390
	24. Deflection temp., °F. @ 264 p.s.i. fiber stress	D648	225-450	225-450	300-500	200-450	300-500	—
	@ 66 p.s.i. fiber stress		—	—	—	—	—	258
ELECTRICAL	25. Volume resistivity, *ohm-cm.* (50% RH and 23°C.)	D257	10^{14}	10^{14}	10^{15}	10^{15}	10^{15}	1.2×10^{18}
	26. Dielectric strength, short-time, 1/8-in. thickness, volts/mil	D149	250-400	250-400	—	—	—	500-600
	27. Dielectric strength, step-by-step 1/8-in. thickness, volts/mil	D149	250-400	250-400	—	—	—	450-550
	28. Dielectric constant, 60 cyc.	D150	3.5-5.0	3.5-5.0	3.7	3.2	2.98	2.24-2.8
	29. Dielectric constant, 10^3 cyc.	D150	3.5-5.0	3.5-5.0	3.7	—	2.95	2.3-2.7
	30. Dielectric constant, 10^6 cyc.	D150	3.5-5.0	3.5-5.0	3.4	3.2	2.88	2.3-2.5
	31. Dissipation (power) factor, 60 cyc.	D150	0.01	0.01	0.003	0.005	0.005	0.0012
	32. Dissipation (power) factor, 10^3 cyc.	D150	0.01	0.01	0.012	—	0.007	0.023-0.027
	33. Dissipation (power) factor, 10^6	D150	0.01	0.01	0.024	0.0016	0.010	0.009-0.017
	34. Arc resistance, sec.	D495	120-180+	120-180+	—	Excellent	Excellent	360
OPTICAL	35. Refractive index, n_D	D542	—	—	—	—	—	1.425
	36. Clarity	—	Opaque		Transparent	Transparent	Transparent	Transl. to Opaque
	37. Transmittance, %		—		—	—	—	—
	38. Haze, %	—	—		—	—	—	—
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8-in. thick., %	D570	0.03-0.20	0.04-0.20	Excellent	—	Good	0.00
	40. Flamability[a] Burning rate, in./min. AEB, in./ATB, sec.[b]	D635	—	—	—	—	—	0.16
	41. Effect of sunlight		Slight	Slight	Darkens	None	Darkens	None
	42. Effect of weak acids	D543	None	None	None	None	None	None
	43. Effect of strong acids	D543	Slight	Slight	—	Attacked by some	Attacked by some	None
	44. Effect of weak alkalies	D543	Slight		None	None	None	None
	45. Effect of strong alkalies	D543	Slight to attacked		None	Attacked by some	Attacked by some	None
	46. Effect of organic solvents	D543	Slight	Slight	None	None	None	Hologenated compounds cause slight swelling

a. This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.
b. AEB = Avg. extent of burning in inches; ATB = Avg. time of burning in seconds.

	FLUOROPLASTICS (Cont'd)							FURAN	INOMERS	MELAMINE-FORMALDEHYDE MOLDING COMPOUNDS (see also next page)		
	Polytetra-fluoro-ethylene molding compound	PFA fluoroplastic	FEP fluoroplastic	Poly-vinylidene fluoride	ETFE	ETFE glass reinforced	E-CTFE	Asbestos filled		No filler	Alpha cellulose filled	Cellulose filled
1.		Very good	Good	Excellent	Excellent	Very good	Excellent	Good	Excellent	Good	Excellent	Good
2.		625-700	600-750	400-550	575-625	575-625	500	275-300	280-350	300-330	280-370	290-360
3.	2000-5000	800-3000	1000-2000	500-15000	800-2000	800-2000	1000-20000	100-500	100-800	2000-5000	1500-8000	1500-6000
4.	--	700-8--	625-760	450-550	570-650	570-650	525-575	—	300-550	—	290-340	—
5.	--	5000-20000	5000-20000	15000-20000	3000-20000	3000-20000	5000-20000	—	2000-20000	—	15000-20000	—
6.	2.5-4.5	2.0	2.0	1.8plts.3.6pdr.	—	—	3.0-4.0	—	2.0	2.0	2.1-3.1	2.2-2.5
7.		.040	0.03-0.06	0.030	0.030-0.040	.002-.030	0.020-0.025	—	0.003-0.02	0.011-0.012	0.005-0.015	0.006-0.008
8.	2.14-2.20	2.12-2.17	2.12-2.17	1.75-1.78	1.7	1.80	1.68-1.69	1.75	0.93-0.96	1.48	1.47-1.52	1.45-1.52
9.	12.9-12.5	13.0-12.8	13.0-12.8	15.7-15.6	16.3	14.9	16.5-16.4	15.8	30.0-29.0	18.7	18.8-18.2	20.0-19.1
10.	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Fair to good	Fair to good	—	Fair to good	Good
11.	2000-5000	4300	2700-3100	5500-7400	6500	12000	7000	3000-4500	3500-5000	—	7000-13000	5000-9000
12.	200.0-400.0	300	250-330	100-300	100-400	8	200	—	350.0-450.0	—	0.6-0.9	0.6
13.	0.58	—	0.5	1.2	1.2	12.0	240,000	15.8	0.2-0.6	—	12.0-14.0	11.0
14.	1700	—	2200	8680	7100	10000	—	10000-13000	—	40000-45000	40000-45000	33500
15.		—	—		—	—	7000	600-9000	No yield	11000-14000	10000-16000	9000-11500
16.	3.0	No break	No break	3.6-4.0	No break	9.0	No break	—	6.0-15.0	—	0.24-0.35	0.27-0.36
17.	D50-D55 (Shore)	D64	D60-D65	D80(Shore)	R50, D75	R74	R95	R110	D50-D65 (Shore)	—	M115-M125	M115-M125
18.	--	1.2	—	2.0	2.0	9.5	240,000	—	0.3	—	1.1 x 10^{6}	—
19.	--	--	-	1.2	—	—	—	—	—	—	—	—
20.	6.0	--	6.0	3.0	--	—	3.8	—	5.8	—	7.0-10.0	6.5-8.5
21.	0.25	-	0.28	0.33	46-.47	—	—	—	0.55	—	0.4	—
22.	10.0	12	8.3-10.5	8.5	5-9	1.0-3.2	8	—	12.0	--	4.0	4.5
23.	500	500	400	300	300-360	392	330-355	265-330	160-220	210	210	250
24.	—	—	--	195	160	410	170	—	100-120	298	350-370	266
	250		158	270-300	220	510	240	—	110	—	—	—
25.	·10^{18}	·10^{15}	·2.0 x 10^{18}	2.0 x 10^{14}	·10^{16}	10^{16}	10^{15}	—	·10^{16}	--	0.8-2.0x10^{12}	—
26.	480	500	500-600	260	400	425	490	—	900-1100	—	270-300	350-400
27.	430	--	--	--		—	--	—	2.4-2.5	—	240-270	250-350
28.	2.1	2.1	2.1	8.4	2.6	3.4	2.3	—	2.4-2.5	—	7.9-9.5	6.2-7.6
29.	2.1	2.1	2.1	7.72	2.6	3.4	2.3	—	—	—	7.8-9.2	6.0-7.5
30.	2.1	2.1	2.1	6.43	2.6	3.4	2.3	—	—	—	7.2-8.4	4.7-7.0
31.	0.0002	0.0002	0.0002	0.049	—	.004	0.0005	—	0.001-0.003	--	0.030-0.083	0.019-0.033
32.	0.0002	0.0002	0.0002	0.018	0.0008	.002	0.0015	—	0.0015	—	0.015-0.036	0.013-0.034
33.	0.0002	0.0002	0.0007	0.17	0.005	.005	0.015	—	0.0019	—	0.026-0.045	0.032-0.060
34.	·300		·300	50-70	72	110	--	-	·90	100-145	110-140	95-135
35.	1.35	—	1.338	1.42	1.40	—	—	—	1.51	—	—	—
36.	Opaque	Transp. to transl.	Transp. to transl.	Transp. to transl.	Transp. in thin sec.	Opaque	Transp. to transl.	Opaque	Transparent	Opalescent	Translucent	Opaque
37.				—	—		—	--	75-85(125mil)	—	29.9 (0.50in.)	--
38.				-	--	--	3-5	--	3-17 (125 mil)		--	—
39.	0.00	0.03	·0.01	0.04	029	.022	0.01	0.01-0.20	0.1-1.4	0.3-0.5	0.1-0.6	0.34-0.80
40.		--		--	--		—	—	1.0	—	—	—
	0.16		0.16	—	--	--		—	—	--	--	—
41.	None	None	None	None	None	Slight	None	None	Requires UV stabilizer	Colors may fade	Pastels yellow	Slight color change
42.	None	None	None	None	None	None	None	None to slight	Slow attack	None	None	None to slight
43.	None	None	None	Attacked by fuming sulfuric	None	Slight	None	Attacked by oxidizing acids	Attacked by oxidizing acids		Decomposes	Decomposes
44.	None	None	None	None	None	None	None	None	Very resistant	None	None	None
45.	None	None	None	None	None	None	None	None to slight	Very resistant	--	Attacked	Decomposes
46.	None	None	None	Resists most solvents	None	None	Resists essentially all solvents	Resistant	Very resistant @ 75° F.	None	None	None

	PLASTICS PROPERTIES CHART (Cont'd)	ASTM test method	MELAMINE-FORMALDEHYDE MOLDING COMPOUNDS (Cont'd) Flock filled	Asbestos filled	Macerated fabric filled	Macerated fabric filled (phenolic modified)	Glass fiber filled (including nodular)	Melamine-phenol molding compounds	NITRILE BARRIER RESINS
PROCESSING	1. Molding qualities	—	Good	Good	Good	Good	Good	Good	Good
	2. Compression molding temp. °F	—	275-300	280-340	275-330	300-350	280-340	300-350	300-375
	3. Comp. molding pressure, p.s.i.	—	4000-8000	1000-7000	4000-8000	4000-8000	2000-8000	2000-5000	500-2000
	4. Injection molding temp., °F.	—	—	—	—	—	—	350-400	420
	5. Injection molding pressure, p.s.i.	—	—	—	—	—	—	15000-20000	—
	6. Compression ratio	—	4.0-7.0	2.1-2.5	5.0-10.0	5.0-10.0	—	2.1-4.4	—
	7. Mold (linear) shrinkage, in./in.	—	0.006-0.007	0.005-0.007	0.003-0.004	0.003-0.006	0.001-0.004	0.004-0.010	0.003-0.005
	8. Specific gravity (density)	D792	1.50-1.55	1.70-2.0	1.5	1.5	1.8-2.0	1.5-1.7	1.1-1.15
	9. Specific volume, cu. in./lb.	D792	18.5-17.8	16.3-13.8	18.5	18.5	13.8-10.0	20.9-17.8	—
	10. Machining qualities	—	Good	Fair	Good	Good	Good	Fair	Good
MECHANICAL	11. Tensile strength, p.s.i.	D638	7000-9000	5500-7000	8000-10500	6000-10500	5000-10000	6000-8000	8000-16000
	12. Elongation, %	D638	—	0.30-0.45	0.6-0.8	0.6	—	0.4-0.8	3.5-15
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	—	19.5	14.0-16.0	16.0	24.0	8.0-17.0	5.0-6.8
	14. Compressive strength, p.s.i.	D695	30000-35000	30000	30000-35000	25000-30000	20000-35000	26000-30000	11.0-12.5
	15. Flexural yield strength, p.s.i.	D790	13000	9000-11000	12000-15000	14000-17000	15000-23000	8000-10000	13000-17000
	16. Impact strength, ft. lb./in. of notch (½ x ½ in. notched bar, Izod test)	D256	0.40-0.45	0.28-0.40	0.6-1.0	1.1-1.4	0.6-18.0	0.27-0.38	1.0-3.5
	17. Hardness, Rockwell	D785	—	M110	M120	M115	—	E95-100	M80-M101, 79-81 (Shore D)
	18. Flexural elastic modulus, p.s.i. x 10^5	D790	—	—	—	—	—	10.0-12.0	4.2-6.4
	19. Compressive modulus, p.s.i. x 10^5	D695	—	—	—	—	—	—	1.0-2.0
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq.cm./1(°C./cm.)	C117	—	13.0-17.0	10.6	10.1	11.5	4.0-7.0	6.2
	21. Specific heat, cal./°C./gm.	—	—	—	—	—	—	0.35-0.40	0.33
	22. Thermal expansion, 10^{-4} in./in./°C.	D696	—	2.0-4.5	2.5-2.8	1.8-2.8	1.5-1.7	1.0-4.0	6.65
	23. Resistance to heat, °F. (continuous)	—	250	250-400	250	250	300-400	275-325	—
	24. Deflection temp., °F. @ 264 p.s.i. fiber stress	D648	—	265	310	375	400	285-310	189-198
	@ 66 p.s.i. fiber stress		—	—	—	—	—	—	165-215
ELECTRICAL	25. Volume resistivity, ohm-cm. (50% RH and 23° C.)	D257	—	1.22×10^{12}	10^9-10^{10}	—	2.0×10^{11}	—	2.7-2.9×10^{15}
	26. Dielectric strength, short-time, 1/8-in.-thickness, volts/mil	D149	300-330	410-430	250-350	130-370	170-300	220-325	220-243
	27. Dielectric strength, step-by-step, 1/8-in. thickness, volts/mil	D149	—	280-320	200-300	—	170-240	—	223-240
	28. Dielectric constant, 60 cyc.	D150	—	6.4-10.2	7.6-12.6	10.5-15.5	9.7-11.1	7.0-7.7	4.80 (100 cyc.)
	29. Dielectric constant, 10^3 cyc.	D150	—	9.0	7.1-7.8	7.9-9.7	—	—	4.55
	30. Dielectric constant, 10^6 cyc.	D150	—	6.1-6.7	6.5-6.9	6.1-6.7	6.6-7.5	5.2-6.0	3.95
	31. Dissipation (power) factor, 60 cyc.	D150	—	0.07-0.17	0.07-0.34	0.10-0.16	0.14-0.23	0.02-0.04	0.070 (100 cyc.)
	32. Dissipation (Power) factor, 10^3 cyc.	D150	—	0.07	0.03-0.05	0.10-0.16	—	—	0.0315
	33. Dissipation (factor), 10^6 cyc.	D150	—	0.041-0.050	0.036-0.041	0.050-0.065	0.013-0.015	0.04-0.06	0.055
	34. Arc resistance, sec.	D495	110-150	120-180	115-125	100-200	180	130-180	98
OPTICAL	35. Refractive index, n_D	D542	—	—	—	—	—	—	1.511-1.532
	36. Clarity	—	Opaque	Opaque	Opaque	Opaque	Opaque	Opaque	Transparent
	37. Transmittance, %	—	—	—	—	—	—	—	78-90
	38. Haze, %	—	—	—	—	—	—	—	—
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8-in. thick, %	D570	0.16-0.30	0.08-0.14	0.3-0.6	0.2-1.3	0.09-0.21	0.30-0.65	—
	40. Flammability[c] Burning rate, in./min AEB, in./ATB, sec.[d]	D635	—	—	—	—	0.16(FR gr.)	—	—
	41. Effect of sunlight	—	Slight color change	Slight color change	Slight discoloration	Color darkens	Slight	Nil	Strength loss, slight yellowing
	42. Effect of weak acids	D543	None to slight	None to slight	None	None	None	Good	None
	43. Effect of strong acids	D543	Decomposes	Decomposes	Decomposes	Decomposes	Decomposes	Fair	Attack
	44. Effect of weak alkalies	D543	None	Very slight attack	None	None	None	Fiar-Good	None
	45. Effect of strong alkalies	D543	Decomposes	Slight attack	Attacked	Attacked	None to slight	Poor-Fair	Slight attack
	46. Effect of organic solvents	D543	None on bleed-proof colors	None	None on bleed-proof colors	None on bleed-proof colors	None	Good	Resists alcohols, aliphatic and chlorinated hydrocarbons, oils; plasticized and whitened by ketones, dissolves in acetonitrile and DMF

* Materials are anistropic, therefore properties vary with the orientation of the filler.
a Dry as molded, cc 0.2% water.
b As conditioned to 50% R.H.
c *This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.*
d AEB = Avg. extent of burning in inches; ATB = Avg. time of burning in seconds.

NYLONS

(see also next page)

	TYPE 6/6				TYPE 6					TYPE 6/6-6	TYPE 6/12
	Unmodified	Nucleated*	33% glass reinforced*	Molybdenum disulphide*	Unmodified	Nucleated	30-35% glass reinforced	Elastomer copolymer	Cast	Copolymer	Unmodified
1.	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	--	Fair-excellent	Excellent
2.	—	—	—	—	—	—	—	—	—	—	—
3.	—	—	—	—	—	—	—	—	—	—	—
4.	520-620	500-550	520-560	500-600	440-550	440-550	480-550	450-580	--	350-400	450-550
5.	Limited only by the pressure required to fill the mold and by the capacity of the machine										
6.	3.0-4.0	3.0-4.0	3.0-4.0	—	--	--	—	—	—	—	—
7.	0.008-0.015	0.014-0.02	0.005	0.007-0.018	0.006-0.014	0.005-0.015	0.004	.008-.018	—	0.006-0.015	0.011
8.	1.13-1.15	1.13-1.16	1.38	1.16-1.17	1.12-1.14	1.12-1.14	1.35-1.42	1.08-1.11	1.15-1.17	1.08-1.14	1.06-1.08
9.	24.5-24.1	24.5-23.9	20.1	—	24.8-24.2	24.8-24.2	20.5-19.5	24.9-25.6	24.1-23.6	25.6-24.3	26.1-25.6
10.	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Poor-excellent	Excellent
11.	12000-11000^b	13600-10700^b	28000^a-22000^b	13700^a	11800-10000^a	13000^a-9000^b	25000^a-13000^b	7500-11000^a	11000-14000	7400-12400	8800
12.	60^a-300^b	15^a-200^b	3^a-5^b	15^a	200^a-300^b	20^a-200^b	3	150-270^a	30-320	40-300	150^a-340^b
13.	—	4.6^a-2.0^b	—	5.53	—	4.7^a-1.3^b	14.5^a-8.0^b	—	3.5-4.5	1.5-4.1^a-0.4-1.1^b	2.9-1.8
14.	15000(yield)	—	29400^a	12500^a-25600^b	13000	16000	19000	—	—	—	—
15.	17000^a-6100^b	17900^a-6700^b	41000^a	17000^a-29000^b	—	17500^a-6400^b	33000^a-18000^b	5000-12000	7000-17500	—	—
16.	1.0^a-2.1^b	0.9^a-3.8^b	2.2^a-2.6^b	4.5^a	1.0^a-3.0^b	0.9^a-3.0^b	3.0	1.8-No breaks	0.8-3.0 (1/2x1/8in.bar)	0.7-No break	1.0^a-1.4^b
17.	R120-M83	R123-M86	M100	R119	R119	$M89^a$-$R94^b$	$M101^a$-$M78^b$	R81-R110	R95-R120	R83-R119	R114
18.	4.20^a-1.85^b	4.8^a-2.3^b	13	4.5^a	3.95^a-1.4^b	5.0^a-1.8^b	15.0^a-8.0^b	1.1-3.2^a	1.1-4.5^a	1.5-4.1^a	2.9^a-1.8^b
								0.6-1.3^b	0.8-1.6^b	0.4-1.1^b	
19.	—	--	—	—	2.5	—	--	—	—	—	—
20.	5.8	5.8	5.1	—	5.8	5.8	5.8	—	—	—	5.2
21.	0.4	0.4	0.3	—	0.4	0.4	0.35-0.5	—	—	0.4	0.3-0.4
22.	8.0	---	1.5-2.0	5.4	8.3	8.0	2.0-3.0	3.11×10^{-5}	9.0	—	—
23.	180-250	180-250	180-300	180-250	180-250	180-250	200-300	180-250	180-250	250	180-250
24.	167	171	485	260	155	185	410	113-130	200-425	170	410
	374	425-430	495	—	365	375	430	260-350	400-425	430	—
25.	10^{11}-10^{14}	10^{11}-10^{14}	10^{11}-10^{14}	10^{11}	10^{11}	10^{12}	5×10^{11}	—	—	10^{10}	10^{13}
26.	600	600	--	360	400	400	400	440-450	300-400	400	400
27.	280	280	400	—	350	350	375	410-430	—	—	—
28.	4.3^a	3.8^a-8.2^b	4.1	—	3.8	3.8^a-10.7^b	4.2^a-12.1^b	3.5-4.5	3.7	—	3.9
29.	3.0-5.3^a	3.7^a-7.0^b	4.0^a-8.0^b	—	3.7	3.7^a-8.4^b	4.2-9.4^b	3.4-4.1	3.7	—	3.6
30.	—	3.4^a-4.0^b	3.4^a-4.0^b	—	3.4	3.5^a-4.0^b	3.9^a-4.5^b	3.3-3.4	3.7	—	3.5
31	0.020^a	0.01^a-0.14^b	0.006	---	0.01	0.010^a-0.19^b	0.01^a-0.19^b	0.01-0.08	0.020	—	.02
32.	0.029^a	0.02^a-0.14^b	0.01^a-0.2^b	—	0.02	0.015^a-0.20^b	0.016^a-0.19^b	0.01-0.07	0.02	—	.02
33.	0.04^a	0.02^a-0.08^b	0.02^a-0.1^b	—	0.03	0.026^a-0.10^b	0.023-0.11	0.02-0.04	0.02	—	.02
34.	130-140	—	148	—	—	—	—	—	—	—	—
35.	153	—	—	—	—	—	—	—	—	—	—
36.	Translucent to Opaque			Opaque	Translucent to Opaque			—	Translucent to Opaque		
37.	—	—	—	—	—	—	—	—	—	—	—
38.	-		---	—	—	—	—	—	—	—	—
39.	1.5	1.5	1.0	0.8-1.1	1.3-1.9	1.3-1.9	1.2	1.3-1.5	0.6-1.2	1.5-2.0	0.4
40.	—	—	1.1	—	—		—	—	—	—	—
	—	—	--	—	0.6-0.7/5.0-15.0		—	—	—	—	—
41.	Nylons are embrittled by prolonged exposure to sunlight but stabilized grades are available; finely dispersed carbon black is the most effective stabilizer										
42.	Resistant		Resistant except hydrofluoric acid	Resistant			Resistant except hydrofluoric acid	Resistant		Less resistant than 6/6 and 6	More resistant than 6/6 and 6
43.	Attacked										
44.	None										
45.	Resistant	Slight	Attacked by high concentrates	Resistant		Attacked by high concentrates		Resistant			
46.	Resistant to common solvents but dissolved by phenols and formic acid										Resistant to common solvents but dissolved by phenols

PLASTICS PROPERTIES CHART (Cont'd)	ASTM test method	NYLONS (Cont'd) TYPE 6/6 Unmodified	TYPE 6/12 30-35% glass reinforced*	TYPE 6/10 Unmodified	TYPE 6/10 30-35% glass reinforced*	TYPE 11 Unmodified	TYPE 11 30% glass reinforced	TYPE 12 Unmodified	TYPE 12 30% glass reinforced	Transparent, clear
PROCESSING										
1. Molding qualities	—	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
2. Compression molding temp., °F.	—	—	—	—	—	—	—	—	—	—
3. Comp. molding pressure, p.s.i.	—	—	—	—	—	—	—	—	—	—
4. Injection molding temp., °F.	—	450-500	450-550	450-550	450-550	390-520	490-540	360-525	450-535	482-608
5. Injection molding pressure, p.s.i.	—	—	—	—	—	—	—	—	—	~ 18000
6. Compression ratio	—	—	—	—	—	—	—	—	—	—
7. Mold (linear) shrinkage, in./in.	—	0.010-0.015	0.003	0.012	0.004	0.012	—	0.003-0.015	0.003	0.004-0.006
8. Specific gravity (density)	D792	1.08-1.10	1.31-1.38	1.07-1.09	1.31-1.38	1.03-1.05	1.26	1.01-1.02	1.23	1.12
9. Specific volume, cu. in./lb.	D792	—	21.1-20.0	25.9-25.4	21.1-20.0	26.6-26.4	—	27.1-27.0	22.5	24.8
10. Machining qualities	—	Good	Excellent	Good	Excellent	Good	Excellent	Good	Excellent	Excellent
MECHANICAL										
11. Tensile strength, p.s.i.	D638	8500[a]	24000[a]-20000[b]	8500[a]-7100[b]	20000	8000	14000	8000-9250	17400	12100-9750[b]
12. Elongation, %	D638	125[a]	4.5[a]-5.0[b]	85[a]-300[b]	2	300	5	300	3.0-5.0	70-150
13. Tensile elastic modulus, 10^5 p.s.i.	D638	2.75[a]	12[a]-9[b]	2.8[a]-1.6[b]	10	1.85	—	1.8	—	4.1[b]
14. Compressive strength, p.s.i.	D695	—	—	—	18000	—	—	—	—	17500-14000[b]
15. Flexural yield strength, p.s.i.	D790	—	—	—	23000	—	—	—	22300	13260[b]
16. Impact strength, ft. lb./in. of notch (½ x ½ in. notched bar, Izod test)	D256	1.1[a]	2.6[a]-2.8[b]	1.2	3.4	1.8	—	2.0-5.5	3.0	—
17. Hardness, Rockwell	D785	R-111	E40-50	R111	E40-50	R108	—	R106-R109	R109	M-93
18. Flexural elastic modulus, p.s.i. x 10^5	D790	2.9[a]	112[a]-9[b]	2.8[a]-1.6[b]	10.0	1.7	—	1.65	10.0	3.9[b]
19. Compressive modulus, p.s.i. x 10^5	D695	—	—	—	—	1.8	—	—	—	3.4
THERMAL										
20. Thermal conductivity, 10^{-4} cal./sec./sq.cm. /1(°C./cm.)	C177	—	—	5.2	5.1	5.2	9.6	5.2	3.9	5
21. Specific heat, cal./°C./gm.	—	—	—	0.4	0.35	0.3	0.42	0.3	—	0.35
22. Thermal expansion, 10^5 in./in./°C.	D696	—	12.0	9.0	7.3	10.0	3.0	10.0	7.5	2.8
23. Resistance to heat, °F. (continuous)	-	200	200-300	180-250	200-300	180-300	200-300	180-250	250-300	185-212
24. Deflection temp., °F. @ 264 p.s.i. fiber stress	D648	135-140	200-425	180	437	130	343	130	203-345	256
@ 66 p.s.i. fiber stress		330-340	400-425	330	420	300	356	293	320	284
ELECTRICAL										
25. Volume resistivity, ohm-cm. (50% RH and 23°C.)	D257	—	10^{12}	10^{12}	10^{12}	10^{13}	10^{14}	10^{13}	10^{13}	5×10^{15}
26. Dielectric strength, short-time, 1/8 in. thickness, volts/mil	D149	600	520	400	500	425	500	450	452	350
27. Dielectric strength, step-by-step 1/8-in. thickness, volts/mil	D149	510	490	—	45	—	—	400	400	340
28. Dielectric constant, 60 cyc.	D150	3.7	—	3.9	4.2	3.7-3.8	—	4.2	—	3.7[a]
29. Dielectric constant, 10^3 cyc.	D150	3.6	3.7	3.6	4.0	3.2-3.7	—	3.8	—	3.5[a]
30. Dielectric constant, 10^6 cyc.	D150	3.3	3.4	3.5	3.5	—	—	3.1	3.0	3.1
31. Dissipation (power) factor, 60 cyc.	D150	0.020	—	0.04	0.026		—	0.04	—	0.017[a]
32. Dissipation (power) factor, 10^3 cyc.	D150	0.023	0.024	0.04	0.025	—	—	0.05	—	0.028[a]
33. Dissipation (power) factor, 10^6 cyc.	D150	0.022	0.016	0.04	0.022	—	—	0.03	.06	0.022[a]
34. Arc resistance, sec	D495	—	—	—	98	—	—	110.0		120
OPTICAL										
35. Refractive index, n_D	D542	—	—	—	—	—			—	1566
36. Clarity		Translucent to opaque								Transparent
37. Transmittance, %	—	—	—	—	—	—	—	—	—	95
38. Haze, %	—	—	—	—	—	—	—	—	—	
RESISTANCE CHARACTERISTICS										
39. Water absorp., 24 hr., 1/8 in. thick, %	D570	0.48	0.2	0.4	0.2	0.3	0.2	0.25	0.07	0.4
40. Flammability[c] Burning rate, in./min. AEB, in./ATB, sec.[d]	D635	—	—	—	—	—	—	—	—	—
41. Effect of sunlight		Nylons are embrittled by prolonged exposure to sunlight but stabilized grades are available, finely dispersed carbon black is the most effective stabilizer								
42. Effect of weak acids	D543	More resistant than 6/6 and 6								Resistant
43. Effect of strong acids	D543	Attacked								
44. Effect of weak alkalies	D543	None								Resistant
45. Effect of strong alkalies	D543	Resistant								
46. Effect of organic solvents		Resistant to common solvents but dissolved by phenols and formic acid	Resistant to common solvents but dissolved by phenols	Resistant to common solvents but dissolved by phenols and formic acid		Resistant to common solvents but dissolved by phenols				Resistant to common solvents but dissolved by phenols and formic acid

* Materials are anistropic, therefore properties vary with the orientation of the filler.
a Dry as molded, cc 0.2% water
b As conditioned to 50% R.H.
c This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.
d AEB - Avg. extent of burning in inches. ATB - Avg. time of burning in seconds.

	PHENOL-FORMALDEHYDE AND PHENOL-FURFURAL MOLDING COMPOUNDS											
								Compounded with butadiene-acrylonitrile copolymer			
	No filler	Woodflour and cotton flock filled	Asbestos filled	Mica filled	Glass fiber filled	Macerated fabric and cord filled	Pulp performed and molding board	Woodflour cotton flock filled	Asbestos filled	Rag filled	Metal filled (iron, lead)
1.	Poor	Excellent	Excellent	Good	Good to excel.	Good to fair	Good	Fair to good	Fair to good	Fair to good	Good
2.	270-320	290-380	290-380	270-350	300-380	280-380	290-350	300-360	310-360	310-360	280-320
3	2000-4000	2000-5000	2000-5000	2000-5000	1000-6000	2000-4000	2000-4000	2000-4000	2000-4000	2000-4000	2000-5000
4.	—	330-400	330-400	330-380	330-390	320-370	—	—	—	—	—
5.	—	10000-20000	10000-20000	8000-19000	5000-20000	7000-20000	—	—	—	—	—
6.	2.0-2.5	1.0-1.5	1.0-1.5	2.1-2.7	2.0-10.0	3.0-18.0	1.5-3.5	2.5-3.2	2.4	3.8-5.2	—
7.	0.010-0.012	0.004-0.009	0.002-0.009	0.002-0.006	0.000-0.004	0.002-0.009	0.0018-0.008	0.004-0.009	0.004-0.007	0.002-0.004	0.003-0.004
8.	1.25-1.30	1.34-1.45	1.45-2.00	1.65-1.92	1.69-1.95	1.36-1.43	1.36-1.42	1.29-1.35	1.57-1.65	1.30-1.35	2.0-4.2
9.	22.2-21.3	20.9-17.8	20.9-11.9	15.8-14.3	15.8-14.1	20.4-19.4	20.4-19.6	22.3-20.5	17.3-16.8	21.3-21.0	—
10.	Fair to good	Fair to good	Good to poor	Poor	Poor to fair	Fair to good		Good			
11.	7000-8000	5000-9000	4500-7500	5500-7000	5000-18000	3000-9000	4300-12000	3500-5000	4000-5000	3000-5000	4000-7000
12.	1.0-1.5	0.4-0.8	0.18-0.50	0.13-0.50	0.2	0.37-0.57	0.3-0.7	0.75-2.25	—	—	—
13.	7.5-10.0	8.0-17.0	10.0-30.0	25.0-50.0	19.0-33.0	9.0-14.0	9.0-13.0	—	—	—	—
14.	10000-30000	22000-36000	20000-35000	25000-30000	16000-70000	15000-30000	16000-35000	15000-20000	10000-20000	15000-20000	15000-30000
15.	12000-15000	7000-14000	7000-14000	8000-12000	10000-60000	8500-15000	7000-18500	5000-7000	6000-8000	7000-9000	7000-12000
16	0.20-0.36 Use E scale E80-95	0.24-0.60 77-98	0.26-3.50 E66-97	0.27-0.38 E85-91	0.3-18.0	0.75-8.00	0.5-4.5	0.40-0.90	0.34-0.40	2.0-2.3	0.3-0.5
17.	M124-128	M100-115	M105-115	E88	E54-E101	E79-E82	E60-E85	M45-M60	M50	M50-M70	M80-M115
18.	—	10.0-12.0	10.0-22.0	—	20.0-33.0	10.0-14.0	—	3.0-5.0	5.0-6.0	3.5-5.5	18.0-26.0
19.	—	—	—	—	—	—	—	—	—	—	—
20	3.0-6.0	4.0-8.2	6.0-22.0	10.0-14.0	8.2-14.5	4.0-9.0	4.0-7.0	5.0-6.0	4.6	4.9	14.0-20.0
21.	0.38-0.42	0.32-0.40	0.28-0.32	0.28-0.32	0.24-0.27	0.30-0.35	0.34-0.36	0.33	—	—	—
22.	2.5-6.0	3.0-4.5	0.8-4.0	1.9-2.6	0.8-2.05	1.0-4.0	3.0-4.5	1.5-3.5	4.0	2.1	—
23.	250	300-350	350-500	250-300	350-550	220-250	300-400	200	225	200	—
24	240-260 —	300-370 —	300-500 —	300-500 —	300-600 —	250-330 —	260-340 —	200-230 —	250 —	225-250 —	350-425 —
25.	10^{11}-10^{12}	10^{9}-10^{13}	10^{10}-10^{13}	10^{12}-10^{14}	10^{12}-10^{13}	10^{11}-10^{12}	10^{10}-10^{13}	10^{10}	2.5×10^{11}	10^{10}-10^{11}	—
26	300-400	260-400	200-360	350-400	140-400	200-400	250-550	275-325	275-350	225-175	—
27	250-350	250-350	150-310	250-390	120-400	150-300	200-450	225-275	250-300	175-225	—
28.	5.0-6.5	5.0-13.0	5.0-20.0	4.7-6.0	5.0-7.1	5.2-21.0	5.0-8.0	9.0-15.0	15.0	13.0-17.0	—
29.	4.5-6.0	4.4-9.0	6.0-16	4.4-5.5	5.0-6.9	4.9-11.0	5.0-8.0	—	—	—	—
30.	4.5-5.0	4.0-6.0	5.0-10.0	4.2-5.2	4.5-6.6	4.5-7.0	4.0-7.0	5.0	5.0	4.0-6.0	—
31.	0.06-0.10	0.05-0.30	0.05-0.20	0.03-0.05	0.04-0.05	0.08-0.64	0.04-0.30	0.14-0.50	0.15	0.30-0.5	—
32.	0.03-0.08	0.04-0.20	0.05-0.20	0.025-0.04	0.012-0.027	0.04-0.20	0.02-0.20	—	—	—	—
33.	0.015-0.03	0.03-0.07	0.35-0.80	0.005-0.013	0.010-0.026	0.03-0.09	0.03-0.7	0.08-0.10	0.10	0.08-0.15	—
34.	Tracks	Tracks	10-190	Tracks	4-190	Tracks	2-130	Tracks	Tracks	Tracks	—
35.	1.5-1.7	—	—	—	—				—		
36.	Transp. to transl.		Opaque						Opaque		
37	—	—	—	—	—				—		
38			—		—				—		
39	0.1-0.2	0.3-1.2	0.10-0.5	0.01-0.05	0.03-1.20	0.40-1.75	0.6-1.8	1.0-2.0	10.15-0.20	1.0-2.0	0.03-0.15
40			0.25-0.38		0.13-0.5	—	—	—	—	—	—
		1.1-1.35/55-67	—	0.16	0.5-10/7.5-12	—	—	—	—	—	—
41.	Surface darkens					General darkening					
42		None to slight depending on acid									
43.	Decomposed by oxidizing acids, reducing and organic acids, none to slight effect										
44	Slight	Slight to marked, depending on alkalinity									
45	Decomposes	Attacked by strong alkalies			Attacked						
46	Fairly resistant	Fairly resistant on bleedproof materials									

PLASTICS PROPERTIES CHART (Cont'd)		ASTM test method	PHENOLIC CAST RESINS			PHENYLENE OXIDE BASED RESINS		POLYALLOMER
			No filler	Mineral filled	Asbestos filled	Non-reinforced	20-30% glass reinforced	
PROCESSING	1. Molding qualities	—	—	—	—	Excellent	Very good	Excellent
	2. Compression molding temp., °F	—	—	—	—	400-460	—	—
	3. Comp. molding pressure, p.s.i.	—	—	—	—	500-1000	—	—
	4. Injection molding temp. °F	—	—	—	—	425-600	500-650	430-445
	5. Injection molding pressure, p.s.i.	—	—	—	—	14000-20000	15000-40000	1000-2000
	6. Compression ratio	—	—	—	—	1.3-2.2	—	—
	7. Mold (linear) shrinkage, in./in.	—	—	—	—	0.006	0.001-0.004	0.01-0.02
	8. Specific gravity (density)	D792	1.236-1.320	1.68-1.70	1.70	1.06-1.10	1.21-1.36	0.896-0.899
	9. Specific volume, cu. in./lb.	D792	21.3-20.9	16.5-16.3	16.3	26.1-25.2	22.9-20.2	—
	10. Machining qualities	—	Excellent	Good to fair	Fair to good	Excellent	Excellent	Good
MECHANICAL	11. Tensile strength, p.s.i.	D638	5000-9000	4000-9000	3000-6000	7800-9600	14500-17000	3050-3850
	12. Elongation, %	D638	1.5-2.0	—	—	50.0-60.0	4.0-6.0	400.0-500.0
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	4.0-7.0	—	18.8	3.55-3.80	9.25-12.0	—
	14. Compressive strength, p.s.i.	D695	12000-15000	29000-34000	10500-12500	16000-16400	17600-17900	—
	15. Flexural yield strength, p.s.i.	D790	11000-17000	9000-12000	5000-8000	12800-13500	18500-20000	—
	16. Impact strength, ft. lb/in. of notch (½ = ½ in. notched bar, Izod test)	D256	0.24-0.40	0.35-0.50	—	5.0 (1/2 x 1/8 in. bar)	2.3 (1/2 x 1/8 in. bar)	1.7C-6.0P
	17. Hardness, Rockwell	D785	M93-M120	M85-M120	R110	R115-119	R106-108	R50-85
	18. Flexural elastic modulus, p.s.i. x 10^5	D790	—	—	—	3.6-4.0	7.5-11.0	0.70-1.10
	19. Compressive modulus, p.s.i. x 10^5	D695	—	—	—	3.7	9.0-13.0	—
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq.cm./1 (°C./cm)	C177	3.5	—	8.4	5.16	3.8	2.0-4.0
	21. Specific heat cal./°C./gm.	—	0.3-0.4	—	0.3	0.32	—	0.5
	22. Thermal expansion, 10^{-5} in./in./°C.	D696	6.8	7.5	3.3	5.2	2.2	8.3-10.0
	23. Resistance to heat, °F. (continuous)	—	160	160	300	175-220	240-265	—
	24. Deflection temp., °F. @ 264 p.s.i. fiber stress	D648	165-175	150-175	—	212-265	270-300	124-133
	@ 66 p.s.i. fiber stress		—	—	—	230-280	280-310	165-192
ELECTRICAL	25. Volume resistivity, ohm-cm. (50% RH and 23°C.)	D257	10^{12}-10^{13}	10^9-10^{12}	—	10^{16}-10^{17}	10^{17}	10^{15}
	26. Dielectric strength, short-time 1/8-in. thickness, volts/mil	D149	250-400	100-250	—	400-550	420-600	800-950
	27. Dielectric strength, step-by-step, 1/8-in. thickness, volts/mil	D149	130-300	75-200	—	400-550	420-600	—
	28. Dielectric constant, 60 cyc.	D150	6.5-17.5	—	—	2.64	2.93	2.3
	29. Dielectric constant, 10^3 cyc.	D150	5.5-12.0	14.0-30.0	—	2.64	2.93	2.3
	30. Dielectric constant, 10^6 cyc.	D150	4.0-5.5	9.0-15.0	—	2.64	2.92	2.3
	31. Dissipation (power) factor, 60 cyc.	D150	0.10-0.15	—	—	0.0004	0.0009	$< 5 \times 10^{-4}$
	32. Dissipation (power) factor, 10^3 cyc.	D150	0.01-0.055	0.10-0.30	—	0.0004	0.0010	—
	33. Dissipation (power) factor, 10^6 cyc.	D150	0.04-0.05	0.7-0.20	—	0.0009	0.0015	$< 5 \times 10^{-4}$
	34. Arc resistance, sec.	D495	—	—	—	75	70-120	—
OPTICAL	35. Refractive index, n_D	D542	158-1.66	—	—	—	—	1.492
	36. Clarity	—	Transp transl., opaq.	Opaque	Opaque	Opaque	—	Transp. to transl.
	37. Transmittance, %	—	—	—	—	—	—	—
	38. Haze, %	—	—	—	—	—	—	—
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8-in. thick, %	D570	0.2-0.4	0.12-0.36	—	0.066	0.06	< 0.01
	40. Flammability[a] Burning rate, in./min. AEB, in./ATB, sec[b]	D635	—	—	—	< 0.16	< 0.16	< 0.16
	41. Effect of sunlight	-	Colors may fade	Darkens	Darkens slightly	Colors may fade	Colors may fade	Crazes; can be protected
	42. Effect of weak acids	D543	None	None to slight		None	None	None
	43. Effect of strong acids	D543	None	Attacked by oxidizing acids		None	None	Attacked slowly by oxid. acids
	44. Effect of weak alkalies	D543	Moderate to none	Nil	None	None	None	None
	45. Effect of strong alkalies	D543	Strong	Decomposes		None	None	Very resistant
	46. Effect of organic solvents	D543	Moderate to none		Generally resistant	Soluble or swells in some aromatics and chlorinated aliphatics; resistant to alcohols	Softens in some aromatics and chlorinated aliphatics; resistant to alcohols	Resistant below 80°C.

a This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions

b AEB = Avg. extent of burning in inches, ATB = Avg. time of burning in seconds.

	POLY(AMIDE-IMIDE)			POLY-ARYL ETHER	POLY ARYL-SULFONE	POLYBUTADIENES		POLY-BUTYLENE	POLYCARBONATES (see also next page)		
						Molding compounds					
	Unfilled	Mineral filled	Graphite filled			Glass filled	Track resistant		Unfilled	Less than 10% glass filled	10 to 40% glass filled
1.	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Good to excel.	Excellent	Very good
2.	630-650	630-650	630-650	—	700-750	325-400	325-380	300-350	480-620	—	—
3.	3000-4000	3000-4000	3000-4000	—	1000-2000	300-3000	500-3000	500-1000	1000-2000	—	—
4.	675-725	675-725	650-725	540-590	700-800	—	—	290-380	480-650	520-650	575-650
5.	18000-30000	20000-40000	18000-25000	10000-20000	20000-50000	—	—	10000-30000	10000-20000	10000-20000	15000-40000
6.	—	—	—	2.6-1.8	2.5	3.0-8.0	3.0-4.0	2.5	1.74-5.5	—	—
7.	0.006	0.005	0.005	0.007	0.007-0.009	.0003-.005	0.0003-0.009	0.003 unaged- 0.026 aged	0.005-0.007	0.002-0.003	0.001-0.003
8.	1.41	1.86	1.45	1.14	1.36	1.6-2.0	—	0.908-0.917	1.2	1.25	1.24-1.52
9.	19.6		—	25.2	20.4	—	—	30.4-30.2	23.0	22.2	22.4-18.2
10.	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Good	Poor	Excellent	Fair to good	Fair
11.	13300	11300	13000	7500	13000	4000-15000	4000-6000	3800-4400	8000-9500	9600	12000-25000
12.	2.5	2.1	2.5	25.0-90.0	13-20	0.5-1.5	0.5-1.0	300.0-380.0	100.0-130.0	10.0	0.9-5.0
13.	—	—	—	3.2	3.7	5-30	5.0-10.0	0.26-0.50	3.0-3.5	4.5	5.0-17.0
14.	35000	46700	33860	—	17900	—	—	—	12500	14000	13000-21000
15.	23400	21500	22100	11000	17200	12000-40000	7000-15000	—	13500	15000	17000-32000
16.	1.0	0.5	0.8	8.0 (1/2 x 1/4 in. bar)	1.2 @ 73°F.	2.0-18.0	2.0-4.0	No break	12.0-18.0 (1/2 X 1/8 in. in. bar)	4.0-5.0 (1/2 x 1/8 in. in. bar)	1.2-4.0 1.9-6.5 (1/4 x 1/2 in.)
17	E104	E100	E98	R117	M110	(55-65 Barcol)	(50-60 Barcol)	55-65 (Shore D)	M70-78, R115-125	M85	M88-95
18.	7.0	11.3	7.1	3.0	3.95	10-40	1.0-1.3	0.49	3.2-3.5	5.0	5.0-14.0
19.	—	—	—	—	3.4	—	—	0.31	3.45	5.2	5.0-15.0
20.	—	—		7.13	4.55	—	—	—	4.6	4.8	4.9-5.2
21.	—	—	—	0.35	—	—	—	0.45	0.28-0.30	—	—
22.	3.4-4.0	—	—	3.6	4.7	—	—	15.0	6.6	3.42	1.7-4.0
23.	550	550	550	250	500	400	350	225	250	275	275
24.	540	545	565	300	525	-490	-490	130-140	265-285	288	289-300
	540	545	565	320		—	—	215-235	270-290	295	300-310
25.	0.8×10^{15}	—	—	1.5×10^{16}	3.2×10^{16}	—	—	—	2.1×10^{16}	3×10^{16}	$4.0\text{-}5.0 \times 10^{16}$
26.	-400	—	—	430	350	—	—	—	380	450	450
27.		—	—	—	—	—	—	—	380	450	400
28.	—	—	—	3.14	3.94	—	—	—	2.97-3.17	3.10	3.0-3.53
29.	—	—	—	2.85	3.80	—	—	2.25	3.02	—	—
30.	3.8-4.1	4.1	—	3.10	3.70	—	—	2.25	2.92-2.93	3.05	3.0-3.48
31.	—	—	—	0.006	0.003	—	—	—	0.009	0.0008	0.0009-0.0013
32.	—	—	—	0.004	0.0035	—	—	0.005	0.0021	—	—
33.	0.0005-0.0007	0.008	—	0.007	0.013	—	—	0.005	0.010	0.0075	0.0067-0.0075
34.	—	—	—	180+	67	180-230	200-300	—	10-120	5-120	5-120
35.	—	—	—	—	1.67	—	—	1.50	1.586	—	—
36	—	—	—	Transl. to Opaque	Opaque	—	—	Translucent	Transp. to Opaque	Translucent to Opaque	
37.	—	—	—	—	—	—	—	—	85-91	—	—
38.	—	—	—	—	—	—	—	—	0.5-2	—	—
39.	0.28	0.20	0.27	0.25	1.1	—	—	0.01-0.026	0.15-0.18	0.12	0.07-0.20
40.	—	—	—	—		—	—	1.08	—	—	—
41		—	—	None to yellows slight em-brittlement	Slight darkening	—	—	Crazes rapidly		Slight color change, slight embrittlement	
42	Very resistant	Very resistant	Very resistant	None	None	None	—	Resistant		None	
43.	Very resistant	Very resistant	Very resistant	Resists some	None	None	—	Attacked by oxidizing	Attacked slowly	Attacked by oxidizing acids	
44.	Slight attack	Slight attack	Slight attack	None	None	None	—	Very resistant		Limited resistance	
45	Attacked	Attacked	Attacked	None	None	None	—	Very resistant		Attacked	
46	Very resistant	Very resistant	Very resistant	Soluble in chlorinated aromatics, esters, ketones	Soluble highly polar solvents, un-affected by most common solvents, fuel, lubricants	Some swelling in hot aromatics	—	—	Resistant paraffinics; soluble in aromatic and chlorinated hydrocarbons	Soluble in chlorinated hydrocarbons	

PLASTICS PROPERTIES CHART (Cont'd)		ASTM test method	POLYCARBONATES (Cont'd)	THERMOPLASTIC POLYESTER					POLYESTERS	
			ABS-polycarbonate alloy	Non-reinforced	PCDT	18% glass filled	30% glass filled	36% glass filled	Linear aromatic	Aromatic copolyester compression molding grade
PROCESSING	1. Molding qualities	—	Good	Excellent	Excellent	Good to excel.	Good to excel.	Good to excel.	Good	Good
	2. Compression molding temp., °F	—	Not. rec.	—	—	—	—	—	658-800	700
	3. Comp. molding pressure, p.s.i.	—	—	—	—	—	—	—	4000-10000	12000
	4. Injection molding temp., °F	—	490-540	437-540	440	500-540	437-500	500-550	—	—
	5. Injection molding pressure, p.s.i.	—	8000-25000	8000-23000	—	8000-23000	8000-23000	17000	—	—
	6. Compression ratio	—	—	—	—	—	—	—	3.1	4.0-1.0
	7. Mold (linear) shrinkage, in./in.	—	0.005-0.009	0.015-0.020	0.002	0.002-0.006	0.002-0.008	0.001-0.003	0.007	0.012
	8. Specific gravity (density)	D792	1.10-1.20	1.31-1.38	1.2	1.48-1.67	1.52	1.73	1.45	1.35
	9. Specific volume, cu. in./lb.	D792	26.0-24.0	20.2-21.1	—	18.2-18.7	18.2	17	19.2	20.5
	10. Machining qualities	—	Good to excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
MECHANICAL	11. Tensile strength, p.s.i.	D638	7500-8300	8200	7290	16000-19600	17000-19000	25000	2500	10000
	12. Elongation, %	D638	10-150	50-300	210	2.0-3.0	2-4	2	6.5	7-9
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	3.0-3.8	2.8	—	8	13 x 10^5	16	6.3	1.90
	14. Compressive strength, p.s.i.	D695	8500-11000	8600-14500	—	16200-18000	18000-23500	30000	16000	20000
	15. Flexural yield strength, p.s.i.	D790	10500-14500	12000-16700	10600	26000-26500	26000	38000	5600	15000
	16. Impact strength, ft. lb./in. of notch (½ x ½ in. notched bar, Izod test)	D256	8.0-13.0@73°F 1.5-3.5@-40°F (1/2 x 1/8 in. bar)	0.8-1.0	1.0 @ 73°F. 0.7 @ -40°F.	1.2-1.3	1.3-1.6	1.4	—	0.4
	17. Hardness, Rockwell	D785	R106-120	M68,78,85,98	R108	M90,109	M90	M110	88 (Shore D)	R-124
	18. Flexural elastic modulus, p.s.i. x 10^5	D790	3.0-4.2	3.3-4.01	2.97	8	11.0-12.0	16	10.3	4.5
	19. Compressive modulus, p.s.i. x 10^5	D695	—	—	1.75	0.7 x 10^6	0.7 x 10^6	—	—	3.0
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq.cm./1(°C./cm.)	C177	6.0-9.0	4.2-6.9	—	7.0	7.0	7.1	18.0	9.0
	21. Specific heat, cal./°C./gm.	—	—	0.28-0.55	—	0.25-0.30	0.30	0.22	—	0.31
	22. Thermal expansion, 10^{-5} in./in./°C.	D696	6.2	6.0-9.5	4.4/°F	1.1-2.5	1.1-6.1	2	2.8	2.87 x 10^{-5} in./in./°F
	23. Resistance to heat, °F. (continuous)	—	200-250	122-250	—	200-300	240-350	200-300	600	550
	24. Deflection temp., °F @ 264 p.s.i. fiber stress	D648	annealed-220-260	122-185	154	415	428	455	—	572
	@ 66 p.s.i. fiber stress		235-266	240-374	—	465	437	480	—	600
ELECTRICAL	25. Volume resistivity, ohm-cm. (50% RH and 23° C.)	D257	2.2-4.0 x 10^{16}	10^{15}-2 x 10^{16}	—	20 x 10^{16}	10^{16}	10^{16}	10^{16}	10^{15}
	26. Dielectric strength, short time, 1/8-in. thickness, volts/mil	D149	350-500	420-556	420	460	460-556	—	770	450
	27. Dielectric strength, step-by-step 1/8 in. thickness volts/mil	D149	350-460	300, 400 (1.1 mm)	—	400, 550 (2.0 mm)	400, 550 2.0 mm)	—	—	—
	28. Dielectric constant, 60 cyc.	D150	2.4-5.0	3.29-3.3	3.1	3.9	3.7-3.81	4.1	3.22	3.72
	29. Dielectric constant, 10^3 cyc.	D150	2.4-4.5	3.2-3.46	—	3.8	3.6	4.0	3.36	3.68
	30. Dielectric constant, 10^6 cyc.	D150	2.4-3.8	3.1-3.28	—	3.7	—	3.8	3.28	3.64
	31. Dissipation (power) factor, 60 cyc.	D150	0.003-0.007	—	0.0004	0.003	0.002-0.0017	0.002	0.0029	0.0046
	32. Dissipation (power) factor, 10^3 cyc.	D150	0.003-0.006	0.0014-0.005	—	0.005	0.002-0.0025	0.004	0.0062	0.0085
	33. Dissipation (power) factor, 10^6 cyc.	D150	0.006-0.013	0.0022-0.03	—	0.02	130	0.017	0.0025	0.0151
	34. Arc resistance, sec.	D495	70-120	75-192	—	130-146	—	—	—	Tungsten rod 127
OPTICAL	35. Refractive index, n_D	D542	—	—	—	—	—	—	Opaque	Opaque
	36. Clarity	—	—	Opaque	Transparent	Opaque	Opaque	Opaque	0	0
	37. Transmittance, %	—	—	—	70-5 mils	—	—	—	100	100
	38. Haze, %	—	—	—	0.4	—	—	—	0.02	0.04
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8 in. thick., %	D570	0.20-0.35	0.08-0.09	0.2	0.02-0.07	0.07-0.08	0.05	—	—
	40. Flammability[a] Burning rate, in./min. AEB, in./ATB, sec.[b]	D635	0.8-1.27	0.4	0.8	0.5	1.1 0.16(FR gr.)	—	—	—
	41. Effect of sunlight	—	None to slight yellowing, some embrittlement	Discolors very slightly	—	Discolors very slightly	Colors may fade	Discolors very slightly	None	None[c]
	42. Effect of weak acids	D543	None	Resistant	Resistant	Resistant except hydrofluoric acid	None	Resistant excep hydrofluoric ac	Slight	Slight
	43. Effect of strong acids	D543	Attacked by conc. oxidizing acids	Attacked by oxidizing acids	Attacked by oxidizing acids	Attacked slowly by high conc. oxidizing acids	None	Attacked slowly by high conc. oxidizing acids	Slight	Slight
	44. Effect of weak alkalies	D543	None	Resistant	Resistant	Slight	Considerable attack	Slight	Slight	Slight
	45. Effect of strong alkalies	D543	Slight	Attacked	Slight	Attacked	Considerable attack	Attacked	Attacked	Attack
	46. Effect of organic solvents	D543	Soluble in ketones, esters and some partly chlorinated hydrocarbons	Resistant to common solvents, slightly attacked by partly halogenated hydrocarbons	Attacked by ketones, hydrocarbons	Resistant to common solvents, slightly attacked by partly halogenated hydrocarbons	Swollen by some polar solvents but generally resistant	Resistant to common solvents, slightly attacked by partly halogenated hydrocarbons	Excellent	Excellent

a This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.
b AEB = Avg. extent of burning in inches: ATB = Avg. time of burning in seconds.
c Withstands 1000 megarads of radiation without loss of properties.

POLYESTERS (THERMOSETTING) AND ALKYDS

(see also next page)

	Cast polyester		Glass reinforced polyester					Alkyd		
	Rigid	Flexible	Preformed chopped roving	Premix chopped glass	Woven cloth	Sheet molding compound	Low shrink compound	Granular and putty types, mineral filled	Asbestos filled	Glass filled
1.	—	—	Excellent	Excellent	Hand lay up	Good	Good	Excellent	Excellent	Excellent
2.	—	—	170-320	280-350	Rm. temp. 250	270-350	270-350	270-350	280-320	290-350
3.	—	—	250-2000	500-2000	0.300	300-1200	400	100-4000	500-2000	1000-6000
4.	—	—	—	—	—	—	270-330	280-390	330-380	280-380
5.	—	—	—	—	—	—	2000	2000-20000	10000-20000	2500-20000
6.	—	—	—	—	—	—	1.0	1.8-2.5	2.0-2.5	1.0-11.0
7.	—	—	0.000-0.002	0.001-0.012	0.000-0.002	0.001-0.004	0.001	0.003-0.010	0.004-0.007	0.001-0.010
8.	1.10-1.46	1.01-1.20	1.35-2.30	1.65-2.30	1.50-2.10	1.65-2.60	1.60-2.40	1.60-2.30	1.65-2.20	2.03-2.33
9.	25.2-19.0	27.4-23.0	20.5-13.9	—	18.5-13.2	—	—	17.3-12.0	16.8	13.2
10.	Good	Fair	Good	Good	Good	Good	Good to excel.	Poor to fair	Poor to fair	Poor to fair
11.	6000-13000	500-3000	15000-30000	3000-10000	30000-50000	8000-20000	4500-20000	3000-9000	4500-9000	4000-9500
12.	5.0	40.0-310.0	0.5-5.0	0.5	0.5-2.0	—	—	—	—	—
13.	3.0-6.4	—	8.0-20.0	10.0-25.0	15.0-45.0	—	10.0-25.0	5.0-30.0	20-30	20.0-28.0
14.	13000-30000	—	15000-30000	20000-30000	25000-50000	15000-30000	15000-30000	12000-38000	22500	15000-36000
15.	8500-23000	—	10000-40000	7000-20000	40000-80000	10000-36000	9000-35000	6000-17000	8000-10000	8500-26000
16.	0.2-0.4	7.0	2.0-20.0	1.5-16.0	5.0-30.0	7.0-22.0	2.5-15.0	0.30-0.50	0.45-0.50	0.50-16.0
17.	M70-M115 50-75 (Barcol)	84-94 (Shore D)	50-80 (Barcol)	50-80 (Barcol)	60-80 (Barcol)	50-70 (Barcol)	40-70 (Barcol)	60-70 (Barcol) 98 (E scale)	M99	50-80 (Barcol) 95 (E scale)
18.	—	—	10-30	10-20	—	10.0-22.0	10.0-25.0	20	20-30	20.0
19.	—	—	—	—	—	—	—	20-30	—	—
20.	4.0	—	—	10.0-16.0	—	—	—	12.2-25.0	—	15.0-25.0
21.	—	—	—	0.25	—	—	—	0.25	—	0.25
22.	5.5-10.0	—	2.0-5.0	2.0-3.3	1.5-3.0	2.0	0.6-3.0	2.0-5.0	—	1.5-3.3
23.	250	250	300-350	300-350	300-350	300-400	300	300-450	450	450
24.	140-400	—	400	400	400	375-500	375-500	350-500	315	400-500
25.	10^{15}	—	10^{14}	10^{12}-10^{15}	10^{14}	10^{14}-10^{15}	10^{12}x10^{14}	10^{13}-10^{15}	6.6x10^{8}	6x10^{12}-1.5x10^{15}
26.	380-500	250-400	350-500	345-420	350-500	380-450	380-450	350-450	380	250-530
27.	280-420	277	300-450	275-390	300-400	300-400	300-400	300-375	290	200-400
28.	3.00-4.36	4.4-8.1	3.8-6.0	5.3-7.3	4.1-5.5	4.4-6.3	4.5-6.0	5.1-7.5	—	5.9-7.3
29.	2.8-5.2	4.5-7.1	4.0-6.0	4.68	4.2-6.0	4.4-6.1	4.5-6.0	5.0-6.4	5.2	5.4-7.4
30.	2.8-4.1	4.1-5.9	3.5-5.5	5.2-6.4	4.0-5.5	4.2-5.8	4.2-6.0	4.6-6.1	4.5	5.2-6.8
31.	0.003-0.028	0.026-0.310	0.01-0.04	0.011-0.041	0.01-0.04	0.007-0.021	0.1-0.2	0.009-0.06	—	0.007-0.041
32.	0.005-0.025	0.016-0.050	0.01-0.05	—	0.01-0.06	0.007-0.015	0.01-0.02	0.007-0.040	0.11	0.007-0.04
33.	0.006-0.026	0.023-0.060	0.01-0.03	0.008-0.022	0.01-0.03	0.016-0.024	0.01-0.02	0.006-0.040	0.04-0.06	0.008-0.023
34.	125	135	120-180	120-240	60-120	121-202	—	75-240	138	130-420
35.	1.523-1.570	1.537-1.550	—	—	—	—	—	—	—	—
36.	Transparent to opaque		Transl. to opaq.	Opaque	Transl. to opaq.	Opaque	Opaque	Opaque	Opaque	Opaque
37.	—		—	—	—	—	—	—	—	—
38.	—		—	—	—	—	—	—	—	—
39.	0.15-0.60	0.50-2.50	0.01-1.00	0.06-0.28	0.05-0.50	0.10-0.15	0.01-0.25	0.05-0.50	0.14	0.03-0.5
40			0.7-2.0			—	—	—	—	—
41.	Yellows slightly	—	Slight	0.16(FRgr.) Depends on pigmentation	Slight	Slight	— Slight	0.16(FRgr.) None	— None	— None
42.	Ortho & gen. purp. iso resis. some at RT chem resis. iso resis. to 170° F; Bis. & HBPA to 210°F.; chlor. anhyd. resis. most at RT, some to 350°F.					None	None	None	None	Poor to fair
43	Ortho & gen. purp. not resis. strong or oxidizing; chem. resis. iso resis. strong to 170°F., not resis. low-concen. oxidizing at RT; Bis & HBPA resis. strong to 210°F., oxidizing to 170°F., chlor. anhyd. resis. most at RT, some to 250°F.					—	Attacked by high conc.	Attacked	Slight	Poor to fair
44	Ortho & gen. purp. resis some at RT; chem. resis. iso to 170°F. and Bis. & HBPA to 210°F.; chlor. anhyd. resis. some to 210°F.					Slight	Slight	Attacked	None	Poor to fair
45	Ortho & gen. purp. iso & chem. resis. iso not resis.; chem. resis. Bis. resis. to 170°F.; chlor. anhyd. resis. some to 170°F.					Attacked	Attacked	Decomposes	Slight	Poor to fair
46.	Ortho & gen. purp. iso not resis., chem. resis. iso resis. some & Bis. & HBPA most at RT; chlor. anhyd. resis. most at RT, some to 200°F Effect of salts: Ortho & gen. purp. iso resis. some at RT; chem. resis. iso resis. to 170°F, Bis. & HBPA to 120°F.; chlor. anhyd. resis. most to 250°F.					Slight	Slight to considerable	Fair to good	None	Fair to good

	PLASTICS PROPERTIES CHART (Cont'd)	ASTM test method	POLYESTERS (THERMOSETTING) AND ALKYDS (Cont'd)		POLYETHER SULPHONE	POLYETHYLENES AND ETHYLENE COPOLYMERS (see also next page)				
			Synthetic fiber filled	Vinyl ester		Low density	Medium density	High density	Polyethylene cross-linkable compounds: Rotational molding grades	Polyethylene cross-linkable compounds: Molding grades
PROCESSING	1. Molding qualities	—	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
	2. Compression molding temp., °F.	—	280-350	270-300	590-690	275-350	300-375	300-450	390-450	240-450
	3. Comp. molding pressure, p.s.i.		500-3000	100-200	1000-1500	100-800	100-800	500-800	500-800	100-800
	4. Injection molding temp., °F.	—	280-380	—	590-750	300-600	300-600	300-600	—	250-300
	5. Injection molding pressure, p.s.i.	—	2000-20000	—	10000-20000	8000-30000	8000-30000	10000-20000	—	—
	6. Compression ratio	—	1.0-5.0	—	—	1.8-3.6	1.8-2.2	2.0	—	—
	7. Mold (linear) shrinkage, in./in.	—	0.005-0.0010	—	0.007	0.015-0.050	0.015-0.050	0.02-0.05	0.02-0.05	0.007-0.090
	8. Specific gravity (density)	D792	1.24-2.10	1.03-1.083	1.37	0.910-0.925	0.926-0.940	0.941-0.965	0.930-0.939	0.95-1.45
	9. Specific volume, cu. in./lb.	D792	22.4-13.2	—	19.7-20.2	30.4-29.9	29.9-29.4	29.4-28.7	—	—
	10. Machining qualities	—	Fair to excellent	—	Excellent	Good	Good	Excellent	—	Good to excellent
MECHANICAL	11. Tensile strength, p.s.i.	D638	4500-8000	10500	12200(at yield)	600-2300	1200-3500	3100-5500	2500-2700	1600-4600
	12. Elongation, %	D638	—	3.5-5.5	30-80(at break)	90.0-800.0	50.0-600.0	20-1300	450-660	10.0-440.0
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	20.0	—	3.5-3.54	0.14-0.38	0.25-0.55	0.6-1.8	—	0.5-5.0
	14. Compressive strength, p.s.i.	D695	20000-30000	—	—	—	16.0	2700-3600	—	2000-5500
	15. Flexural yield strength, p.s.i.	D790	10000-20000	17800-18400	18650(at yield)	—	4800-7000	—	—	2000-6500
	16. Impact strength, ft. lb./in. of notch (½ x ½ in. notched bar, Izod test)	D256	0.50-4.50	—	1.6	No break	0.5-6.0	0.5-20.0	No break	1.0-20.0
	17. Hardness, Rockwell	D785	95(M scale) 76(E scale)	—	M88	D41-D50 (Shore), R10	D50-D60 (Shore), R15	D60-D70 (Shore)	D60-63 (Shore)	55-80 (Shore D)
	18. Flexural elastic modulus, p.s.i. x 10^5	D790	17.0	4.7-4.9	3.7-3.75	0.08-0.60	0.60-1.15	1.0-2.6	1.0	0.7-3.5
	19. Compressive modulus, p.s.i. x 10^5	D695	—	—	—	—	—	—	—	0.5-1.5
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq.cm.,/1(°C./cm.)	C177	7.0-16.5	—	3.2-4.4	8.0	8.0-10.0	11.0-12.4	—	—
	21. Specific heat, cal./°C./gm.	—	—	—	0.26	0.55	0.55	0.55	—	—
	22. Thermal expansion, 10^{-5} in./in./°C.	D696	3.0-5.5	—	5.5	10.0-22.0	14.0-16.0	11.0-13.0	—	10.0-35.0
	23. Resistance to heat, °F. (continuous)	—	300-430	200-220	300-390	180-212	220-250	250	—	275
	24. Deflection temp., °F. @ 264 p.s.i. fiber stress	D648	245-430	—	397	90-105	105-120	110-130	140	105-145
	@ 66 p.s.i. fiber stress		—	185-215	—	100-121	120-165	140-190	—	130-225
ELECTRICAL	25. Volume resistivity, ohm-cm.	D257	10^8-10^{16}	2.6x10^{15}	10^{17}-10^{18}	>10^{16}	>10^{16}	>10^{16}	—	200-15 x 10^8
	26. Dielectric strength, short-time, 1/8-in. Thickness, volts/mil	D149	365-500	445-541	400	450-1000	450-1000	450-500	—	—
	27. Dielectric strength, step-by-step, 1/8-in. thickness, volts/mil	D149	325-450	—	—	420-700	500-700	440-600	—	—
	28. Dielectric constant, 60 cyc.	D150	3.8-5.0	4.38-4.88	3.50	2.25-2.35	2.25-2.35	2.30-2.35	—	—
	29. Dielectric constant, 10^3 cyc.	D150	3.7-4.9	4.35-4.72	3.50	2.25-2.35	2.25-2.35	2.30-2.35	—	—
	30. Dielectric constant, 10^6 cyc.	D150	3.6-4.7	4.15-4.27	3.50	2.25-2.35	2.25-2.35	2.30-2.35	—	2.63-3.11
	31. Dissipation (power) factor, 60 cyc.	D150	0.012-0.026	0.0097-0.0210	0.001	<0.0005	<0.0005	<0.0005	—	—
	32. Dissipation (power) factor, 10^3 cyc.	D150	0.001-0.03	0.0055-0.0210	0.0035	<0.0005	<0.0005	<0.0005	—	—
	33. Dissipation (power) factor, 10^6 cyc.	D150	0.010-0.016	0.013-0.019	0.006	<0.0005	<0.0005	<0.0005	—	0.001-0.002
	34. Arc resistance, sec.	D495	85-185	—	—	135-160	200-235	—	—	—
OPTICAL	35. Refractive index, n_D	D542	—	—	1.65	1.51	1.52	1.54	—	—
	36. Clarity	—	Opaque	—	Transparent	Transparent to opaque				
	37. Transmittance, %	D791	—		—	0-75	10-80	0-40	—	—
	38. Haze, %	—	—			4-50	4-50	10-50	—	—
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8 in. thick, %	D570	0.05-0.20	0.2	0.43	<0.01	<0.01	<0.01		<0.01-0.06
	40. Flammability[a] Burning rate, in./min. AEB, in./ATB, sec.[b]	D635	—	—	—	1.04 0.8/0-25(FRgr.)	1.00-1.04 0.6/10-60(FRgr)	1.00-1.04	—	—
	41. Effect of sunlight	—	None	—	Slight yellowing strength loss	Unprotected material crazes rapidly, requires black for complete protection but weather resistant grades available in natural and colors				
	42. Effect of weak acids	D543	None	Good	None	Resistant	Very resistant			
	43. Effect of strong acids	D543	Slight	Good	None	Attacked by oxidizing acids	Attacked slowly by oxidizing acids			
	44. Effect of weak alkalies	D543	None	Good	None	Resistant	Very resistant			
	45. Effect of strong alkalies	D543	Slight	Good	None	Resistant	Very resistant			
	46. Effect of organic solvents	D543	Fair to good	Fair to good	Aliphatic—none; aromatic—partly soluble	Resistant below 60°C except to chlorinated solvents		Resistant below 80°C		

a This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.
b AEB = Avg. extent of burning in inches; ATB = Avg. time of burning in seconds.
c Btu. hr. ft.^{2} °F. in.
d Btu. lb. °F.
e Unprotected material crazes rapidly, requires black for protection

	POLYETHYLENES AND ETHYLENE COPOLYMERS (Cont'd)				POLYIMIDES						POLYMETHYLPENTENE POLYMER	POLYPHENYLENE SULFIDES	
	Polyethylene cross-linkable compounds Wire and cable grades	Ethylene-ethyl acrylate copolymer	Ethylene vinyl acetate copolymer	Ultra high molecular weight	Thermoplastic	Condensation	Glass filled	Graphite filled	PTFE filled	Encapsulating grade		Unfilled	40% glass filled
1.		Excellent	Excellent	Fair	Excellent	—	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
2.		200-300	200-300	400-500	660		380-480	380-480	380-480	—	540-555	600-650	600-650
3.		50-1000	50-2500	800-1200	4000-5000	—	1500-6000	1500-6000	1500-6000	—	500-1000	1000-2000	1000-2000
4.		250-600	250-430	—		—	—	—	—	—	540-580	625-700	625-700
5.		8000-20000	8000-20000		—	—	—	—	—	—	8000-20000	5000-15000	10000-20000
6.		—	—	—	3.0-4.0	—	—	—	—	—	2.0-2.5	—	—
7.	0.020-0.050	0.015-0.035	0.007-0.012	—	—	—	0.001-0.002	0.006	0.008	0.003	0.015-0.030	0.010	.002
8.	0.91-1.40	0.93	0.920-0.960	0.94	1.43	1.43-1.51	1.9	1.45	1.42	1.55	0.83	1.34	1.64
9.		—		29.4	19.3		14.5	18.0	19.4	17.8	33.3	20.6	—
10.	Good to excellent	Fair	Fair	Good to excellent	Excellent		Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent
11.	1500-3100	1600-2100	1440-2800	2500-3500	17100	9000-13000	27000	5700	5000	2600	3500-4000	10000	21000
12.	180-600	700-750	550-900	300-500	10	4-9	<1%	<1%	<1%	<1%	13-22	3	3
13.		0.041-0.075	0.02-0.12	0.20-1.10	1.88	32000-40000	28.5	—	—	—	1.6-2.1	4.8	11.2
14.		—	—	—	29900	—	32500	20000	20000	9700	—	—	—
15.		3000-3600			28800	15000-17000	49500	12800	7100	10000	—	20000(at brk)	37000(at brk)
16.		No break	No break	No break	0.7	0.5-1.0@73°F.	17@77°F.	0.25	0.25	0.76	0.4-1.6	0.3@75°F. 1.0@300°F. (½x¼ in. bar)	0.8@75°F. 1.8@300°F. (½x¼ in. bar)
17.	33-57 (Shore D)	D27-36 (Shore)	D17-45 (Shore)	D60-70 (Shore)	E99	32-58	M120	M110	M115	50 (Shore D)	L67-74	R124	R123
18.			0.01-0.20	1.30-1.40	4.81	—	32.5	9.0	3.9	6.1	1.4-2.0	6.0	22.0
19.		—		—	295	—	24.6	—	—	—	—	—	—
20.	—	—	—	—	2.3-2.6[c]	—	12	3.5	5.2	6.7	4.0	6.84	—
21.		0.55	0.55	—	0.27[d]	—	—	—	—	—	0.52	—	—
22.	10.0-35.0	16.0-25.0	16.0-20.0	7.2	5.0	—	1.5	1.5	6.6	4.5	11.7	5.5	4.0
23.	275	190-200	—	—	550	—	500 in air	500 in air	500 in air	500 in air	250-320	400-500	400-500
24.	100-175	—	93	105-120	270-280	>470	660	>550	>550	>550	—	278	>425
	100-175	—	140-147	155-180	—	—	660	>550	>550	>550	—	—	—
25.	—	10^{16}	10^{15}	10^{16}	10^{16}	10^{16}-10^{17}	5×10^{15}	10^{3}	2×10^{16}	8×10^{14}	10^{16}	10^{16}	10^{16}
26.	230-1420	450-550	620-780	710	560	400	500	—	380	725	—	595	490
27.	—	—	620-780	680		—	—	—	—	—	700	—	—
28.	2.28-7.60	2.7-2.9	2.50-3.16	—	3.43	—	4.84	—	—	—	2.12	—	—
29.	2.27-7.40	2.7-2.9	2.60-2.98	—	3.42	3.5	4.70	—	4.0	—	2.12	3.11	3.79
30.	2.27-7.50	2.7-2.8	2.6-3.2	2.30	—	—	4.74	—	3.2	4.5	2.12	3.22	3.88
31.	0.003-0.044	0.01-0.02	0.003-0.020	—	0.0055	—	0.0034	—	—	—	0.00007	—	—
32.	0.00048-0.04900	0.01-0.02	0.011-0.017	—	0.0018	0.002	0.003	—	0.002	—	0.00003	0.0004	0.0037
33.	0.0004-0.0050	0.01-0.02	0.03-0.05	0.0002		—	0.0055	—	0.005	0.013	0.000025	0.0007	0.0041
34.	—	—	—	—	230	230	—	—	—	—	—	—	—
35.	—	—	—	—	—	—	—	—	—	—	1.465	—	—
36.	Transparent to opaque	Translucent	Transp.-opaq.	Transl.-opaque	Opaque	—	Opaque	Opaque	Opaque	Opaque	Transp., opaq.	Opaque	Opaque
37.	—	—	0-80	—		—	—	—	—	—	90	—	—
38.	—	—	2-40	—	—	—	—	—	—	—	5.0	—	—
39.	<0.01-0.06	0.04	0.05-0.13	0.01	0.3	0.32	0.20	0.6	0.3	0.11	0.01	02	.01
40.	—	—	—	—	—	—	—	—	—	—	1.0	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—
41.	Same as for polyethylene	Very slight yellowing	Very slight yellowing	—	—	—	—	—	—	—	See footnote[e]	—	—
42.	Very resistant	Resistant	Resistant	Very resistant	Resistant	—	Resistant	Resistant	Resistant	Resistant	None	None	
43.	Attacked slowly by oxidizing acids	Attacked by oxidizing acids	Attacked	Attacked by oxidizing acids	Resistant	—	Resistant	Resistant	Resistant	Resistant	Attacked slowly by oxidizing acids	Attacked slowly by oxidizing acids	
44.	Very resistant	Resistant	Resistant	Very resistant	Slow attack	—	Slow attack	Slow attack	Slow attack	Slow attack	None	None	
45.	Very resistant	Resistant	Resistant	Very resistant	Attack	—	Attack	Attack	Attack	Attack	Very resistant	None	
46.	Resistant below 80°C	Attacked by chlorinated solvents; soluble in aromatic solvents above 50°C	Soluble in chlorinated and aromatic solvents over 50°C	Resists many solvents below 80°C.	Very resistant	—	Very resistant	Very resistant	Very resistant	Very resistant	Attacked by chlorinated aromatic solvents	Resistant below 375-400°F.	

	PLASTICS PROPERTIES CHART (Cont'd)	ASTM test method	POLYPROPYLENES				
			Unmodified	Copolymer	Inert Filled	Glass reinforced	Impact (rubber modified)
PROCESSING	1. Molding qualities	--	Excellent	Excellent	Excellent	Excellent	Excellent
	2. Compression molding temp., °F.	--	340-450	340-550	340-550	340-550	340-450
	3. Comp. molding pressure, p.s.i.	--	500-1000	500-1000	500-1000	500-1000	500-1000
	4. Injection molding temp., °F.	--	400-550	400-550	375-550	400-550	400-550
	5. Injection molding pressure, p.s.i.	--	10000-20000	10000-20000	10000-20000	10000-20000	15000
	6. Compression ratio	--	2.0-2.4	2.0-2.4	--	--	2.0-2.4
	7. Mold (linear) shrinkage, in./in.	--	0.010-0.025	0.010-0.025	0.005-0.015	0.002-0.008	0.01-0.25
	8. Specific gravity (density)	D792	0.902-0.910	0.890-0.905	1.0-1.3	1.05-1.24	0.890-0.91
	9. Specific volume, cu. in./lb.	D792	30.8-30.4	31.2-30.5	26.0	24.5	30.8-30.5
	10. Machining qualities	--	Good	Good	Fair-good	Fair	Good
MECHANICAL	11. Tensile strength, p.s.i.	D638	4300-5500	2900-4500	4500-8200	6000-14500	2800-4400
	12. Elongation, %	D638	200.0-700.0	200-700 (at break)	3.0-20.0 (at break)	2.0-3.6	350.0 -500.0
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	1.60-2.25	1.0-1.7	4.0-8.0	4.5-9.0	1.0-1.7
	14. Compressive strength, p.s.i.	D695	5500-8000	3700-8000	--	5500-7000	4000-6500
	15. Flexural yield strength, p.s.i.	D790	6000-8000	5000-7000	8000-9000	7000-11000	--
	16. Impact strength, ft. lb./in. of notch (½ x ½ in. notched bar, Izod test)	D256	0.5-2.2 @ 73°F. (1/8 x 1/2 in. bars)	1.1-20.0 @ 73°F. (1/8 x 1/2 in. bars)	0.4-3.0 @ 73°F. (1/8 by 1/2 in. bars)	1.0-5.0 @ 73°F. (1/8 x 1/2 in. bars)	1.0-15.0 @ 73°F (1/8 x 1/2 in. bars)
	17. Hardness, Rockwell	D785	R80-110	R50-96	R94-100	R110	R50-85
	18. Flexural elastic modulus, p.s.i. x 10^5	D790	1.7-2.5	1.3-2.0	3.0-6.5	3.8-8.5	1.2-1.8
	19. Compressive modulus, p.s.i. x 10^5	D695	1.5-3.0	--	2.4	--	--
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq.cm../1 (°C./cm.)	C177	2.8	2.0-4.0	--	--	3.0-4.0
	21. Specific heat, cal./°C./gm.	--	0.46	0.5	--	--	0.5
	22. Thermal expansion, 10^{-5} in./in./°C.	D696	5.8-10.2	8.0-9.5	2.9	2.9-5.2	6.0-8.5
	23. Resistance to heat, °F. (continuous)	--	225-260	190-240	250-280	270-290	200-250
	24. Deflection temp., °F.		125-140	115-140	140-200	230-300	120-135
	@ 264 p.s.i. fiber stress	D648					
	@ 66 p.s.i. fiber stress		200-250	185-235	210-290	305-310	160-210
ELECTRICAL	25. Volume resistivity, ohm-cm. (50% RH and 23°C.)	D257	10^{16}	10^{17}	1.5-2.8 x 10^{15}	--	10^{15}
	26. Dielectric strength, short-time, 1/8 in. thickness, volts/mil	D149	500-660	500-660	450-650	--	500-650
	27. Dielectric strength, step-by-step 1/8 in. thickness, volts/mil	D149	450-650	450-600	--	--	450-600
	28. Dielectric constant, 60 cyc.	D150	2.2-2.6	2.25-2.30	2.50-2.75	2.37	2.3
	29. Dielectric constant, 10^3 cyc.	D150	2.2-2.6	2.24-2.30	2.50-2.65	2.36	2.3
	30. Dielectric constant, 10^6 cyc.	D150	2.2-2.6	2.24-2.30	2.50-2.60	2.38	2.3
	31. Dissipation (power) factor, 60 cyc.	D150	0.0005	0.0001-0.0005	0.0054-0.0070	0.0022	0.0003
	32. Dissipation (power) factor, 10^3 cyc.	D150	0.0005-0.0018	0.0001-0.0008	0.0036-0.0050	0.0017	0.0003
	33. Dissipation (power) factor, 10^6 cyc.	D150	0.0005-0.0018	0.0001-0.0018	0.0021	0.0035	0.0003
	34. Arc resistance, sec.	D495	136-185	136	121	74	--
OPTICAL	35. Refractive index, n_D	D542	1.49	--	--	--	--
	36. Clarity	--	Transp., transl., op.		Opaque	Opaque	Translucent
	37. Transmittance, %		55-90				
	38. Haze, %		1.0-3.5				
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8 in. thick., %	D570	0.01-0.03	0.01-0.03	0.02-0.10	0.01-0.05	0.01-0.03
	40. Flammability[b]		0.75-0.83		1.5-2.5	0.75-0.83	--
	Burning rate, in./min.	D635					
	AEB, in./ATB, sec.[c]		0.2-0.8/4-16(FRgr.)		--	--	
	41. Effect of sunlight		Unprotected material crazes rapidly; requires black for complete protection, but weather-resistant grades available in natural and colors.				
	42. Effect of weak acids	D543	None				
	43. Effect of strong acids	D543	Attacked slowly by oxidizing acids				Attacked slowly by oxidizing acids.
	44. Effect of weak alkalies	D543	None	None	None	None	None
	45. Effect of strong alkalies	D543	Very resistant		Very resistant	Resistant	Very resistant
	46. Effect of organic solvents	D543	Resistant below 80°C				Attacked by hydrocarbons and chlorinated hydrocarbons

a Determined on ¼ in. thick specimens.
b This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.
c AEB = Avg. extent of burning in inches; ATB = Avg. time of burning in seconds.

POLYSTYRENES

	POLYSTYRENE MOLDING COMPOUNDS AND SHEET						STYRENE-ACRYLONITRILE COPOLYMER	
	Unfilled free-flowing general-purpose heat-resistant	Impact-resistant medium-impact high-impact heat-resistant	Special heat and chemical resistant type	Impact flame retardant	General purpose flame retardant	20 to 30% glass filled	Unfilled	20 to 33% glass filled
1.	Excellent	Excellent	Good	Excellent	Excellent	Excellent	Good	Excellent
2.	265-400	250-400	300-400	250-400	265-400	—	300-400	—
3.	1000-10000	1000-10000	1000-5000	1000-10000	1000-10000	—	1000-10000	—
4.	325-500	350-600	350-700	350-500	350-425	450-625	375-575	450-575
5.	10000-30000	10000-30000	10000-30000	10000-30000	10000-30000	15000-40000	10000-33000	15000-40000
6.	1.6-4.0	1.6-4.0	1.6-4.0	1.6-4.0	1.6-4.0	1.6-4.0	1.6-4.0	1.6-4.0
7.	0.001-0.006(C) 0.002-0.006(I)	0.002-0.006	0.001-0.008	0.002-0.006	0.002-0.006	0.001-0.002	0.002-0.007	0.001-0.002
8.	1.04-1.09	1.04-1.10	1.04-1.10	1.10	1.08	1.20-1.33	1.075-1.100	1.20-1.46
9.	26.0-25.6	28.1-25.2	26.2-24.8	25.2	25.6	22.2-20.9	25.8-25.2	23.9-19.9
10.	Fair to good	Good	Fair to good	Good	Fair to good	Good	Good	Fair
11.	5000-12000	1500-7000	6500-12000	5000	7000	9000-15000	9000-12000	8500-20000
12.	1.0-2.5	2.0-90.0	1.4-2.5	13	2	0.75-1.30	1.5-3.7	1.1-3.8
13.	4.0-6.0	1.4-5.0	4.0-6.0	3.0	4.5	8.4-12.9	4.0-5.6	4.0-14.0
14.	11500-16000	4000-9000	11500-16000	—	—	13500-18000	14000-17000	22000
15.	8000-14000	3000-12000	10000-17000	—	—	10500-20000	14000-19000	22000-26000
16.	0.25-0.40 (¼ in. bar) 1.6 (1/8 x 1/2 in.)	0.5-8.0 (23°C.)[a] 0.4-2.5 (-25°C.) (1/8 x 1/2 in.)	0.35-0.60 (¼ in. bar)	1.21 (1/8 x 1/2 in.)	0.25 (1/8 x 1/2 in.)	0.4-4.5	0.35-0.50	0.4-4.0
17.	M65-M80	M10-80; R30-100	M65-M90	M10	M70	M70-M95	M80-M90	M100, E60
18.	4.0-4.7	1.5-4.6	—	—	—	8.0-10.0	to 5.5	8.0-18.0
19.	—	—		—	—	—	5.3	—
20.	2.4-3.3	1.0-3.0	1.9-3.0	—	2.4-3.3	—	2.9	—
21.	0.32	0.32-0.35	0.32-0.35	—	0.32	0.23-0.27	0.32-0.34	—
22.	6.0-8.0	3.4-21.0	6.0-8.0	—	6.0-8.0	1.8-4.5	3.6-3.8	2.7-3.8
23.	150-170	140-175	170-220	—	—	180-200	140-205	200-220
24.	220 max. 180-230	195 max. 180-220	180-235 195-240	175 —	195 —	195-220 207-231	190-220 —	190-230 215-240
25.	10^{16}	10^{16}	10^{13}-10^{17}	10^{15}	10^{15}	3.2×10^{16}	10^{16}	$1.4\text{-}2.1 \times 10^{17}$
26.	500-700	300-600	400-600	500	500	350-425	400-500	510
27.	400-600	300-600	300-500	450	500	350-430	300-600	410
28.	2.45-3.1	2.45-4.75	2.45-3.4	3.2	3.1	—	2.6-3.4	3.6
29.	2.40-2.65	2.4-4.5	2.4-3.2	—	—	—	2.6-3.3	3.5
30.	2.40-2.7	2.4-3.8	2.4-3.1	2.8	2.7	—	2.6-3.1	3.4
31.	0.0001-0.0006	0.0004-0.0020	0.0005-0.0030	0.0006	0.0006	0.004-0.014	0.006-0.008	0.00645
32.	0.0001-0.0003	0.0004-0.0020	0.0005-0.0030	—	—	0.001-0.004	0.007-0.012	0.00652
33.	0.0001-0.0004	0.0004-0.0020	0.0005-0.0050	0.003	0.001	0.001-0.003	0.007-0.010	0.00668
34.	60-140	20-140	60-135	140	140	25-40	100-150	16
35.	1.59-1.60	—	1.57-1.60	—	—	—	1.56-1.57	—
36	Transparent	Transl., opaque	Transparent	Translucent, opaque	Transparent	Transl., opaque	Transparent	Transl., opaque
37.	87-92	35-57	88-90	—	87	—	78-88	—
38.	0.1-3.0	77	—	—	—	—	0.4-0.1	—
39.	0.03-0.10	0.05-0.6	0.05-0.40	—	—	0.05-0.10	0.20-0.30	0.08-0.22
40	1.5	1.5 —	1.5 —	0.5/3.0	— —	1.0 —	— —	0.1 —
41	Yellows slightly	Some strength loss, yellows slightly	Yellows slightly	Some strength loss, yellows	Yellows slightly	Yellows slightly	Yellows slightly	Yellows slightly
42.	None	None	None	None	None	None	None	Resistant
43.	Attacked by oxidizing acids	Attacked by oxidizing acids	Attacked by oxidizing acids	Attacked by oxidizing acids	Attacked by oxidizing acids	Attacked by oxidizing acids	Attacked by oxidizing acids	Attacked by oxidizing acids
44	None	None	None	None	None	Resistant	None	None
45	None	None	None	None	None	Surface only	None	Surface only
46.	Soluble in aromatic and chlorinated hydrocarbons	Soluble in aromatic and chlorinated hydrocarbons 140°-200°F.	Soluble in aromatic and chlorinated hydrocarbons 200-220°F.	Soluble in aromatic and chlorinated hydrocarbons		Soluble in aromatic and chlorinated hydrocarbons	Soluble in ketones, esters, some chlorinated hydrocarbons	Soluble in ketones, esters, some chlorinated hydrocarbons

PLASTICS PROPERTIES CHART (Cont'd)		ASTM test method	POLYSULFONE	POLYURETHANES: Cast urethane, Liquid	POLYURETHANES: Cast urethane, Unsaturated	POLYURETHANES: Urethane elastomers thermoplastic	SILICONES (see also next page): Cast resin, Flexible (including RTV)
PROCESSING	1. Molding qualities	—	Excellent	Good to excellent	Excellent	Good to excellent	Excellent
	2. Compression molding temp., °F.	—	550-600	185-250	—	285-350	—
	3. Comp. molding pressure, p.s.i.	—	1000	100-5000	—	100-5000	—
	4. Injection molding temp., °F	—	650-750	—	—	350-450	—
	5. Injection molding pressure, p.s.i.	—	15000-20000	—	—	6000-15000	—
	6. Compression ratio	—	1.8-2.2	—	—	3.0-1	—
	7. Mold (linear) shrinkage, in./in.	—	0.007	0.0-0.20	—	0.001-0.030	0-0.006
	8. Specific gravity (density)	D792	1.24	1.10-1.50	1.05	1.05-1.25	0.99-1.50
	9. Specific volume, cu. in./lb	D792	22.3	27.0-22.0	—	26.5-22.0	—
	10. Machining qualities		Excellent	Fair to excellent	Good	Fair to excellent	—
MECHANICAL	11. Tensile strength, p.s.i.	D638	10200 (at yield)	175-10000	10000-11000	4500-8400	350-1000
	12. Elongation, %	D638	50-100 (at break)	100-1000	3-6	100-650	100-10000
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	3.6	1.0-10.0	—	0.1-3.5	900.0
	14. Compressive strength, p.s.i.	D695	13900 (at yield)	20000	—	20000	100
	15. Flexural yield strength, p.s.i.	D790	15400 (at yield)	700-4500	19000	700-9000	—
	16. Impact strength, ft. lb./in. of notch	D256	1.3 (¼ in. bar) 1.2 (1/8 in. bar) (-40°F.)	25.0 to flexible	0.4	Does not break	—
	17. Hardness, Rockwell	D785	M69-R120	10A-90D (Shore)	30-35 (Barcol)	65A-80D (Shore) M28, R60	15-65 (Shore A)
	18. Flexural elastic modulus, p.s.i. x 10^5	D790	3.9	0.1-1.0	6.1	0.1-1.3	—
	19. Compressive modulus, p.s.i. x 10^5	D695	3.7	0.1-1.0	—	0.04-0.09	—
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq.cm./1(°C./cm.)	C177	2.8	5.0	—	1.7-7.4	3.5-7.5
	21. Specific heat, cal./°C./gm	—	0.31	0.42-0.44	—	0.40-0.45	—
	22. Thermal expansion, 10^{-5} in./in./°C	D696	5.2-5.6	10.0-20.0	—	10.0-20.0	8.0-30.0
	23. Resistance to heat, °F. (continuous)	—	300-345	190-225	200	190	500
	24. Deflection temp., °F. @ 264 p.s.i. fiber stress	D648	345	Varies over wide range	190-200	Varies over wide range	—
	@ 66 p.s.i. fiber stress		358		—		
ELECTRICAL	25. Volume resistivity, ohm-cm (50% RH and 23°C.)	D257	5.0 x 10^{16}	2.0 x 10^{11}-10^{15}	6.9-10^{16}	2.0 x 10^{11} -0.11 x 10^{14}	10^{14}-10^{15}
	26. Dielectric strength, short-time, 1/8 in. thickness, volts/mil	D149	425	300-500	—	330-630	550
	27. Dielectric strength, step-by-step[c] 1/8 in. thickness, volts/mil	D149	400	400-500	830-840	530	550
	28. Dielectric constant, 60 cyc.	D150	3.07-3.14	4.0-7.5	3.4-3.5	5.4-7.6	2.75-4.20
	29. Dielectric constant, 10^3 cyc.	D150	3.06-3.13	4.0-7.5	3.4-3.5	5.59-7.60	—
	30. Dielectric constant, 10^6 cyc.	D150	3.03-3.10	6.5-7.1	—	4.21-5.10	2.6-2.7
	31. Dissipation (power) factor, 60 cyc	D150	0.0008	0.015-0.017	0.008	0.015-0.048	0.001-0.025
	32. Dissipation (power) factor, 10^3 cyc	D150	0.0010	0.50-0.060	0.005	0.043-0.060	—
	33. Dissipation (power) factor, 10^6 cyc	D150	0.0034	—	—	0.050-0.100	0.001-0.002
	34. Arc resistance, sec	D495	75-122	0.1-0.6	—	122	115-130
OPTICAL	35. Refractive index, n_D	D542	1.633	1.50-1.60	—	1.50-1.60	1.43
	36. Clarity	—	Transparent, opaque	Clear to opaque	Clear	Clear to opaque	Clear grades available
	37. Transmittance, %	—	—	—	—	—	—
	38. Haze, %		5.0	—			
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8-in. thick., %	D570	0.22	0.02-1.5	0.1-0.2	0.7-0.9	0.12 (7 days @ 77°F.)
	40. Flammability[a] Burning rate, in./min.	D635					
	- AEB, in./ATB, sec[b]		0.4/5.0	—	—	—	—
	41. Effect of sunlight	—	Strength loss, slight yellowing	None to yellow	—	None to yellows slightly	None
	42. Effect of weak acids	D543	None	Slight	None	Slight to dissolves	Little or none
	43. Effect of strong acids	D543	None	Attacked (moderate)	Slight to moderate	Moderate to dissolves	Slight to severe
	44. Effect of weak alkalies	D543	None	Slight	None	Slight to dissolves	Little or none
	45. Effect of strong alkalies	D543	None	Slight to attacked	Slight	Moderate to dissolves	Moderate to severe
	46. Effect of organic solvents	D543	Aliphatic—none; aromatic—partly soluble	None to moderate	Aliphatic—none; aromatic moderate	Resists most solvents; most grades are insoluble but swell in polar solvents; specialized soluble grades available for coatings and adhesives	Insoluble but swells in some

a This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.
b AEB = Avg. extent of burning in inches; ATB = Avg. time of burning in seconds.
c The data for rigid vinyl sheet should be regarded as a guide only since the materials produced by the various manufacturers differ considerably from the charts and from each other.

	SILICONES (Cont'd)	STYRENE-BUTADIENE THERMO-PLASTIC	THERMOPLASTIC ELASTOMERS			UREA-FORMALDE-HYDE MOLDING COMPOUND	VINYL POLYMERS AND COPOLYMERS (see also next page)		
	Molding compounds						Vinyl chloride and vinly chloride-acetate molding compounds, sheets, rods and tubes		
	Glass fiber filled		Polyolefin	Block copolymers of styrene and butadiene or styrene and isoprene	Block copolymers of styrene and ethylene butylene	Alpha cellulose filled	Rigid[a]	Flexible unfilled	Flexible filled
1.	Good	Good	Excellent	Excellent	Excellent	Excellent	Fair to good	Good	Good
2.	310-360	250-325	400	250-325	300-350	275-350	285-400	285-350	285-350
3.	1000-5000	100-3000	4000	100-3000	4500-9000	2000-8000	750-2000	500-2000	500-2000
4.		300-425	400-475	300-425	390-450	290-320	300-415	320-385	320-385
5.		15000-30000	6000-19000	4000-15000	5000-15000	15000-20000	10000-40000	8000-25000	8000-25000
6.	2.0-6.0	2.0	—	2.0-2.5	2.5-3.0	2.2-3.0	2.0-2.3	2.0-2.3	2.0-2.3
7.	0-0.005	0.001-0.005	0.005-0.020	0.001-0.005	0.006-0.022	0.006-0.014	0.001-0.005	0.010-0.050 (Varies with plasticizer)	0.008-0.035
8	1.80-1.90	0.93-1.10	0.88-0.90	0.93-1.10	0.90-1.20	1.47-1.52	1.30-1.58	1.16-1.35	1.3-1.7
9	15.4-14.6	37.4-27.5	—	—	—	18.8-18.2	20.5-19.1	23.8-20.5	21.3-16.3
10.	Fair	Poor	Poor to fair	Poor to fair	Poor to fair	Fair to good	Excellent	—	—
11	4000-6500	600-3000	650-2000(D412)	600-1700	1000-3000	5500-13000	6000-7500	1500-3500	1000-3500
12		300.0-1000.0	150-300(D412)	500-1350	600-800	0.5-1.0	40-80	200.0-450.0	200.0-400.0
13	-	0.008-0.500	—	0.008-0.50	—	10.0-15.0	3.5-6.0	—	—
14.	10000-15000	Max. stress 5000 no break	—	Max. stress 5000, no break		25000-45000	8000-13000	900-1700	1000-1800
15.	10000-14000	Max. stress 60-900 no break	-	Max. stress 60-900, no break		10000-18000	10000-16000	—	—
16	0.3-8.0	No break	No break	No break	No break	0.25-0.40	0.4-20.0	Varies depending on type and amount of plasticizer	
17.	M80-M90	40-90 (Shore A)	A65-A92 (Shore)	40-90 (Shore A)	50-90 (Shore A)	M110-M120	65-85 (Shore D)	50-100 (Shore A)	50-100 (Shore A)
18.	10-25	0.04-1.50	0.015-0.2	0.04-1.50	0.04-1.0	13-16	3-5	—	—
19.	—	0.036-1.200	—	0.036-1.20	—	—	—	—	—
20.	7.0-9.0	3.6	4.5-5.0	3.6	—	7.0-10.0	3.5-5.0	3.0-4.0	3.0-4.0
21.	0.19-0.22	0.45-0.50	—	0.45-0.50	—	0.4	0.25-0.35	0.3-0.5	0.3-0.5
22.	2.0-5.0	13.0-13.7	13.0-17.0	13.0-13.7	—	2.2-3.6	5.0-10.0	7.0-25.0	—
23.	·600	130-150	250-300	130-150	130-300	170	130-175	150-175	150-175
24.	·900	Sub zero · 150	—	· 0-120	—	260-290	140-170	—	—
	—	Sub zero · 120	—	· 0-150	—	—	135-180	—	—
25.	10^{14}	5.0×10^{13} -2.5×10^{16}	$·10^{16}$	5 @ F 10^{13}- 2.5×10^{16}	8.4×10^{13}	10^{12}-10^{13}- $0.5\text{-}5.0 \times 10^{11}$	$>10^{16}$	10^{11}-10^{15}	10^{11}-10^{4}
26.	200-400	420-520	600-650	420-520	—	300-400	350-500	300-400	250-300
27.	125-300	420-540	—	420-540	—	220-300	—	275-290	225-750
28.	3.3-5.0	2.5-3.4	2.20-2.25	2.5-3.4	—	7.0-9.5	3.2-4.0	5.0-9.0	5.0-6.0
29.	3.2-4.5	2.5-3.4	2.20-2.25	2.5-3.4	—	7.0-7.5	3.0-3.8	4.0-8.0	4.0-5.0
30.	3.2-4.3	2.5-3.4	2.20-2.25	2.5-3.4	2.8-3.0	6.8	2.8-3.1	3.3-4.5	3.5-4.5
31	0.004-0.030	0.002-0.003	0.0004-0.0005	0.002-0.003	—	0.035-0.043	0.007-0.020	0.08-0.15	0.10-0.15
32.	0.0035-0.0200	0.001-0.003	0.0006-0.0008	0.001-0.003	—	0.025-0.035	0.009-0.017	0.07-0.16	0.09-0.16
33.	0.002-0.020	0.001-0.003	0.0011-0.0021	0.001-0.003	0.007	0.25-0.35	0.006-0.019	0.04-0.14	0.09-0.10
34.	200-250	95	·180	95	121-132	80-150	60-80	—	—
35.	—	1.52-1.55	—	1.52-1.55	1.47-1.52	1.54-1.56	1.52-1.55	—	—
36.	Opaque	Transparent, opaque	Translucent	Transparent to opaque	Transparent to opaque	Translucent opaque	Transparent, translucent and opaque		
37.	—	—	—	—	—	39.4(0.50 in.)	76-82	—	—
38.	-		—	—	—	—	8-18	—	—
39.	0.2	0.19-0.39	0.010	0.19-0.39	—	0.4-0.8	0.04-0.4	0.15-0.75	0.50-1.0
40.		—	· 1.0	—	—	—	—	—	—
				—	—	—	· 0.16 (sheet)	—	—
41	None	Slight color change	Specially stabilized grades for weather-ability	Slight color change	None to slight	Pastels grey	Varies with formulation	Varies with stabilizer	Slight
42.	None to slight	None	Resistant	None	None	Attack	None	None	None
43.	Slight	Attacked by oxidizing acids	Attacked by oxidizing acids	Attacked by oxidizing acids	Attacked by oxidizing acids	Decomposed or surface attacked	None to slight	None to slight	None to slight
44.	None to slight	None	Resistant	None	Resistant	Slight to marked	None	None	None
45.	Slight to marked	Slight	Resistant	Slight	Resistant	Decomposes	None	None	None
46.	Attacked by some	Dissolves	Resistant to oxygenated solvents	None to poor	None to poor	None to slight	Resists alcohols, aliphatic hydrocarbons, oils; soluble or swells in ketones and esters; swells in aromatic hydrocarbons		

PLASTICS PROPERTIES CHART (Cont'd)		ASTM test method	VINYL POLYMERS AND COPOLYMERS (Cont'd) Vinylidene chloride molding compounds	Vinyl formal molding compound	Chlorinated polyvinyl chloride compound	Vinyl butyral molding compounds Flexible unfilled	Injection molding grade Opaque 15% glass	Propylene vinyl chloride copolymer Rigid
PROCESSING	1. Molding qualities	—	Excellent	Good	Good	Good	Fair	Excellent
	2. Compression molding temp., °F	—	220-350	300-350	350-400	280-320	—	290-360
	3. Comp. molding pressure, p.s.i.	—	250-5000	1000-10000	1500-2000	100-3000	—	1000-2000
	4. Injection molding temp., °F	—	300-400	300-400	375-425	250-340	270-405	350-400
	5. Injection molding pressure, p.s.i.	—	10000-30000	10000-30000	15000-40000	15000-30000	1300-2000	8000-20000
	6. Compression ratio	—	2.0	—	2.0-2.5	—	1.6-2.2	2.0-2.6
	7. Mold (linear) shrinkage, in./in.	—	0.005-0.025	0.0015-0.0030	0.003-0.007	—	0.001-0.0005	0.0025-0.0035 (Inj)
	8. Specific gravity (density)	D792	1.65-1.72	1.2-1.4	1.49-1.58	1.05	1.54	1.28-1.40
	9. Specific volume, cu. in./lb.	D792	16.8-16.1	23.0-19.8	18.4-17.8	26.2	18.0	21.4-18.05
	10. Machining qualities	—	Good	Good to poor	Excellent	—	Good	Excellent
MECHANICAL	11. Tensile strength, p.s.i.	D638	3000-5000	10000-12000	7500-9000	500-3000	9500	5000-8000
	12. Elongation, %	D638	Up to 250.0	5.0-20.0	4.5-65.0	150.0-450.0	2-3	100.0-140.0
	13. Tensile elastic modulus, 10^5 p.s.i.	D638	0.5-0.8	3.5-6.0	3.60-4.75	—	8.7	3.5-4.5
	14. Compressive strength, p.s.i.	D695	2000-2700	—	9000-22000	—	9000	7750-11700
	15. Flexural yield strength, p.s.i.	D790	4200-6200	17000-18000	14500-17000	Varies depending on type and amount of plasticizer	13500	10000-15400
	16. Impact strength, ft. lb./in. of notch (½ x ½ in. notched bar, Izod test)	D256	0.3-1.0	0.8-1.4	1.0-5.6		1.0	0.36-32.00
	17. Hardness, Rockwell	D785	M50-M65	M85	R117-122	10-100 (Shore A)	118	M18-55 R107-119
	18. Flexural elastic modulus, p.s.i. x 10^5	D790	—	—	3.8-4.5	—	7.5	3.52-5.04
	19. Compressive modulus, p.s.i. x 10^5	D695	—	—	3.35-6.00	—	—	—
THERMAL	20. Thermal conductivity, 10^{-4} cal./sec./sq.cm./1 (°C./cm.)	C177	3.0	3.7	3.3	—	—	—
	21. Specific heat, cal./°C./gm	—	0.32	—	0.33	—		
	22. Thermal expansion, 10^{-5} in./in./°C.	D696	19.0	6.4	6.8-7.6	—	—	10-15
	23. Resistance to heat, °F. (continuous)	—	160-200	120-150	230	—	140	140-175
	24. Deflection temp., °F		130-150	150-170	202-234	—	155	150-170
	@ 264 p.s.i. fiber stress	D648						
	@ 66 p.s.i. fiber stress		—	—	215-247	—	165	—
ELECTRICAL	25. Volume resistivity, ohm-cm (50% RH and 23°C.)	D257	10^{14}-10^{16}	—	10^{15}	5.0 x 10^{10}	10^{15}	1 x 10^{16}
	26. Dielectric strength, short-time, 1/8 in. thickness, volts/mil	D149	400-600	490	1220-1500	350	600-800	—
	27. Dielectric strength, step-by-step, 1/8 in. thickness, volts/mil	D149	400-600	455	—	325	335-380	335-380
	28. Dielectric constant, 60 cyc.	D150	4.5-6.0	3.7	3.08	5.60	—	3.1-3.7
	29. Dielectric constant, 10^3 cyc.	D150	3.5-5.0	3.6	2.8-3.6	5.10		3.1-3.6
	30. Dielectric constant, 10^6 cyc.	D150	3.0-4.0	3.0	3.2-3.6	3.92	—	2.8-3.3
	31. Dissipation (power) factor, 60 cyc.	D150	0.030-0.045	0.013	0.01887-0.02080	0.115		0.008-0.010
	32. Dissipation (power) factor, 10^3 cyc.	D150	0.060-0.075	0.019	0.0092-0.0108	0.057		0.01-0.02
	33. Dissipation (power) factor, 10^6 cyc.	D150	0.05-0.08	0.023	0.020	0.061		0.015-0.025
	34. Arc resistance, sec.	D495	—	—	—	—	20	—
OPTICAL	35. Refractive index, n_D	D542	1.60-1.63	1.50	—	1.47-1.49	—	—
	36. Clarity	—	—	—	—	—	Opaque	Transp.-opaq.
	37. Transmittance, %	—	—	—	—	—		84-87
	38. Haze, %	—	—	—	—	—	—	6.5-11
RESISTANCE CHARACTERISTICS	39. Water absorp., 24 hr., 1/8-in. thick., %	D570	0.1	0.5-3.0	0.02-0.15	1.0-2.0	0.008	0.07-0.4
	40. Flammability[a] Burning rate, in./min. AEB, in./ATB, sec[b]	D635	—	—	—	—	—	0.35-0.55/
	41. Effect of sunlight		Slight	Slight	Slight	Slight	Slight	Slight to poor depending on grade
	42. Effect of weak acids	D543	None	Attacked	None	Slight	None	None
	43. Effect of strong acids	D543	Resistant	Attacked	None	Slight	None to slight	None to slight
	44. Effect of weak alkalies	D543	Resistant	Resistant	None	Slight	None	None
	45. Effect of strong alkalies	D543	Resistant	Resistant	None	Slight	None	None
	46. Effect of organic solvents	D543	None to slight	Attacked by some	Resists alcohols, aliphatic hydrocarbons, oils; soluble or swells in ketones and esters; swells in aromatic hydrocarbons	Resists aliph. hydro., most oils. Swells in ketones, esters, and arom. hydro., dis. in alcohols	Excellent resistance to alcohols, aliphatic hydrocarbons and oils. Soluble or swells in ketones and esters. Swells and may lose rigidity in aromatic hydrocarbons	Same as for rigid vinyl chloride

a. This numerical flame spread rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.
b. AEB = Avg. extent of burning in inches, ATB = Avg. time of burning in seconds.

CHAPTER 4

PROCESS AND FABRICATION OF PLASTICS

GENERAL

158. Processing. Forming and converting plastics into end products is a highly specialized field with more than 15 different major processes used. Some of the methods are similar to conventional metal working techniques, others are unique. This chapter outlines these processes, and indicates the advantages and limitations of each process from the standpoint of design implications. Selection of any process for a given part must be made on the basis of part geometry, process compatability and cost to produce a given number of parts. Every plastic part should be "costed-out" by all possible processes before a selection is made.

CALENDERING

159. General. This process (see Figure 13) is restricted to thermoplastic materials and is used to convert them into continuous sheets and films, which may be patterned or textured to provide special surface effects. In addition, the process is used for applying plastic coatings to textiles, paper or other supporting material. In calendering, the plastic material is softened by heat, plasticizer and possibly some solvent, and is fed between a series of several pairs of large heated revolving rolls which squeeze the material between them into the desired thickness. The space between the last series of revolving rolls controls the thickness of the end item, film or sheet.

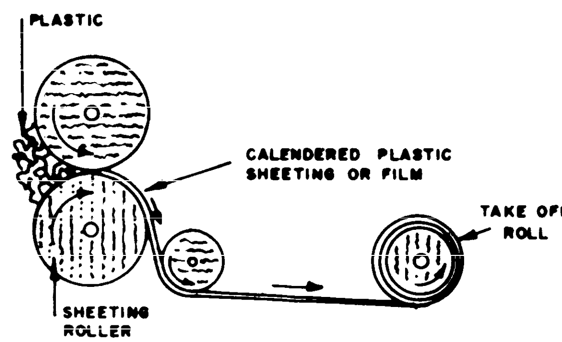


FIGURE 13. Illustration of a Simplified Calendering Operation

160. Materials. Thermoplastics are primarily vinyls, cellulosics and styrenes.

161. Process Features. Tolerance control is good. Pattern effects are obtained at low cost. Plasticizer requirements can lead to plasticizer "migration", causing material to shrink, embrittle and crack with age.

CASTING

162. General. This process differs from other processing methods in that external pressure for forming is not required. Gravity and heat will settle the mass. Both thermosetting and thermoplastic resin liquids or melts can be poured into molds of various sorts and set to a solid by curing with catalysts, at room or higher temperatures in the case of the thermosetting resins, or chilling in the case of thermoplastics. Casting of film is made on a continuously moving turntable or belt, or by precipitation in an aqueous chemical bath. In the turntable or belt process, the liquid resin is spread to the desired thickness and, as it dries, the film is stripped off.

163. Materials. The most extensively used casting materials are the epoxies, phenolics, polyesters, styrenes, acrylics and silicones.

164. Typical Applications. This process is used for rods, tubes, cylinders, sheets and slabs for further fabrication into parts; also, for potting and encapsulation.

165. Process Features.

(1) Better optical and strength properties can be obtained by casting than with extrusion or molding.
(2) Molds may be made of relatively low cost materials such as wood, plaster-of-paris, or sand-resin formulations.
(3) Materials can be compounded with reinforcing fillers prior to casting.
(4) High cost because of large amount of hand labor.
(5) Incomplete removal of air bubbles causes high scrap rate.
(6) Relatively few liquid plastic syrups are available for casting.

COATINGS

166. General. Plastics are widely used as coatings on a host of different materials. Coating materials are composed of both thermosetting and thermoplastic resins compounded with pigments, colorants, fillers and other ingredients. Coating methods include brushing, spraying, dipping, roller coating, spread coating, and fluidized-bed coating.

Brush coating, as the name implies, coats the material by brushing on the plastic compound, sometimes using a silk screen for decorative effects. Spray coating applies the plastic solution to the material by use of a spray gun, operated by hand in the case of single objects, or automatically on a moving belt for continuous materials. Articles may be coated by dipping in a solution of plastic, several times if necessary to achieve the desired thickness, and then drying the dipped article to solidify the plastic coating.

In spread coating, the material to be coated passes over a roller and under a long blade or doctor knife. The plastic coating compound is spread on the material just in front of the knife, the thickness of the coating being regulated by controlling the distance of the knife blade from the material and the speed at which the material is drawn under the knife.

In roller coating, three vertical rolls are used. One roller picks up the plastic coating solution on its surface from a trough and contacts a second roll, thus transferring the coating to it. The transfer roll, in turn, then applies the coating to the material as it passes over the third roll in contact with the coater roll. The third roll is usually rubber covered, while the metering and transfer rolls are precision ground steel rolls. The thickness of the coating is controlled accurately by the distance between the two steel rolls. A flexible doctor knife continuously cleans the metering roll surface to ensure a coating free of any contamination by extraneous particles.

The fluidized-bed coating method is used for protecting metal substrates where other means of applying coatings are impractical. In this method, the substrate is heated to proper temperature and then dipped in a fluidizing-bed containing a large mass of extremely fine particles of thermoplastic held in suspension by air pressure. Particles adhering to the substrate fuse together. The coated article is usually placed in an oven to complete the fusion process. The final thickness is dependent upon temperature of substrate, length of time in immersion, and number of cycles. This process may be used for vinyls, TFE fluorocarbons, nylons, cellulosics, acetals and polyethers. It permits the coating of substrates with plastics, which are not available in liquid form, to achieve such specific properties as chemical resistance, low friction, etc. The process is relatively expensive. Close control of tolerance and thickness is difficult. Size of object is limited to coating tank size and height of fluidized-bed. Provisions for suspension must be made to avoid bare spots on areas to be coated; and conversely, areas not to be coated must be masked.

EXTRUSION

167. General. Thermoplastic molding powders are fed through a hopper to a heated plasticizing cylinder, then driven, usually by a rotating screw(s), through a die of the desired cross-section. The process is continuous and features low cost tooling, wherein material thickness can be precisely controlled and comparatively intricate profiles can be produced at high continuous production rates. Orientation of

molecules increases strength in the direction of extrusion. Maximum productivity is limited by the plasticizing capacity of a particular machine, and extrudability of the particular polymer. Thicknesses must be uniform along the length, preventing production of stepped extrusions. Variations in profile are limited to one direction. Extremely close tolerances are difficult to maintain.

This process is used for the fabrication of pipe, rods, sheets, tubes, bars, stock shapes, and profiled parts such as edgings, trim, retainers, joint and panel molding, clips and holding devices, handle strips, light shields, sliding door tracks, gaskets and refrigerator breaker strips. In addition, this process can be used for coating paper, textiles, metal sheets, wires and cable at controlled thicknesses.

LAMINATING

168. General. Laminated plastics are plies of sheet material (bases), usually impregnated with a thermosetting resin (binder) and bonded together by means of heat and pressure to form sheet, tube, rod, or molded shapes. Laminated plastics are one form of "reinforced plastics". The term "reinforced plastics" is used extensively, since it includes molded parts in which the reinforcing is not usually in laminated form.

Basically, the laminating process is carried out by impregnating base sheet stock with the liquid or dissolved thermosetting resin. If a dissolved resin is used, the sheet stock is passed from the impregnating tank through a heated drying tunnel, to remove solvent and advance the polymerization from the tacky A-stage to a non-tacky B-stage. From this point on, the handling of the stock is determined by the physical shape desired in the finished product. If a flat laminate is to be made, the correct number of sheets, stacked one upon the other, are simultaneously subjected to heat and pressure between two polished plates, with the impregnant (binder) curing or setting to a C-stage. To make tubes or hose, the stock is wound upon heated mandrels, while under tension, until the desired thickness is achieved. The "rolled tube" is then baked until the binder has cured. To make a molded tube, the assembly is cured in a mold under combined heat and pressure. Molded tubes are denser and stronger, but show seams at the part-lines of the mold.

Solid laminated rods are made by winding the impregnated filler on a very thin mandrell, which is withdrawn before molding. The center channel is filled-up when pressure is applied. Rods may also be turned out of flat-laminated rigid and machinable stocks.

Articles with irregular shapes, such as gears and bearings, are often formed by cutting impregnated sheet to pattern, then stacking and molding.

The pressures applied during molding affect both the manufacturing cost and the properties of the finished product. Early plastics laminates used thermosetting resins which required high molding pressure; that is 250 to 2,000 p.s.i., or more. High temperatures ranging from 300°F. upward were likewise necessary. Hot-pressed laminates of this kind are still manufactured in great quantities and have the best properties for many applications. However, the range of useful properties in laminates has been greatly extended by the subsequent development of thermosetting binders that have made it possible to mold and cure laminates at pressures of 0.5 to 300 p.s.i., and temperatures as low as 70°F. These are the so-called "low-pressure" laminates.

For this work, it is highly desirable to have the binders in liquid syrup or emulsion form. These resins are made by keeping the resin molecules small, and by incorporating catalysts and hardeners of kinds and in amounts that result in setting of the binder at low working temperatures and pressures.

FILAMENT WINDING

169. General. Glass filaments, usually as rovings but occasionally as monofilaments, are saturated or coated with resin, and machine-wound onto removable mandrels having the shape of the desired finished parts. The finished part is cured at either room temperature or in an oven, depending upon the resin used and the size of the part. This process provides precisely oriented reinforcing-filaments with excellent uniformity and excellent strength-to-weight ratios. This process is widely used for pressure vessels, tanks and tubes, because filaments are positively placed in tension. The process is limited to shapes of positive curvature such as spheres or cylinders. Drilling or cutting will reduce strength.

BLOW MOLDING

170. General. Blow molding is a hybridization of the basic extrusion and molding techniques, and rapidly produces thin-walled, hollow thermoplastic parts.

The extruder produces a thin cylinder of plastic (parison) which is passed between the jaws of a split mold. The mold is closed and pinches off the bottom of the heated parison. Air pressure directed into the parison forces the material against the mold faces.

The process is used mainly for making bottles, carboys, and other containers, automobile heater ducts, traffic blinker housings, and packaging units. Polyethylene, polypropylene, and rigid and flexible vinyls are used extensively. Nylon, acetal, cellulose acetate and butyrate are frequently used. Occasionally, ABS and styrenes are used.

The process is excellent for producing large thin-walled parts. Extremely complex parts are possible. Blow-molded parts are nearly free of strain, eliminating warping and stress cracking. Low mold costs permit economical short runs.

The process is generally restricted to hollow or tubular parts. Dimensional tolerance must be high ($\pm$ 5 percent is considered good commercial practice). Excessive thinning occurs if configuration of mold varies excessively from cross-section to cross-section.

COMPRESSION MOLDING

171. General. Thermosetting resin, usually partially preformed is placed in a heated mold cavity. The mold is closed, and heat and high pressure are applied to the plastic. Under heat and pressure, the material softens and is forced to fill the mold cavity while undergoing a chemical reaction that crosslinks the polymer chains and hardens the plastic into a finish form. Occasionally, tetrafluorethylene polymers and vinyls are formed in this manner. The process is used to form large parts such as housings, switch bases, furniture drawers, automobile body panels, radio and television cabinets, and washing machine agitators. Small parts such as closures, tube bases, buttons, wiring devices, dial knobs, and handles may also be formed by this process. The process features little waste and low finishing costs. However, intricate parts with under-cuts, small holes, and delicate inserts are not practical. Tolerances closer than $\pm$ 0.005 inch are difficult to achieve, and then usually at a premium price.

INJECTION MOLDING

172. General. This process is characterized by the fact that the thermoplastic molding-mix is preheated, in a plasticizing cylinder, to a temperature high enough for it to attain a quasi-liquid condition. Then the molding-mix is forced by a plunger or screw through a nozzle into a closed mold which is cold enough to "freeze" the material to a solid, sufficiently rigid for ejection.

Generally, a multiple-cavity mold is used, with six or more molded parts being formed at one time. The molded parts are joined together by a network of material in the form of the sprue and runners. The runners are progressively thinner, so that the individual pieces may be broken off at the gates. The sprue, runners, and gates, represent scrap which is ground-up and returned to the process. Holding this scrap to 20 percent or less is considered good.

This process features high production rates and economical use of raw material, since the scrap can be re-ground and re-used. It is capable of producing relatively complex and intricate configurations which include metallic inserts. Surface finish can be controlled to produce patterns of high luster. Little finishing is required, and molded parts have good dimensional accuracy if the mold design and the processing has been done correctly.

Tool-and-die costs are high and necessitate time-delays for their manufacture; therefore, the process is not practical for short runs. Tendency of plastics to chill too rapidly, when filling the mold section, can result in incomplete parts. Internal stresses develop when plastic material is chilled too rapidly. There are limitations on design imposed by the need to open the mold and remove the parts. Part sizes are limited by machinery dimensions, strength of mold clamps, and plasticizing-capacity of cylinder. TFE fluorocarbons cannot be injection molded.

Typical applications include the molding of cases and housings for radios and appliances, refrigerator and auto parts, handles, knobs, gears, impellers, plumbing and hardware, appliance parts, auto tail lights and medallions, telephone handsets, steering wheels, refrigerator breaker strips, bearings, valve and pump parts, coil forms, fasteners, fittings, fan blades and grilles.

Most recently injection molding has also become a popular conversion technique for thermosetting resins, notably phenolics, epoxies and DAT's. These materials employ a reciprocating screw injection press in an operation identical to injection molding. Unlike "jet" molding, the nozzles are usually not significantly hotter than the preceding barrel section and cure is effected in the mold which is at an elevated temperature.

JET MOLDING

173. General. This process is a modification of injection molding expecially designed to accomodate some thermosetting molding compounds. It derives its name from the elongated nozzle or "jet" attached to the front of the injection molding cylinder, and is equipped with both a high intensity heating element which permits instantaneous temperature up to 1000^{O}F., as well as with cooling coils. The thermosetting plastic is just barely softened enough, in the heated cylinder of the injection molding machine, to permit the plunger to push the plastic into the nozzle where it is quickly heated to a fluid consistency, and injected into the mold. The small amount of plastic remaining in the jet is quickly cooled to prevent its setting-up to a hard infusible plug, while the plunger is being withdrawn and a fresh supply of plastic is charged to the rear of the cylinder.

SHELL MOLDING

174. General. Shell molding is a method of making a thin-sectioned plastics article or "shell" by coating the outside of a male form or the inside of a cavity mold, with a plastic. It is sometimes referred to as "slush molding", or solvent molding. Liquid resin solutions or dispersions, as well as hot plastic melts, may be used. Both thermoplastic and thermosetting compounds can be shell molded. Sometimes it requires several coats of the resin solution, with drying or curing in-between. The principle of shell molding is based on adherence of the plastic to the walls of the mold, where the walls are coantacted by the resin solution or melt. The male forms may be dipped into the solution or melt several times to build-up the desired shell thickness. After setting, the shell-formed plastics article may be stripped from the male form, if it is a flexible plastic; or the male form may be collapsed and withdrawn, or melted, if made of a lower melting material than the plastic, such as wax. In case of a cavity mold, this is filled with the solution or melt, and a layer of plastic is deposited on the inner walls by warming the mold in the case of a solution, or chilling in the case of a melt. After the proper thickness of layer has been deposited, the excess plastics solution or melt is poured from the mold cavity and the deposited coating allowed to harden. The shell-formed plastic article may then be stripped and withdrawn from the mold, if flexible; or vice-versa, the mold stripped from the article, particularly if a rubber mold. A great many flexible toys, dolls, animals, as well as bathing caps, are made by shell molding.

TRANSFER MOLDING

175. General. Transfer molding is a combination of injection and compression molding, designed to handle thermosetting resins. The plastics is first melted in a heated cylinder, and then fed by plunger through sprues and runners to a closed mold; then it is compressed into the desired shape, and polymerization is completed.

Transfer molding differs from compression molding because instead of charging the molding material directly to the mold as in compression molding, it is first heated to a melt in a separate chamber. The essential difference between transfer and injection molding is the fact that for transfer molding only enough material is heated at each cycle to fill the mold cavities, whereas in injection molding a reservoir of molten plastic is maintained in the heat cylinder, with only a part of it being used at each plunger stroke.

This process is used mainly to mold thermosets. In this process the flow of material is easily controlled, production rates are rapid, dimensional accuracy is good, and thin sections and delicate inserts may be used.

Molds for transfer molding are elaborate and size of parts are somewhat limited. Waste is high, since runners and sprues cannot be recycled.

Typical applications are automobile distributor heads, camera and projector parts, switch parts, electrical parts, buttons, closures and coil forms.

THERMOFORMING

176. General. There are seven basic techniques for the thermoforming of thermoplastic sheets. All of the techniques involve the heating of the material until it becomes limp, causing the sheet or film to slump over the mold or form profile. Vacuum, air, or mechanical pressure is used to create close prolific conformity. Free-forming employs pressure or vacuum without a mold to produce simple "bubbles". The type of thermoforming used depends on material and amount of draw required.

177. Straight Vacuum Forming. Here the sheet is clamped in a stationary frame, then heated and the frame is clamped to the mold cavity. Finally, a vacuum is applied through holes in the mold cavity to draw the plastic sheets in contact with the inner mold surfaces, where it is chilled. Automatic and semi-automatic vacuum-forming machines have been developed for this operation.

178. Drape Vacuum Forming. Here the heated sheet is draped over the male form, and vacuum is employed to pull it down in contact with the surfaces of the male form. Relief maps and embossed and texture mats are made in this manner.

179. Male Form Forced Above Sheet. Here a male plug, descending from above by means of hydraulic pressure is forced into the heated plastic sheet secured in a frame. Partial forming to the shape of the male plug takes place. Vacuum is then applied through the holes of the male plug, causing the sheet to be pulled tightly around the plug; then the formed sheet is chilled.

180. Vacuum Snap-Back Forming. Here the heated plastic sheet is positioned over a cavity and pulled partially into the cavity by the application of vacuum within the cavity. A male plug is then moved up and down on top of the concave plastic sheet to a predetermined position, and the vacuum is released in the cavity to allow the stretched sheet to snap-back against the male plug. Vacuum is then applied through holes in the male plug, and the formed sheet is chilled.

181. Plug and Ring Forming. Here the heated sheet is placed over a ring, and clamped into position. A male plug, mounted above it, is forced into the plastics sheet thus stretching it to conform to the shape of the male plug; then the formed sheet is chilled to freeze it into shape.

182. Air Pressure Forming. Many variations are employed to make use of excessive air pressure, above that possible in vacuum forming. In many of the latter operations, this may be accomplished by placing the mold in an autoclave where it can be heated by placing vacuum on one side of the heated sheet and high pressure on the other, before chilling it. In one instance, the heated sheet is first clamped into position above a cavity of the mold. A cored plug then pushes the heated sheet into the cavity and tightly seals the mold. The air pressure is introduced through holes in the plug, pushing the sheet against the sides of the female mold. Holes in the latter allow the air to escape from the underside of the sheet. In another case, the sheet is clamped over the female cavity mold, heated to the softening point, and the air is applied on the underside to blow the sheet into a hemispherical shape of the desired size. Vacuum is then applied within the mold cavity, and the blister inverted and sucked into contact with the surfaces of the female mold where it is hardened.

183. Matched Metal Mold Forming. This is somewhat similar to compression molding, where a heated sheet of plastic resin impregnated-fabric or compounded thermosetting resin is placed between matched male and female dies; then, hydraulic pressure is applied on the two parts of the mold to compress the sheet within the opening between the two halves. With water coils embedded in the metal molds,

the formed sheet can be cooled, thus setting it into the shape of the mold. Thermoplastic materials are also being formed to shape by modification of this method.

CONTACT MOLDING (HAND LAY-UP)

184. General. A low cost mold is employed. Layers of reinforcing material are placed by hand against the mold surface; resin is added, either by spraying or brushing, after each layer is located. After sufficient numbers of mats or cloths have been saturated with resin, it is allowed to harden without external application of heat and without further applied pressure.

VACUUM BAG MOLDING

185. General. This technique involves a similar procedure as contact (hand lay-up) molding, except that when the lay-up is completed, a flexible sheeting is placed over the impregnated reinforcement, and a vacuum is drawn between the sheeting and mold surface. This provides about 12 p.s.i. pressure on the part; this pressure makes higher glass contents possible.

PRESSURE BAG MOLDING

186. General. The steps outlined for vacuum bag molding are followed, and a tailored bag is placed against the sheeting. Then pressure is applied inside the bag to expand it against the impregnated reinforcement (sometimes the pressure is applied directly onto the sheeting). Pressures up to 50 p.s.i. are usually used; therefore, high glass loadings are possible. A modification of this system is the autoclave molding method, where the entire assembly is placed in a large autoclave that contains hot air or steam at 50 to 100 p.s.i.

VACUUM INJECTION MOLDING

187. General. This method involves the use of two molds, generally made of fiber reinforced plastic. The reinforcement is laid between the two molds, and the resin is poured into a moat around the bottom; the resin is then sucked up (by vacuum) through the reinforcement. This tends to give air-free parts, and is used primarily for large parts. Usually, glass contents are low.

FLUIDIZED BED MOLDING

188. General. The cycle of the spraymold system of forming plastics is: (1) a mold of grounded metal passes over a fluidized bed of plastic powder containing an electrostatic charge grid. (2) The charged powder grounds out on the mold, forming a coating of uniform thickness with localized excess being repulsed by the static charge on the powder. (3) The mold is heated from the rear to melt and fuse the powder to a continuous film. (4) The mold is cooled from the rear until the plastic solidifies. (5) The finished part is stripped.

The desirable properties for plastics used in the process are: (1) a fluidizable powder, (2) a capacity to retain electrostatic charge, (3) the ability to fuse without charring, (4) rapid melting which speeds production, and (5) rapid flow out, which also has the effect of speeding production.

This process is relatively new and has many advantages such as: (1) No scrap is produced; therefore, no recycle system is required and the finished parts have a single heat history. (2) Output is high. (3) Finished products have accurate detail, and are strain free. (4) Accurate temperature control maintained. (5) Since a single mold half is used, wall thicknesses are uniform. (6) The machinery is compact. The system allows instant shutdown or startup. (7) Lamination of two components is possible in a one-step operation.

RADIATION PROCESSING

189. General. Ionizing radiation offers the advantage of rapidly initiating free radical chemical reactions without the addition of heat or catalyst. The generation of free radicals is a function of exposure time

to the radiation, and is additive. The degree of crosslinking in some polymers can be stopped at any point and continued at a later time if necessary. The competing reactions of chain scission and crosslinking can occur, but typically one reaction will predominate, leading either to a crosslinked or degraded network. Electron radiation can provide rapid room temperature polymerization with little, if any, solvent emission. Radiation is used in the manufacturing of heat shrinkable products such as film, tubing, and tapes, and to control the degree of foaming and cell structure in polyethylene foam.

ROTATIONAL MOLDING

190. General. Rotational molding is a process primarily intended for the manufacture of hollow objects from thermoplastic and to some extent thermosetting materials. The solid or liquid polymer is placed in a mold; the mold is first heated, and then cooled while being rotated about two perpendicular axes simultaneously. In the first portion of the heating stage a porous skin is formed on the mold surface which gradually melts to form a homogeneous layer of uniform thickness. When molding a liquid material, it tends to flow and coat the mold surface until the gel temperature of the resin is reached. The mold is then cooled with forced air, water spray, or both. Then the mold is opened, the finished part removed and the mold recharged for the following cycle.

Early emphasis of the rotational molding process was in the toy industry. Almost every hobbyhorse and squeeze toy in the U. S. is made on a rotational molding machine. After much development work polycarbonate, nylon, acetal, and many other materials are now good candidates for rotational molding applications.

HEAT OR PRESSURE SEALING

191. Heat Joining. This process is used to provide strong, permanent, pressure-tight joints. A fusion-type bond results from melting the surfaces of the plastic parts, and then maintaining them in contact during cooling and solidification. Joining by application of heat should be considered for parts of similar materials and through the use of appropriate jigs and fixtures, and be adapted to production line operations. Heat joining is also useful to fabricate massive sections from which prototypes can be machined.

192. Hot Plate Welding. This method is used as a rapid assembly technique for the production of strong, permanent, leak-free joints. The two surfaces to be joined are held lightly against a heated metal surface to melt the surface layer. An aluminum heating plate with a thermostatic switch is suggested for hot plate welding, since it maintains a uniform temperature throughout. The metal surface of the heating tool may be coated with a thin Teflon layer to prevent sticking.

193. Hot Wire Welding. This method consists of passing an electrically-heated thin-resistance wire along the joint between two pieces of similar plastic which have been clamped together. The current in the wire generates sufficient heat to melt the adjacent surfaces. Since the pieces are pressed together, the material flows around the wire as it is slowly moved, forming a weld. While this technique produces very little flash and is simple, rapid, and adaptable to complex shapes, it does require well-mating surfaces. An additional requirement is constant application of contact pressure throughout the melting and fusion stage.

194. Induction Heating. The electrical properties of thermoplastic resins are such that they cannot be heated directly by induction heating. They can, however, be heated by thermal conduction from an induction-heated metal-insert placed at the interface of the parts to be joined.

The welding cycle begins with the high-resistance metallic-insert being placed at the joint interface. Sections are then placed in an alternating magnetic field, and pressure is applied to the joint while the field is energized. Current, induced in the metal insert, generates heat which in turn melts the surrounding plastic resin. Then the field is de-energized, and a slight pressure is maintained on the joint during cooling. Weld strength is dependent primarily on the size and geometry of the metal insert. For light duty applications, a simple ring of small-gauge wire may be used. Molten plastic can flow through the perforations, and a stronger weld is formed by virtue of the relatively large area of contact. Woven wire screening, used as an insert, provides the largest area of direct union that can be obtained with an insert of any given size.

195. Hot Flaring. In its simplest form, this method may be accomplished by heating the end of a metal rod to a temperature slightly below the melting point of a plastic, and pressing the rod against the plastic with sufficient force to cause flaring. The heated tool should not remain in contact with the plastic any longer than is required to accomplish the flaring.

Modification of the basic process can be made to accomplish the flaring. Experimentation with temperature, pressure, contact times, and tool profile will define these parameters for a specific application.

196. Spin Welding. Spin welding is rapid and efficient for all thermoplastic resins. It should be considered for parts of the same thermoplastic resins having circular sections when strong, permanent, leak-free joints are required. Interrupted welds of 15 percent or more of the circumference have been successfully made. Spin welding dissimilar materials generally results in low bond strength at the joints.

There are three basic variables in the spin welding operation: rotational speed, joint pressure, and spin time:

Rotational Speed – This depends on the circular joint diameter. The average linear velocity at the joint should be at least 20 ft/sec. Speeds greater than 500 rpm are not usually recommended for standard rotating equipment. Therefore, for joint diameters less than one inch where high speeds would be indicated (based on 20 ft/sec. linear velocity), greater joint pressure and/or longer cycle time may be used to generate the necessary frictional heat.

Joint Pressure – During spinning, joint pressure or thrust should be approximately 200 p.s.i., normal to the contacting surfaces. Polyethylene and polypropylene resins can be spin welded at contact pressures of 50 to 100 p.s.i. Adjustments in contact pressure should be made to suit specific applications and joint configurations.

Spin Time – This is the length of time that air pressure is applied to the air cylinder during the forward stroke of the rotating spindle. A typical spin weld cycle is as follows:

(1) A switch activates the air valve to the cylinder, and the rotating driving tool advances towards the parts which have been positioned and held in alignment.
(2) An electric timer begins as the switch is activated.
(3) The rotating driving tool engages and spins one part relative to the other under pressure, creating a layer of melt by frictional heat.
(4) Excess melt is pushed out and forms a bead at the joint.
(5) At a predetermined time, the driving tool is retracted to complete the spin weld cycle.

Once melting has occurred, it is essential that the relative motion be stopped to allow the melt to solidify under pressure. Failure to stop this motion will cause tearing of the weld, and result in low weld strength. Motion may be stopped by an electric motor brake, or preferably, through driving tool design.

197. Hot Gas Welding. The equipment used in this process is portable and relatively inexpensive. It consists of a hot gas (nitrogen) or flameless torch, pressure regulator, and filler rod. The temperature for welding should be at 540°F for polyethylene, and 630°F. for acetal. There is some deterioration of properties (primarily elongation) when plastics are welded by a blast of hot air. Nitrogen is the gas most commonly used.

Filler rods used are of a composition the same as, or similar to, that of the material to be welded. Diameter of the filler rod varies from 1/16 to 3/16 inch. A round rod is preferable because it produces a smooth and even deposit. Its diameter should be constant throughout its length, to permit application of constant pressure and to produce a uniform deposit.

Plastic welds resemble those produced by electric arc welding. No preparation is needed for the fillet weld. For the butt weld, the two pieces should be welded as in arc welding, but at a smaller angle (60 to 80 degrees) and with no sharp edges.

The prepared surfaces must be clean. Roughening the surfaces will improve the welded bond. When a butt weld is made, a sealing run on the reverse side insures higher tensile strength

In plastics welding a simple bonding process takes place between filler rod and parent material, since only the actual mating surfaces melt. Other parts, such as the center of the rod, remain relatively unaffected and rigid. The slight pressure, that is applied to force the filler rod into its "bed", has the effect of combining the melted surfaces into one homogeneous mass. Thus, a bonded, integral weld is produced.

To produce uniform coalescence, the surfaces, as well as the filler rod, should be preheated before insertion into the weld. The filler rod cannot adhere to the parent material if the surfaces have not been sufficiently preheated and melted. Overheating, on the other hand, causes a degradation of the material and too much sub-surface melting.

Tensile strengths for butt welds may be as high as 90 percent of the parent tensile strength. The figures for fillet welds are somewhat lower, but by means of reinforcements, sufficient strength may be obtained.

SINTERING

198. General. In this process, particles of plastic are compacted under pressure into the approximate dimensions of the finished part, and then placed in an oven to fuse. Following the fusion process, the material may be post formed under heat and pressure. This process is primarily used for tetrafluoroethylene resins, since this is about the only method by which they can be economically processed. Nylon resins, with or without additives (graphite and molybdenum disulphide), are being sintered for some applications. For tetrafluoroethylene, dense parts with excellent electrical and mechanical properties are obtainable. For nylon, porous parts which can be filled with lubricants for bearing parts are obtainable. Dimensional control and tolerances are only fair. Cost of tools and production is high. Thin sections are difficult to achieve and at present, sharp variations in cross-sectional thickness are impossible.

199. Solid-Phase Forming. During the past few years, much effort has been devoted to the use of well-established metalworking techniques as a method of converting thermoplastic materials into finished parts. Two different terms have been used to describe these metalworking techniques: cold forming and solid-phase forming. The cold forming process is performed at room temperature with unheated materials and tooling. In solid-phase forming the material is heated below its melt temperature and formed while in a heated solid state. In some cases the terms are used interchangeably.

Materials which have been successfully solid-phased formed include acrylonitrile-butadiene-styrene (ABS), ABS/polycarbonate, cellulose acetate butyrate, polypropylene, and high molecular weight-high density polyethylene. Generally for a sheet material to be solid-phase formable it must have sufficient ductility and strength so that necking does not occure under tensile loads.

Although it is possible to solid-phase form at room temperature; preheating the material to approximately 10^{o}-20^{o}F. below its melt temperature and below its glass transition temperature is recommended. This practice provides optimum part properties and dimensional stability.

Cold working of sheet materials prior to forming and the forming process itself, which occurs below the glass transition temperature, result in material orientation with resultant improvement in stiffness and strength.

Solid-phase forming processes such as forging have opened up new areas to the designers: namely, the use of ultra-high molecular weight, high density plastics and heavy section designs. These areas have been severely limited in the past due to difficulties in molding, large mold shrinkage, and high percent of voids. Utilization of these materials and designs will permit fabrication of parts with high rigidity, high strength, extremely good wear, good abrasion resistance and higher impact strength.

Solid-phase forming processes, for the most part, can utilize metalworking equipment with minor modifications. Their inexpensive tooling, high production rates, ease and economy in preprinting and decoration make them attractive techniques for many applications. Other advantages are fabricated parts without flash, trim or weld lines. The principal disadvantage of these processes is that the advantages must economically outweigh the cost of preparing the billets or sheets, and a somewhat reduced service temperature to prevent springback or excessive recovery of strains imposed during forming.

FABRICATION AND FINISHING

200. Fabrication. Fabrication covers two broad categories: (1) machining; and (2) cutting, sewing and sealing of film and sheeting. Finishing, as distinguished from fabrication includes those operations intended to improve the appearance or usefulness of a plastic article, such as printing, painting, metalizing, polishing and embossing.

a. Machining. Practically all plastics, with the exception of the very soft ones, can be machined with conventional wood or metal working machinery. However, allowances must be made for the greater heat sensitivity of most plastics as compared to metals, and for their greater thermal expansion. Plastics are poor heat conductors and therefore sustain a greater heat build-up during machining, causing them to soften and distort especially in the case of thermoplastics. The high cutting speeds used with metals should be avoided in favor of lower speeds; high speeds cause overheating. A light cut and slow feed are recommended for plastics. As with metals, coolants or cutting fluids can be used. Plain or soapy water, cool air, and less frequently, mixtures of water and oil, may be used. Tools should be designed to provide adequate clearance, such as the set of the teeth on a band or circular saw, so as to clear away the plastic chips as fast as they are formed.

The various machining operations include grinding, lathe turning, sawing, milling, routing, drilling, reaming and tapping. It is well to use guides set close to the work. Twist drills are made especially for plastics. They should have two flutes and a point with a 60 degree angle (30 degrees from the axis). Oddly enough, the edges of cutting tools dull more quickly when used on plastics than in the case of metals or woods, and therefore need more frequent sharpening. Ordinary tool steel is satisfactory for most plastics (except for those reinforced with glass and other materials), and stands up as well as the best of the harder steels such as the hardened steels. Sharp edged tools should be used for punching and shearing. Sanding and centerless grinding follow along conventional lines. One use for centerless grinding is in the preparation of Teflon rod for an automatic screw machine, since it is difficult to extrude this material with accurate dimensions.

b. Cutting, Sewing, and Sealing of Film and Sheeting. This category includes operations such as those required to fashion plastic film and sheeting into finished plastic articles; e.g., inflatable toys, garment bags, aprons, raincoats, luggage and the like. The film or sheeting is cut according to a pattern, using cutting tools ranging from hand scissors or knives to power-driven cutting tools.

201. Finishing.

a. General. After fabrication or molding, most plastic articles require some form of finishing, even though this may consist of only the removal of tool marks or mold flashing and bringing out the natural luster of the material. Care in machining will minimize the amount of finishing required. Excessive friction from buffing, sanding or polishing can produce sufficient heat to soften and even dull the plastic surface. Solvent polishing of some of the thermoplastics such as acetates, butyrates and acrylics, can be done by dipping the part for a few seconds in acetone, butyl acetate, ethylene dichloride, or other suitable solvent and allowing them to dry. The solvent reacts with the plastics surface to form a film of the plastic, which dries to a high gloss. Wiping with a cloth, dampened with the solvent, can also be used. Because of the inherent hazards associated with solvents, such as toxicity and flammability, solvent polishing should be done in well ventilated hoods and booths, and precautions should be taken to avoid flames or sources of ignition, or the inhaling of solvent vapors.

There are many methods of adding a decorative or functional surface-effect to a plastic product. Plastics are setting styling trends that have been made possible by the pastel and muted shades available, in addition to the brilliant colors and metallic finishes. Almost any effect can be obtained through choice of materials, color and finishing techniques.

b. Coloring. From the standpoint of color, two general types of plastics must be considered opaque and transparent or water white. The transparent plastics have more color possibilities because they can be decorated on the first or second surface. All the techniques adaptable to opaque plastics can be used with transparent materials.

The most common way to color plastics is to incorporate the color in the base resin. It is economical and permanent. The color is distributed throughout, and will not be affected by abrasion or wear.

c. Spray Painting. Spray painting is a common method of finishing molded plastic parts. Enamels are used primarily on thermosetting plastics because of the high baking temperature required. The use of lacquers on thermoplastics is desirable because the film hardens without high temperature baking. Forced drying at relatively low oven temperatures is quite often used for this type of finish. It is important to remember that each finish must be tested for the specific application. Highly decorative schemes can be obtained by spray painting with a series of marks in progressive steps, using various colors.

A spray and wipe method of painting is often useful when small, depressed letters or designs are to be painted. This is done by spray coating a general area containing the depressed design, and wiping or buffing the paint from the area surrounding the depressions. Paints for this type of application should be chosen selectively in order to avoid damages to the surfaces where the paint is wiped off. Depressions should be deep and narrow with sharply defined edges, to avoid complete removal and to provide good detail.

d. Silk Screening. Silk screening is used for multicolor decorating by using a series of different screens. The screen consists of a carefully marked woven fabric (originally silk, now mostly nylon) stretched on a wooden frame. Paint is pressed through the design area of the screen with a squeegee, onto the part to be finished. Solvent action causes the paint or ink to adhere to the plastic surface. When very sharp definition is required in intricate designs, a photographic screen may be used. Uniform surfaces are extremely important for good screening. Definition of the design can be lost when even the slightest sink or wave is present on the surface.

e. Hot Leaf Stamping. Hot leaf stamping is another process used for clean designs on plastic parts. In this process, a roll leaf or thin carrier film coated with pigment or metallic color is placed between a die and the item to be marked. The die is heated and pressed against the plastic for a short dwell time. The plastic takes on the form of the engraving in the die, and the colored coating is released from the carrier strip. The color bonds itself to the plastic and a permanent embossed mark is obtained. A top stamped effect can be obtained by using a silicone rubber die in lieu of the metal die. Pressures, temperatures, dwell times and roll leafs must be varied according to the plastic being decorated. Roll leaf manufacturers can supply processing information of this type, but a certain amount of testing is always necessary to obtain the desired effect. A good stamping press can often compensate for small variations in part thickness but, again, good mold design is important so that smooth, dimensionally uniform parts can be successfully hot stamped.

f. Decals. The use of decals has increased because of recent developments in equipment and processes. Very high speeds can be obtained with multicolor designs, and cost savings can be significant. This process is especially desirable when vacuum-formed parts are to be decorated. The inherent textures of this type of parts precludes the use of screening or printing.

g. Vacuum Metallizing. Vacuum metallizing has been commonly used in second surface applications on plastics for many years. As new lacquer systems are developed, it is becoming increasingly popular in first-surface applications on opaque plastics. This process consists of three general steps: (1) application of a lacquer base coat; (2) deposition of a metal film; and (3) application of a lacquer top coat. The base lacquer must be of a type that will provide good adhesion to the plastic, allow the metal to have good adhesion to it, cure at relatively low temperatures, and dry smoothly to provide a mirror-like surface for the metals. Aluminum is commonly used for metallizing because it is inexpensive and easily evaporated in the vacuum chamber. After the base coat has been applied, the plastic parts are placed in a vacuum chamber. In the center of the chamber is a tungsten-wire filament on which aluminum staples are placed. The pressure in the chamber is reduced to 0.5 micron of mercury or less, and the filaments are heated to incandescence. When the aluminum has melted and spread evenly over the filament, the temperature is raised until the aluminum evaporates. All exposed parts in a direct line with the filament receive a thin film of aluminum. One pound of aluminum will cover over 20,000 square feet.

Copper alloys, silver, and gold are also used for vacuum metallizing. Gold effects may be obtained with aluminum by dip-dyeing the part after the top coat is dry, or by using a tinted top coat.

The top coat of lacquer is applied to protect the film of deposited metal. It must provide abrasion resistance with high transparency, have good adhesion to the metal, and cure rapidly with a high gloss.

Good mold design and molding techniques are extremely important, when parts are to be metallized. All surface imperfections will be magnified by the highly reflective surface.

MOLD DESIGN AND CONSTRUCTION

202. General. An important part of plastics molding is the mold itself. It is the heart of the operation, for it defines the size and shape of the molded article. If the product is not right, the first place to look for the cause of the trouble is the mold. Molds are usually made of steel to withstand the pressures used in the molding operations; but other metals, and even plaster, rubber, or wooden molds can be used for some molding jobs, especially for special type of plastic materials or short runs. Thermosetting plastic molds have been used in place of metal molds for molding some of the thermoplastic compounds.

COMPRESSION MOLDING

203. General. In compression molding, there are eight important considerations to be given to the mold design: (1) types of plastics material in order to determine the bulk factor and mold shrinkage; (2) size of press to be used, especially the size of platens and the maximum opening between them; (3) molding pressure to be used; (4) parting line on the part to determine the dividing point between the two halves of the mold; (5) size and shape of the part, for this will determine the number of cavities per mold; (6) inclusion of any metal inserts requiring provisions for pulling side-core pins and unscrewing threaded pins; (7) heat requirements for proper spacing of hot oil or steam coils, or electrical resistance wires for fast and uniform heating of the molds; and (8) ejector assembly for removing the molded part from the mold.

b. Mold Design. The first subdivision of molds must be into the three main classes of compression, injection and transfer molds, corresponding to the method of molding. Subdivision from this point may be based upon the operation of the mold. Although injection and transfer molds are almost universally designed for semi-automatic or automatic operation, the molds used in compression molding vary from the simplest hand-operated types to semi-automatic and finally to automatic. In the latter cases, the molds are assembled in the press, and loading and ejection are mechanically controlled according to the refinements of the mold being used. Since the greatest variation occurs in compression molds, these are discussed at length.

Molds used for compression molding consists of a cavity, which forms the outside shape of the part and a plunger which forms the inside shape. The mold members are mounted on plates and leader (guide) pins are used to maintain the proper alignment. The material is generally loaded into the cavity, with the plunger entering the cavity, under pressure, and compresses the part into shape upon mold closing. The material is confined within the area between the force and cavity while it hardens under heat and pressure for the time required to permanently form the part. Provisions for heating the molds can be made directly in the mold, or by use of heated platens mounted on the press. Ejection or knock-out pins or plates, which are used to remove the part from the mold, are normally actuated by press movement.

Generally there are five basic designs used in compression molding:

Flash Type – The cavity is constructed to the overall thickness of the part and is used on relatively simple designs with shallow overall thicknesses, with a horizontal flash line.

Semi-Positive or Landed Plunger – This design is most commonly used in industry, with the cavity detail constructed with a loading area appearing above the cavity area, usually 1/4 to 3/8 inch wider than the total molded shape. The depth is calculated to accomodate the total displacement necessary for the molding powder or preform, and the flash line is horizontal. This design permits good alignment between the plunger and cavity, with ample material displacement and simple tooling provisions for venting to eliminate air or gas and excess material.

Semi-Positive or Landed Plunger with Positive Entrance – This is basically the same design as above, with the exception that the molded area depth is machined from 1/8 to 1/4 inch deeper to permit the plunger to be machined with an extended surface to the same design and shape. This design permits a vertical flash at the parting line, and simplifies the flash removal. It has proven effective on deep drawn parts and in using materials of the higher impact types.

Sub-Cavity Type – Parts that are miniature in size requiring small amounts of material, are effectively molded in this design. The individual cavities are spaced closely together, sometimes in a circular layout consisting of 7,9,19 or 38 cavities, or in a rectangular pattern with a common semi-positive loading area above. This permits one material charge for all cavities, permitting a horizontal flash.

Positive Type – This design has the cavity machined to the shape of the molded part with a loading area above, machined to the same shape to accommodate the material required. The plunger is made to the same shape, telescoping into the cavity, permitting a vertical flash. This design requires accurate material weighing, either in loose powder or preforms, for each shot. The pressure is maintained on the complete molding and offers good dense moldings, and is used on the higher impact materials with deep draws. Overall size is controlled by the accuracy of the material loading and limit pads on the mold.

204. Mold Making. A well designed, durable mold is essential for any successful molding operation. The length of the run, the rate of production, and the accuracy of the detail and dimensions of the part are some of the major factors to be considered in the selection of a mold. Because of the specialized nature of mold making, a large number of mold and die makers have been established for producing the molds and dies required for the molding of plastics. In the larger plastics companies, one of the more important departments is a well equipped and manned mold and die-shop. This requires specialized machines for the hobbing, milling and routing of the massive blocks of steel into the shape of the molds, furnaces for the hardening of the molds, and electroplating baths for the chrome plating of the molds. The machining operations utilize well trained and experienced tool and die makers. Special steels are needed for the molds, and steel companies produce a variety of steels for this purpose. For many molds, a general purpose hot-rolled machine steel can be used. It is easy to machine, and can be readily surface-hardened by carburizing. Softer steels are available for hobbing, which is a method of making mold cavities by pressing a very hard steel core of the proper shape into the softer steel. This is a convenient way of quickly duplicating molds in order to speed up production. Chromium plating of molds provides not only smoother surfaces, but also corrosion resistance and thus prevents deterioration of the mold on long runs. Hard chromium plating is made electrolytically by deposition directly onto the hardened steel surfaces of the mold. In general practice, a deposit of 0.3 to 0.5 mil thickness is sufficient. Where excessively corrosive molding-compounds are to be used, a stainless steel mold is recommended. It will stand up well for runs of a year or two, whereas the usual mold will have to be replaced approximately every six months due to pitting.

In a large plastics molding plant, duplicating machines are standard equipment in the mold-making department. Patterns or models are clamped to one side of the machine, and a tracer is moved over the surface of the pattern. The movement actuates a cutter spindle, which cuts a duplicate shape in a block of steel on the other side of the machine. Some hand-finishing is usually required, but for routine work this operation saves a great deal of the toolmaker's time.

MOLDING EQUIPMENT

205. General. In the selection of the proper molding equipment, there are many factors to be considered in addition to the type of machine to be employed. The larger plastics molding companies have many types of presses adaptable for all kinds of molding operations, some of which are rather specific, while others may accommodate several types of operations as well as plastics materials. Listed below are some of the requirements for the major types of molding equipment to be considered in making a selection. Equipment manufacturers can assist in the setting-up of the exact specifications for the correct machines to be used for a specified molding operation.

206. Compression Molding Presses.

(1) Press capacity in tons for both compression and transfer molding.
(2) Maximum pressure of hydraulic systems.
(3) Maximum mold size.
(4) Number of platens.
(5) Opening between platens.
(6) Maximum stroke of ram.
(7) Press speed for opening and closing.
(8) Motor drive, H.P.
(9) Floor space.

207. Extrusion Machines.

(1) Materials of construction for barrel and screw.
(2) Inside dimensions of barrel; diameter and length.
(3) Type of extruder screws.
(4) Motor drive, H.P.
(5) Type transmission.
(6) Screw speed, rpm.
(7) Maximum output, lb/hr.
(8) Number and type of heating units.
(9) Total heater wattage, kw.
(10) Approximate heat-up time.
(11) Cooling for hopper and barrel.
(12) Temperature controls.
(13) Head press.
(14) Extruder die assembly.

208. Injection Molding Machines.

(1) Capacity, oz. or cu. in./shot.
(2) Melt capacity, oz./min.
(3) Plunger stroke, min. and max.
(4) Injection speed, strokes/min.
(5) Cycle time, min.
(6) Top ram pressure, p.s.i.
(7) Opening between cylinder and mold.
(8) Knockout force, p.s.i.
(9) Mold size.
(10) Motor requirements, H.P.
(11) Temperature and pressure controls.
(12) Degree of automation.
(13) Floor space and tonnage.

209. Blow Molding Equipment.

(1) Type of charging-extrusion or injection
(2) Capacity, lbs./hr.
(3) Rate of pieces, no./hr.
(4) Mold platen size, inches.
(5) Movement of platens, horizontal or vertical
(6) Mold temperature range.
(7) Blowing method, needle or mandrel.
(8) Power requirements: H.P., voltage, phase, wattage, kw.
(9) Degree of automation.
(10) Floor space and tonnage.

210. Sheet Forming Equipment.

(1) Forming method: pressure, vacuum, etc.
(2) Forming area dimensions.
(3) Heater area.
(4) Operating temperature range, ^{o}F.
(5) Heater controls.
(6) Distance between heater and works.
(7) Cooling method.
(8) Maximum depth of draw.
(9) Pressure or vacuum system.
(10) Capacity of pressure or vacuum
(11) Clamping devices.
(12) Degree of automation.

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CHAPTER 5

REINFORCED PLASTICS — LAMINATES AND COMPOSITES

HIGH-PRESSURE INDUSTRIAL LAMINATES

211. General. Laminated plastics are a type of reinforced plastic made up of superimposed layers of reinforcing materials that have been impregnated with a resinous binder and cured under heat and pressure.

For industrial applications, laminated plastics are most frequently used as workhorse-type materials, and they are produced to perform specific job functions requiring materials with predetermined balances of mechanical, electric, electronic, and chemical properties.

These properties are produced in a laminate by altering the types and proportions of reinforcements and resinous binders that are added. Further alteration of the laminate properties are accomplished by the addition of such additives as plasticizers, lubricants, and flame retardants.

A great many of these variations have been standardized, resulting in the establishment of more than 70 standard grades. Materials specifications for almost all applications can be met by at least one of these. If more than one standard grade possesses the required properties, final decisions can be made by considering the most suitable form (sheet, tubing, molding, etc.), and by analyzing the economic aspects relating to laminate grade and machinability.

TABLE III. COMMON RESIN/REINFORCEMENT COMBINATIONS OF THERMOSET LAMINATES*

Resin type →	Phenol formaldehyde					Melamine formaldehyde					Polyester					Epoxy					Silicone				
Reinforcement / Production form	Sheet	Tube	Rod	Molded-macerated	Molded-laminated	Sheet	Tube	Rod	Molded-macerated	Molded-laminated	Sheet	Tube	Rod	Molded-macerated	Molded-laminated	Sheet	Tube	Rod	Molded-macerated	Molded-laminated	Sheet	Tube	Rod	Molded-macerated	Molded-laminated
Cellulose paper	●	●	●	●	●											●	●								
Cotton fabric	●	●	●	●	●	●	●	●		●															
Asbestos paper	●	●	●																						
Asbestos fabric	●	●	●			●	●	●																	
Nylon fabric	●	●	●																						
Glass paper and mat	●									●					●	●									
Glass fabric	●	●	●	●		●	●	●		●	●	●			●	●	●	●		●	●	●	●		

*Materials represented by unfilled boxes can be produced, but do not meet current commercial requirements.

TABLE IV. PROPERTIES OF TYPICAL GRADES OF LAMINATES

Grades	X	XX	XXX	XP	XXP	XXXP	XXXP—C	C	CE	L
Tensile strength, p.s.i.										
Lengthwise	20,000	16,000	15,000	12,000	11,000	12,400	12,400	10,000	9,000	13,000
Crosswise	16,000	13,000	12,000	9,000	8,500	9,500	9,500	8,000	7,000	9,000
Compressive strength, p.s.i.										
Flatwise	36,000	34,000	32,000	25,000	25,000	25,000	25,000	37,000	39,000	35,000
Edgewise	19,000	23,000	25,500					23,500	24,500	23,500
Flexural strength, p.s.i. (1/8 in. thick)										
Lengthwise	*25,000	*15,000	*13,500	*14,000	*14,000	*12,000	*12,000	*17,000	*17,000	*15,000
Crosswise	22,000	14,000	11,800	12,000	12,000	10,500	10,500	16,000	14,000	14,000
Modulus of elasticity in flexure, p.s.i. x 10^6										
Lengthwise	1.8	1.4	1.3	1.2	0.9	1.0	1.0	1.0	0.9	1.10
Crosswise	1.3	1.1	1.0	0.9	0.7	0.7	0.7	0.9	0.8	0.85
Shear strength, p.s.i.	12,000	11,000	10,000	8,000	11,000	11,000	11,000	12,000	11,000	12,000
Izod impact, ft. lb./in. of notch										
Flatwise	*4.0	*1.3	*1.0					*3.20	*2.30	*2.5
Edgewise	0.50	0.35	0.35					1.90	1.40	1.1
Rockwell hardness, M Scale	110	105	110	95	100	105	*95	103	105	105
Specific Gravity	1.36	1.34	1.32	1.33	1.32	1.30	1.30	1.36	1.33	1.35
Coeff. of thermal expansion, cm./cm./°C. x 10^{-5}	2	2	2	2	2	2	2	2	2	2
Water absorption, %/24 hr.										
1/16-in.	*6.00	*2.00	*1.40	*3.60	*1.80	*1.00	*0.75	*4.40	*2.20	*2.50
1/8-in.	3.30	1.30	0.95	2.20	1.10	0.75	0.55	2.50	1.60	1.60
1/2-in.	1.10	0.55	0.45					1.20	0.75	0.90
Dielectric strength, vpm Perpendicular to laminations Short time test										
1/16-in.	700	700	650	650	700	650	650	200	500	200
1/8-in.	500	500	470	470	500	470	470	150	360	150
Dissipation factor, 1 megacycle Condition A	0.06	*0.045	*0.038	0.060	*0.040	*0.035	*0.030	0.10	0.055	0.10
Dielectric constant, 1 megacycle Condition A	6.0	*5.5	*5.3	6.0	*5.0	*4.6	*4.6		5.8	7.0
Insulation resistance, megohms Condition: 96 hr./90% relative humidity, 95° F.		60	1,000		500	20,000	100,000			
Maximum constant operating temperature, °F.	285	285	285	285	285	275	275	265	265	265
Temp. indices †, NEMA °C.										
Electrical	130	130-140	130-140	130	130-140	125	125	85-115	85-115	85-115
Mechanical	130	130-140	130-140	130	130-140	125	125	85-115	85-125	85-125
Bond strength, lb.	*700	*800	*950					1,800	1,800	*1,600
Thickness, in.										
Minimum	0.005	0.031	0.031	0.015	0.015	0.030	0.030	0.015	0.015	0.006
Maximum	2	2	2	0.375	0.375	0.375	0.375	8	0.2	2
Standard colors	natural (variable tan) and black	natural (variable tan) and black	natural (variable tan) and black	natural (variable tan) and black	natural (variable tan) and black	natural (variable tan)	natural (variable tan)	natural (variable tan) and black	natural (variable tan) and black	natural (variable tan) and black
Standard finishes	dull	glossy semi-gloss dull	glossy semi-gloss dull	semi-gloss and dull	semi-gloss and dull	semi-gloss and dull	semi-gloss and dull	semi-gloss	semi-gloss	semi-gloss

NOTE Data shown are NEMA values for those grades and properties established by NEMA. International standards for these products are in preparation by the International Standards Organization. U. S. industry is taking part in this activity, and it is expected that the new standards will be similar to these.

* Properties marked with asterisks are guaranteed maximum or minimum values as the case may be. Other values shown are typical values derived from a number of tests and are included for engineering or design information only.

† Temperature indices are guides only, to be used for comparing materials evaluated under controlled conditions. See NEMA Publ. No. L-15-1969, "Temperature Indices of Industrial Thermosetting Laminates."

(Continued on next page)

TABLE IV. PROPERTIES OF TYPICAL GRADES OF LAMINATES (Cont'd)

Grades	LE	A	AA	G-3	G-9	G-7	G-10 G-11 FR-4	FR-3	N-1
Tensile strength, p.s.i.									
Lengthwise	12,000	10,000	12,000	23,000	37,000	23,000	40,000	14,000	8,500
Crosswise	8,500	8,000	10,000	20,000	30,000	18,500	35,000	12,000	8,000
Compressive strength, p.s.i.									
Flatwise	37,000	40,000	38,000	50,000	70,000	45,000	60,000	30,000	
Edgewise	25,000	17,000	21,000	17,500	25,000	14,000	35,000		
Flexural strength, p.s.i. (1/8-in. thick)									
Lengthwise	*15,000	*13,000	*18,000	*20,000	*55,000	*23,000	*55,000	*20,000	*10,000
Crosswise	13,500	11,000	16,000	18,000	35,000	20,000	45,000	16,000	9,500
Modulus of elasticity in flexure, p.s.i. x 10^6									
Lengthwise	1.00	2.3	1.6	1.5	2.5	1.4	2.7	1.5	0.6
Crosswise	0.85	1.4	1.4	1.2	2.0	1.2	2.2	1.0	0.5
Shear strength, p.s.i.	11,500	9,000	12,000	18,000	20,000	17,000	19,000	11,000	14,000
Izod impact, ft. lb./in. of notch									
Flatwise	*1.8	*1.8	*3.6	*6.50	*12.0	*8.5	*7.0		*4.0
Edgewise	1.0	0.6	3.0	5.50	8.0	7.5	5.5		2.0
Rockwell hardness, M Scale	105	111	103	100	120	100	110	100	105
Specific gravity	1.33	1.72	1.70	1.65	1.90	1.68	1.82	1.36	1.15
Coeff. of thermal expansion, cm./cm./°C. x 10^{-5}	2	1.5	1.5	1.8	1.0	1.0	0.9	2	8.0
Water absorption, %/24 hr.									
1/16-in.	1.95	*1.50	*3.00	2.70	*0.80	*0.30	*0.25	*0.65	*0.60
1/8-in.	1.30	0.95	2.50	2.00	0.70	0.20	0.15	0.50	0.40
1/2-in.	0.70	0.55	1.25	1.50	0.40	0.15	0.10		0.35
Dielectric strength, vpm Perpendicular to laminations Short time test									
1/16-in.	500	225		700	400	400	500	600	600
1/8-in.	360	160	50	600	350	350	400	450	450
Dissipation factor, 1 megacycle Condition A	*0.055			*0.030	*0.017	*0.003	*0.025	0.035	*0.038
Dielectric constant, 1 megacycle Condition A	*5.8			*5.5	*7.12	*4.2	*5.2	4.6	*3.9
Insulation resistance, megohms Condition: 96 hr./90% relative humidity, 95° F					10,000	200,000	200,000	100,000	50,000
Maximum constant operating temperature, °F.	265	310	310	355	285	465	285[1]	265	
Temp. indicest, NEMA, °C.									
Electrical	85-115	140-155	140-155	140	[2]	170	130-170	90-100	
Mechanical	85-125	140-155	140-155	170	140	220	140-180	90-100	
Bond strength, lb.	*1,600	*700	*1,800	*850	*1,700	*650	[3]	950	*1,000
Thickness, in.									
Minimum	0.015	0.031	0.031	0.006	0.006	0.006	0.004	0.031	0.015
Maximum	2	2	4	2	2	2	2	0.250	1
Standard colors	natural (variable tan) and black	natural (variable tan)	natural (variable tan)	natural (variable tan)	grayish brown	natural (white to tan)	natural (green to tan)	natural (gray-tan)	natural (variable tan)
Standard finishes	semi-gloss	semi-gloss	semi-gloss	semi-gloss	semi-sloss	semi-gloss	semi-gloss	semi-gloss	semi-gloss

1 G-10 and FR-4 retain 20% of their flexural strength at 300°F. when tested at this temperature.
2 Not recommended for electrical uses at high temperatures.
3 Bond strength, G-10 and FR-4: 2000 lb.; G-11: 1600 lb.

TABLE IV. DESCRIPTIONS OF TYPICAL LAMINATE GRADES AND THEIR APPLICATIONS* (Cont'd.)

GRADE X

Hard, strong, paper-reinforced laminates; good tensile, compression, and flexural strengths; widely used for mechanical applications when electrical requirements are not severe; should be used with discretion under high humidity conditions

GRADE XX

Hard paper-reinforced laminate with phenolic resin binder, good mechanical properties, high dielectric strength, and resistance to moisture suit it for many usual electrical applications; good machinability.

GRADE XXX

Paper-reinforced laminate with a phenolic resin binder; has approximately the same mechanical properties as Grade XX, but is considerably better electrically due to its high resin content; is desirable for use at radio frequencies and under high humidity conditions (e.g., in telephone jacks where dimensional stability is important); minimum cold flow.

GRADE XP

Paper-reinforced laminate with phenolic resin binder and addition of a plasticizer; similar to Grade X, but more flexible and slightly better electrically (not as strong mechanically); may be punched readily at room temperature in thicknesses up to 1/16-in.; hot punched up to 1/8-in.

GRADE XXP

Paper-reinforced laminate with plasticized phenolic resin binder; similar to Grade XX in electrical and moisture-resistant properties, and to Grade XP in punchability; for electrical or electronic parts, especially those punched.

GRADE XXXP

Paper-reinforced laminate similar to Grade XXX, but bonded with a plasticized resin; low in dielectric losses; low cold flow; recommended for punching of parts requiring high insulation resistance at high frequencies and high humidity; should be punched hot.

GRADES XXXP-C and FR-2

Paper-reinforced laminates similar to XXXP in mechanical properties, dielectric strength, dissipation factor, and dielectric constant, but with better resistance to moisture and high insulation resistance; indicated for high humidity conditions; for best punching; XXXP-C is recommended for punching and shearing at room temperature; FR-2 is a flame retardant grade.

GRADE C

Fabric-reinforced laminate produced from cotton fabric weighing over 4 oz./sq. yd.; thread count not more than 72/in. in filler direction, not over 140 total in warp and filler directions; Grade C is tough and strong, has high impact strength, machines readily, and is excellent for a wide variety of mechanical applications such as gears, pulleys, and sheaves.

GRADES CE and CB

Similar to Grade C in weight of fabric and thread count; greater resistance to moisture than Grade C, and controlled electrical properties; easy to machine, used in electrical applications requiring mechanical strength.

GRADE L

Fine-weave cotton fabric-reinforced grade with phenolic binder; made from fabric weighing not over 4 oz./sq. yd.; minimum thread count/in. in any ply is 72 in filler direction and 140 total in both warp and filler directions; has good mechanical properties; machines easily and cleanly; highly recommended for fine punching or threading; suitable for close tolerance machining; fine pitch gears are typical applications.

GRADE LE

Fine weave cotton fabric-reinforced grade of same thread count as Grade L; similar to Grade L in mechanical and machining characteristics, but superior in moisture resistance, dissipation factor, and other electrical properties; used where good electrical and mechanical property combinations are needed.

GRADE A

Asbestos paper-reinforced grade impregnated with phenolic resin; denser and harder than most other grades, low in moisture absorption, and resistant to heat and flame; dimensionally stable under moisture conditions; suitable for low voltage applications.

GRADE AA

Asbestos woven-fabric base with phenolic resin binder; stronger than Grade A; higher heat resistance than Grade A; machines more readily than Grade A; low moisture absorption and good dimensional stability when exposed to moisture; for applications where resistance to heat is important (e.g., thrust washers, rotor vanes, and seals).

GRADES EP-22 and FR-3

Paper-reinforced laminates bonded with epoxy resin; superior in electrical characteristics to Grade XXXP-IR; excellent mechanical properties; suitable for punching at room temperature; FR-3 is flame retardant; recommended for printed circuit boards and electrical insulation requiring low loss.

GRADE N-1

Staple fiber-nylon grade impregnated with phenolic resin; electrical properties of Grade XXXP and mechanical toughness of Grade C; improved insulation resistance for high humidity applications; high voltage electrical insulators where low dielectric loss, high insulation resistance, plus fungus resistance are required.

GRADE G-3

Continuous-filament woven glass-fabric grade with a phenolic resin binder; excellent thermal endurance; excellent mechanical strength, especially flexural, compressive, shear, and impact; very low dissipation factor.

GRADE G-7

Continuous filament glass-cloth reinforcement with a silicone resin binder; very good dielectric loss factor and insulation resistance under humid conditions over a wide temperature range; excellent heat and arc resistance.

GRADE G-9

Similar to Grade G-5, but bonded with an improved melamine; excellent electric strength properties under wet conditions.

GRADES G-10, G-11, FR-4

Continuous filament woven glass-fabric grades impregnated with epoxy resin; particularly noted for their excellent electrical values; possess low moisture absorption and low dissipation factor, and maintain these excellent electrical characteristics over a wide range of humidities and temperatures; G-10 retains 20% of its flexural strength at 300°F. when tested at the same temperature; FR-4 is flame retardant.

Vulcanized fibre; commercial, bone, and insulation grades

Somewhat similar to Grade C laminate, but with much higher moisture pick-up. Tough and resilient, with high resistance to arc, impact, abrasion, and wear. Used as washers, terminal block covers, insulating plates and switch covers, slot insulation, arc barriers, abrasive discs, railroad track insulation, and trunks and materials handling cases.

*NEMA designations.

REINFORCEMENTS

The paper used in laminates is either kraft, alpha, cotton linter, or blends of these. Kraft emphasizes mechanical strength and dielectric strength perpendicular to laminations. Alpha is used for its electric and electronic properties, machinability, dimensional stability, and uniform appearance. The cotton linter combines greater strength than alpha, with excellent moisture resistance.

Woven cotton fabric is used for mechanical strength. Heavier weights offer the highest strength; light weights (fine weave) sacrifice some strength, but are superior for machining intricate parts.

Asbestos used for the form of paper, mats, or woven fabric produces laminates having good thermal endurance and flame resistance, and excellent chemical and wear resistance.

Glass fibers as woven fabrics or mats produce the highest-strength laminates. They also have superior electrical properties (which are maintained under high temperature and humidity conditions) and high temperature resistance.

Nylon fabrics offer excellent electricals and high impact strengths. Unfortunately, they produce laminates that will tend to flow or creep under elevated temperatures.

Compreg or wood impregnated with resin and pressed under heat and high pressure (not to be confused with plywood) is used in many electric or power applications in European markets.

RESINOUS BINDERS

The resins most commonly used in industrial laminates are phenolics, melamines, polyesters, epoxies (epoxides), and silicones.

Phenolics are the broad-application, low-cost resins of the industry. Long experience with these resins (the oldest in the field) has proved their combination of properties to be desirable for wide application in a great many different areas.

Melamines are used primarily in electrical grades, particularly because of their improved arc resistance, and because they possess high mechanical strength and flame and alkali resistance.

Polyesters are suitable for both mechanical and electrical applications, where low flammability and self-extinguishing characteristics are needed.

Epoxies are most valuable in high-humidity or chemical atmospheres. They possess superior mechanical and bond strengths.

Silicones, used almost entirely with glass cloth, provide heat resistance and electrical superiority over a wide range of conditions. They produce laminates having low moisture absorption and superior arc resistance.

Table IV. shows which reinforcements are used with specific resinous binders, and in what forms they are produced.

FORMS AND SHAPES

Sheet is the most common laminate form. Properties of the various grades in sheet form give a basic comparison between grades. Sheets are used alone or in combination with other products such as rubber, cork, or metal foil.

Tubes are either molded or rolled, and oven cured. Molded tubes have greater density and lower moisture absorption than rolled tubes, while rolled tubes have more uniform wall thickness and better electrical properties due to lack of mold seams. Tubes are often used with metals for added strength.

Rods are generally convolutely wound, then molded. They may also be ground from sheet materials.

Molded-laminated construction is frequently desirable and economical if the quantities involved warrant mold cost and if part configuration requires extensive and intricate machining. The strength and appearance here often are better than machining.

Molded-macerated parts are usually designs that prohibit production by machining from standard forms. Strength characteristics are uniform in the X, Y, and Z directions.

REINFORCED PLASTICS

GENERAL

212. Description. Virtually every known plastic can be and has been reinforced. Thermoplastics as well as thermosets can be made into stronger products by the addition of such fibers as glass, asbestos, sisal, nylon, and other natural and synthetic materials. Usually, reinforced plastics consist of combinations of resinous polymers (mostly thermosetting) with strengthening materials, such as glass in fibrous form. These provide the designer with a method of creating shapes or structures whose properties in any given direction, or in all directions are both predictable and controllable.

Although most plastics are reinforced with fillers either in powder or fibrous form to give them improved mechanical properties, the term "reinforced plastics" is used almost exclusively to describe glass-fiber reinforced-plastics, sometimes abbreviated FRP. The FRP's are related to the laminates of paper, cotton, asbestos, fabric, and of plastics with fibers of these materials or shredded fabric. The latter types are useful for lower structural strength requirements and specialized heat resistance applications. For example, missile nose cones may be fabricated from an asbestos felt tape impregnated with phenolic resins.

213. Functions of the Reinforcement. Because of the unique qualities of glass, its addition in the form of fibrous filaments to a plastic serves to increase mechanical strength, stiffness, fatigue and impact resistance and dimensional stability, while giving it a wider useful temperature range.

Since glass strands act to reinforce the plastic material such as steel reinforces concrete, they may either be placed directionally to resist specific loads or in a random pattern for uniform strength properties in all directions. For example, in a fishing rod, all the strands run lengthwise to take care of the loads, which are essentially all in the longitudinal direction; in an automobile body, the panel strength must be more nearly uniform in all directions, so a random mat is employed.

214. Resins Used for FRP. Many types of resins are in commercial use and are available in the forms of solids (powder, flakes), or liquids (either in solution or emulsion). At present, some thermoplastics but notably the thermosetting varieties, are used in FRP. General comparisons of these resins after molding is given in Table V.

215. Fibrous Glass Reinforcement. Most glass fiber reinforcements are made from either of three different types: "E," "C," and "S" glass.

Specifications related to fiberglass reinforcements include:

MIL-Y-1140, Yarn, Cord, Sleeving, Cloth, and Tape-Glass
MIL-C-9084, Cloth, Glass, Finished for Polyester Resin Laminates
MIL-R-60346, Roving, Glass, Fibrous (For Filament Winding Applications)
WS 1028, Roving, Glass, Epoxy Resin, 20 End, Impregnated, Polaris Fleet Ballistic Missile
WS 1126, Roving, Glass Filament, Polaris Fleet Ballistic Missile
AMS 3824, Cloth, Type "E" Glass

"E" (electrical) glass is the most common glass composition used for yarns and reinforcements. It provides superior electrical characteristics, resistance to water and alkali, and high heat resistance properties that are particularly suited for electrical insulation applications.

TABLE V. GENERAL COMPARISON OF RESIN TYPES WHEN MOLDED

Characteristic	Polyester	Epoxy	Phenolic	Melamine	Silicone	Polystyrene	Polyvinyl Chloride
Color Possibilities	Very good	Good	Limited	Very good	Good	Excellent	Very good
By-Products of Cure	None	None	Water	Water	Water	Thermoplastic	
Molding Pressures[a]	Zero to medium	Zero to medium	Low and high	Low and high	Low and high	Very high	High
Mechanical Properties	Good	Very good	Very good	Very good	Fair	Good	Very good
Electrical Properties	Excellent	Excellent	Good	Excellent	Excellent	Excellent	Good
Water Resistance	Very good	Excellent	Very good	Fair	Good	Excellent	Very good
Heat Resistance	Good	Fair	Excellent	Excellent	Excellent	Poor	Poor
Flammability	SB	SB	SEO	SEO	SEO	SEO	SEO-SEI
Price Range	Medium low	Medium high	Low	Medium high	High	Low	Low to medium
Major Advantages	Fluid before cure	Low shrinkage	Good general properties	Arc resistance, Impact	Heat resistance	Low cost	Flame resistance
Major Disadvantages	Cure shrinkage	Poor mold release	Color	High Cost	High cost	Poor heat resistance	Poor heat resistance

Note:
a Laminating pressure ranges are, broadly (in p.s.i.): Low - 0 to 400; Medium - 400 to 1000; High - over 1000.

"C" (chemical) glass has superior resistance to corrosive action of acids, and is used for such applications as industrial batteries.

"S" (high tensile strength) glass is used for lamination in high performance structures, such as aircraft and missile components. Strength-to-weight ratios exceeding those of most metals can be reliably achieved. "S-2" glass has the same glass batch composition as "S" glass, but a different size system. S-2 glass is also used in aerospace applications and in some commercial applications where high tensile strength is required.

The batch of glass is fed into a furnace where it is melted at high temperature. Fine, precisely controlled filaments are drawn, or pulled rapidly, from streams of the molten glass. These filaments are given a chemical size treatment which protects the individual fibers and provides chemical bonding—glass-to-resin matrix—when used for reinforcement. Finally, the filaments are wound and packaged for further fabrication.

This manufacturing process produces both continuous filament and staple filaments. A continuous filament is an individual fiber of such length that it extends substantially throughout the length of a continuous filament strand. A strand is composed of many continuous filaments that are drawn from the molten glass at speeds in excess of 2 miles/min.

Both continuous and staple fibers can be fabricated into yarns and cords through conventional twisting, plying, and cabling operations.

The various available forms of fiber glass reinforcements are listed in Table VI which also describes in general the use of each in reinforced plastics and summarizes applications.

TABLE VI. GLASS FIBER REINFORCEMENTS AND THEIR USES IN REINFORCED PLASTICS

Nominal form	General description	Process	Nominal glass content of typical laminates, %	Typical application
Rovings	Continuous strands of glass fibers	Filament winding, continuous panel, preforming (matched die molding), spray-up, pultrusion, SMC	25 to 80	Pipe, automotive rod stock, rocket motor cases, ordnance, bathroom components
Chopped strands	Strands cut to lengths of 1/8 to 2 in.	Premix molding, wet slurry preforming, injection molding	15 to 40	Electrical and appliance parts, ordnance components, automotive
Reinforcing mats	Continuous or chopped strands in random matting	Matched die molding, hand layup, centrifugal casting, pultrusion	20 to 45	Translucent sheets, truck and auto body panels, marine
Surfacing and overlaying mats	Nonreinforcing random mat	Matched die molding, hand layup, and filament winding	5 to 15	Where smooth surfaces are required—automobile bodies, some housings
Woven fabrics	Woven cloths from glass fiber yarns	Hand layup, vacuum bag, autoclave, high pressure laminating	45 to 65	Aircraft structures, marine, ordnance hardware, electrical flat sheet and tubing
Woven roving	Woven glass fiber strands—coarser and heavier than fabrics	Hand layup	40 to 70	Marine, large containers
Nonwoven fabrics	Unidirectional and parallel rovings in sheet form	Hand layup, filament winding	60 to 80	Aircraft structures

The strengths of fibrous glass-reinforced plastics are proportional to the concentration (volume) and orientation of the reinforcements. The form of the reinforcements and type of plastic matrix also affect strength.

Rovings. Fiber glass roving consists of a number of untwisted glass strands grouped to form a continuous ribbon of multiple strands. Spun roving is made by looping a continuous single strand upon itself many times, and holding it with a twist.

Rovings are used in sheet molding compound (SMC) for matched metal die molding, continuous panel, filament winding, sprayup, and pultrusion processes.

Rovings can also be converted into chopped strand mat, preforms, and woven roving, or can be chopped into fibers for use in molding compounds.

Standard roving packages contain 60 ends of strands. Newer nomenclature is designed to reduce confusion caused by combining the number of ends with the number of filaments. This newer nomenclature is based on a specified yield per unit weight, yd./lb. The most common package used in commercial applications, which was formerly called 60 end roving, now is typified as 224 yd./lb.

Yields from 57 to 1200 yd./lb. are also commercially available.

Rovings are rated by the following characteristics:

1. Strand integrity – degree to which filaments are held together in the strand.

2. Ribbonization – degree to which strands are held together in the roving bundle.

3. Catenary – degree of sag, or differences in length, between the individual strands that make up the roving bundle.

4. Chopping characteristics – ease of chopping, strand integrity retention, number of long strands, and static problems. Chopping characteristics vary with the size used; for example, silane-sized rovings offer greater resistance to cutting than do chrome-sized rovings.

5. Wetout – speed and degree to which the roving is wet by the resin. Wetout also is dependent upon the size used. Wetout and laminate clarity often are confused, but are not necessarily related. However, good clarity cannot be attained without good wetout, although many systems will yield a milky laminate even if thoroughly wetted out.

Reinforcing mats. There are two basic fibrous glass mat types: chopped strand mat and continuous strand mat. Both offer essentially the same degree of reinforcement, but have different molding and handling characteristics.

Mats provide nondirectional reinforcement, and are used in hand layup, matched metal die molding, continuous laminating (panel), and pultrusion processes. Excepting woven roving, mats are lower in cost than woven products, and are slightly higher in price than bulk chopped strand or roving.

Characteristics of fibrous glass mats such as conformability, moldability, resin holding power, wetout, and porosity are important for various applications. Mats are available in many thicknesses described in terms of weight per square foot, ranging from 0.75 to 4.0 oz./sq. ft. for chopped strand mat.

Surfacing and overlay mats are actually thin nonreinforcing mats used with reinforcing mats to obtain a resin-rich surface on a reinforced plastics part. Surfacing mats are relatively strong and stiff, and are used only on flat sheets and simple shapes. Overlay mats are fluffy, extremely drapable, and can be used on many types of complex shaped parts.

Stiffness, wash resistance, and color of mats depend upon the binder used to hold the mat together. There are two general binder types, soluble and insoluble. Insoluble binders are used on fibrous glass mats for matched metal die and pultruded reinforced plastics moldings. Soluble binders are used for hand layup and panel processes.

Woven roving is generally supplied with a silane type sizing for fast wetting action and maximum laminate strength in both dry and wet service applications. Heavier woven roving styles, where applicable, supply the most reinforcement for the least cost. The lighter styles are often preferred because of their low cost per square foot in comparison with the cost of other fabrics.

The yield of the roving is varied to meet specific weight and strength requirements. Weights range from 12 to 40 oz./sq. yd.; thicknesses range from 0.020 to 0.048 in. Woven roving is most often used in combination with mat.

Uniformity varies with the style of the woven roving. Close weave styles have good conformability, with little danger of weave shifting. Loose weave styles are not recommended, because they can shift position, leaving resin-rich areas and poor uniformity.

Chopped strands. Continuous or spun rovings are chopped into short lengths, then used in premix and wet slurry thermoset compounds and thermoplastic reinforcements. Chopped strands are available in lengths from 1/8 through 2 in., and with different chemical sizes for compatibility with most plastics. Chopped strands often are classified on the basis of strand integrity.

Woven fabrics. Fibrous glass fabrics are woven from glass yarns into a variety of styles, thicknesses and weights. The styles can be varied so that the laminate strength can be either undirectional or orthotropic. Fabric weights range from approximately 1.5 to 26 oz./sq. yd.

Fabrics generally are woven from yarns having a starch-oil sizing. After weaving, the fabric is heat cleaned and finished with a resin-compatible material (e.g., Volan, A-1100, etc.). In the case of S904 fabrics, however, which are regarded as high-performance materials, the yarn is made with a compatible size, and is woven directly into immediately usable reinforcements that eliminate the need for heat cleaning and finishing before the fibrous glass meets the resin.

Milled fibers. Continuous strands are milled into short nodules of glass filaments ranging in length from 1/32 to 1/2 in., the length referring to the diameter of the screen openings used in the processing. A variety of sizes is available, compatible with polyester, epoxy, and other resins. Milled fibers are widely used for encapsulation in the electrical industry, as well as in thermoplastic and silicone compatible compounds, adhesives, patching compounds, and putties.

Yarns. Twisted strands of yarns are used primarily in the weaving of fabric reinforcements and have limited use as a direct reinforcement for plastics.

216. Nomenclature. A standard industry nomenclature is used to designate yarn and roving construction. For example, in the notation ECD 450-1/2, the letter E designates the glass composition (E for E glass, S for S glass). The letter C indicates the fiber type (C for continuous, S for staple). The third letter D represents the average monofilament diameter. The first series of numbers (450) indicates the nominal yardage in hundreds of yards per pound for the basic strand. The second series of numbers (1/2) represents the number of strands in the yarn. The first number shows the number of single strands twisted together and the second number designates the number of twisted strands which are plied together.

TABLE VII. TEXTILE FIBER NOMENCLATURE SYSTEM

Letter Designation	Fiber Diameter (inches x 10^{-5})
B	10 - 14.9
C	15 - 19.9
D	20 - 24.9
E	25 - 29.9
F	30 - 34.9
G	35 - 39.9
H	40 - 44.9
J	45 - 49.9
K	50 - 54.9
L	55 - 59.9
M	60 - 64.9
N	65 - 69.9
P	70 - 74.9

TESTING FRP MATERIALS

217. General. The properties of FRP are determined from various standard test methods which are based on corresponding test methods for metals, plastics, and other materials, but modified in some details because of characteristics peculiar to the products. Table IX lists various standard specifications applicable to glass reinforced plastics. Standard test specifications are based on certain arbitrary conditions which may or may not represent those encountered in service. It must be recognized that the results of these tests are not always applicable to the design of products. Special tests on the specific article are desirable and are frequently necessary to determine its behavior in service.

BASIC PROPERTIES OF FRP

218. General. Fibrous-glass reinforced-plastics are composite materials, and their properties are dependent to a large degree on the components used and the methods of fabrication. Certain defects resulting from poor design or from fabrication techniques may have a pronounced influence on the properties of articles made from glass reinforced plastics. Some of the controlling factors are: (1) type of resin; (2) type of catalyst system; (3) type of filler and pigment; (4) mechanical working during impregnation; (5) humidity during impregnation; (6) type of reinforcement and surface finish; (7) length of glass fibers; (8) orientation of glass fibers; (9) time allowed for impregnation; (10) cure time; (11) cure temperature; (12) rate of heating; and (13) pressure used. Many of these variables depend upon lay-up and molding processes, and ambient conditions existing at time of molding. Due to the range of strengths obtainable in both metals and FRP, generalizations concerning relative strengths of these materials are difficult, and often inaccurate. The low specific gravity and high strength of some FRP compositions result in a higher specific strength, but this is not true of all FRP compositions. The data in Table X are of value for approximate comparisons only, and illustrate the overlap of specific strengths of FRP versus other structural materials. These values are selected figures rounded off to be indicative of average test results at room conditions. Specific moduli and strengths are actual values divided by specific gravity.

219. Mechanical Properties. Table XI lists mechanical properties, wet and dry, for general-purpose polyester resin reinforced with glass fabric; Table XII gives similar data for the same resin reinforced with chopped strand and roving; Table XIII gives data on the mechanical properties of fabric reinforced epoxy and silicone resins.

220. Thermal Properties. Table XIV presents comparative data on thermal properties for FRP, steel, and aluminum.

TABLE VIII.

CONSTRUCTION AND PROPERTIES OF FINISHED CLOTH

Style	Yarn Count per Inch (25.4 mm) Warp	Yarn Count per Inch (25.4 mm) Fill	Yarn Type Warp	Yarn Type Fill	Weave	Weight oz. per sq. yd.	Weight (g/m^2)	Thickness Inch	Thickness (mm)	Breaking Strength, Min. lb. per in. of width	Breaking Strength, Min. (kN/m of width)
104	60	52	D900-1/0	D1800-1/0	Plain	0.56	(18.99)	0.0011	(0.028)	15x5	(2.63x0.88)
325	90	44	D900-1/0	D1800-1/0	Plain	0.70	(23.74)	0.0013	(0.033)	17x5	(2.98x0.88)
106	56	56	D900-1/0	D900-1/0	Plain	0.73	(24.75)	0.0014	(0.036)	12x12	(2.10x2.10)
107	60	35	D900-1/2	D900-1/0	Plain	1.01	(34.25)	0.0018	(0.046)	24x7	(4.20x1.23)
1070	60	35	D450-1/0	D900-1/0	Plain	1.03	(34.92)	0.0017	(0.043)	24x7	(4.20x1.23)
108	60	47	D900-1/2	D900-1/2	Plain	1.40	(47.47)	0.0022	(0.056)	24x20	(4.20x3.50)
1080	60	47	D450-1/0	D450-1/0	Plain	1.40	(47.47)	0.0023	(0.058)	24x20	(4.20x3.50)
112	40	39	D450-1/2	D450-1/2	Plain	2.10	(71.20)	0.0035	(0.089)	40x35	(7.00x6.13)
2112	40	39	D225-1/0	D225-1/0	Plain	2.10	(71.20)	0.0035	(0.089)	40x35	(7.00x6.13)
1125	40	39	D450-1/2	G150-1/0	Plain	2.60	(88.16)	0.0041	(0.104)	40x45	(7.00x7.88)
2125	40	39	D225-1/0	G150-1/0	Plain	2.60	(88.16)	0.0038	(0.097)	40x45	(7.00x7.88)
1610	32	28	G150-1/0	G150-1/0	Plain	2.35	(79.68)	0.0036	(0.091)	35x30	(6.13x7.88)
113	60	64	D450-1/2	D900-1/2	Plain	2.45	(83.07)	0.0034	(0.086)	50x25	(8.76x4.38)
2113	60	56	D225-1/0	D450-1/0	Plain	2.38	(80.70)	0.0032	(0.081)	50x25	(8.76x4.38)
1674	40	32	G150-1/0	G150-1/0	Plain	2.80	(94.94)	0.0043	(0.109)	50x35	(8.76x6.13)
1675	40	32	DE150-1/0	DE150-1/0	Plain	2.83	(95.96)	0.0044	(0.112)	50x35	(8.76x6.13)
116	60	58	D450-1/2	D450-1/2	Plain	3.10	(105.11)	0.0040	(0.102)	60x55	(10.51x9.63)
2116	60	58	D225-1/0	D225-1/0	Plain	3.10	(105.11)	0.0040	(0.102)	60x55	(10.51x9.63)
1165	60	52	D450-1/2	G150-1/0	Plain	3.60	(122.07)	0.0044	(0.112)	55x60	(9.63x10.51)
2165	60	52	D225-1/0	G150-1/0	Plain	3.62	(122.74)	0.0048	(0.122)	55x60	(9.63x10.51)
120	60	58	D450-1/2	D450-1/2	Crowfoot	3.14	(106.47)	0.0042	(0.107)	60x55	(10.51x9.63)
2120	60	58	E225-1/0	D225-1/0	Crowfoot	3.12	(105.79)	0.0042	(0.107)	60x55	(10.51x9.63)

TABLE VIII. (Cont.d.)

181	47	54	E225-1/3	E225-1/3	8H Satin	8.80	(298.38)	0.0100	(0.254)	150x130	(26.27x22.76)
1581	57	54	G150-1/2	G150-1/2	8H Satin	8.80	(298.38)	0.0100	(0.254)	150x130	(26.27x22.76)
7781	57	54	DE75-1/0	DE75-1/0	8H Satin	8.82	(299.06)	0.0092	(0.234)	150x130	(26.27x22.76)
7500	16	14	G75-2/2	G75-2/2	Plain	9.55	(323.81)	0.0145	(0.368)	150x120	(26.27x21.01)
1800	16	14	K18-1/0	K18-1/0	Plain	9.55	(323.81)	0.0130	(0.330)	150x120	(26.27x21.01)
7743	120	20	DE75-1/0	G150-1/0	8H Satin	10.00	(339.07)	0.0096	(0.244)	275x35	(48.15x6.13)
1523	28	20	G150-3/2	G150-3/2	Plain	11.50	(389.93)	0.0140	(0.356)	160x140	(28.02x24.51)
162	28	16	E225-2/5	E225-2/5	Plain	11.70	(396.71)	0.0165	(0.419)	190x125	(33.27x21.89)
164	20	18	E225-4/3	E225-4/3	Plain	12.40	(420.45)	0.0170	(0.431)	190x160	(33.27x28.02)
1564	20	18	G150-4/2	G150-4/2	Plain	12.25	(415.36)	0.0165	(0.419)	190x160	(33.27x28.02)
7664	20	18	G75-2/2	G75-2/2	Plain	12.50	(423.84)	0.0165	(0.419)	190x160	(33.27x28.02)
3732	48	32	G37-1/0	G37-1/0	Crowfoot	12.50	(423.84)	0.0125	(0.318)	175x150	(30.64x26.27)
182	60	56	E225-2/2	E225-2/2	8H Satin	12.20	(413.67)	0.0135	(0.343)	180x160	(31.52x28.02)
1582	60	56	G150-1/3	G150-1/3	8H Satin	13.75	(466.22)	0.0155	(0.394)	160x150	(28.02x26.27)
1527	17	17	G150-3/3	G150-3/3	Plain	12.70	(430.62)	0.0170	(0.432)	180x170	(31.52x29.77)
183	54	48	E225-3/2	E225-3/2	8H Satin	16.00	(542.51)	0.0185	(0.470)	250x225	(43.78x39.40)
1583	54	48	G150-2/2	G150-2/2	8H Satin	16.00	(542.51)	0.0180	(0.457)	250x225	(43.78x39.40)
1544	28	14	G150-4/2	G150-4/4	2/1 Basket	17.70	(600.15)	0.0220	(0.559)	190x160	(33.27x28.02)
7544	28	14	G75-2/2	G75-2/4	2/1 Basket	17.70	(600.15)	0.0220	(0.559)	190x160	(33.27x28.02)
7587	40	21	G75-2/2	G75-2/2	Mock Leno	20.00	(678.14)	0.0315	(0.800)	300x170	(52.53x29.77)
184	42	36	E225-4/3	E225-4/3	8H Satin	25.00	(847.68)	0.0300	(0.762)	300x250	(52.53x43.78)
1584	44	35	G150-4/2	G150-4/2	8H Satin	25.20	(854.46)	0.0300	(0.762)	300x250	(52.53x43.78)
1884	44	35	K18-1/0	K18-1/0	8H Satin	25.00	(847.68	0.0280	(0.711)	300x250	(52.53x43.78)

TABLE VIII. (Cont'd.)

Style	Yarn Count per Inch (25.4 mm)		Yarn Type		Weave	Weight		Thickness		Breaking Strength, Min.	
	Warp	Fill	Warp	Fill		oz. per sq. yd	(g/m^2)	Inch	(mm)	lb. per in. of width	(kN/m of width)
1617	40	40	DE150-1/0	DE150-1/0	Plain	3.14	(106.47)	0.0044	(0.112)	60x50	(10.51x8.76)
1681	56	36	DE150-1/0	DE150-1/0	Plain	3.60	(122.07)	0.0048	(0.122)	60x45	(10.51x7.88)
125	36	34	D450-2/2	D450-2/2	Plain	3.70	(125.46	0.0057	(0.145)	60x55	(10.51x9.63)
118	90	60	D450-1/2	D450-1/2	Crowfoot	3.90	(132.24)	0.0052	(0.132)	75x60	(13.13x10.51)
1676	56	48	DE150-1/0	DE150-1/0	Plain	4.00	(135.63)	0.0048	(0.122)	70x60	(12.26x10.51)
126	34	32	D450-3/2	D450-3/2	Plain	5.30	(179.71)	0.0076	(0.193)	80x55	(14.01x9.63)
1526	34	32	G150-1/2	G150-1/2	Plain	5.27	(178.69)	0.0071	(0.180)	80x55	(14.01x9.63)
7626	34	32	G75-1/0	G75-1/0	Plain	5.20	(176.32)	0.0066	(0.168)	80x55	(14.01x9.63)
1557	57	30	G150-1/2	D450-1/2	Crowfoot	5.27	(178.69)	0.0065	(0.165)	150x30	(26.27x5.25)
7533	18	18	G75-1/2	G75-1/2	Plain	5.65	(191.66)	0.0092	(0.234)	90x85	(15.76x14.88)
3733	18	18	G37-1/0	G37-1/0	Plain	5.60	(189.88)	0.0078	(0.198)	90x85	(15.76x14.88)
127	42	32	D450-3/2	D450-3/2	Plain	5.80	(196.66)	0.0078	(0.198)	80x55	(14.01x9.63)
128	42	32	E225-1/3	E225-1/3	Plain	5.80	(196.66)	0.0072	(0.183)	80x55	(14.01x9.63)
1528	42	32	G150-1/2	G150-1/2	Plain	6.00	(203.44)	0.0073	(0.185)	80x55	(14.01x9.63)
7628	44	32	G75-1/0	G75-1/0	Plain	6.00	(203.44)	0.0069	(0.175)	80x55	(14.01x9.63)
76281	44	32	G75-1/0	G75-1/0	Crowfoot	6.00	(203.44)	0.0069	(0.175)	80x55	(14.01x9.63)
7532	16	14	G75-1/3	G75-1/3	Plain	7.05	(239.04)	0.0120	(0.304)	115x100	(20.14x17.51)
2532	16	14	H25-1/0	H25-1/0	Plain	6.85	(232.26)	0.0097	(0.246)	100x95	(17.51x16.63)
141	32	21	E225-3/2	E225-3/2	Plain	8.50	(282.21)	0.0115	(0.292)	125x90	(21.89x15.76)
7641	32	21	G75-1/2	G75-1/2	Plain	8.50	(282.21)	0.0105	(0.267)	125x90	(21.89x15.76)
143	49	30	E225-3/2	D450-1/2	Crowfoot	8.68	(294.31)	0.0095	(0.241)	250x30	(43.78x5.25)
1543	49	30	G150-2/2	E225-1/0	Crowfoot	8.46	(286.85)	0.0090	(0.229)	250x30	(43.78x5.25)
3743	49	30	G37-1/0	E225-1/0	Crowfoot	8.35	(283.12)	0.0082	(0.208)	250x30	(43.78x5.25)
341	30	49	D450-1/2	E225-3/2	Crowfoot	8.68	(294.31)	0.0095	(0.241)	30x250	(5.25x43.78)

TABLE IX. CONVENTIONAL METHODS OF TESTING THE PROPERTIES OF FIBERGLASS REINFORCED PLASTICS

Property	Nonelectrical Uses			Electrical Use
	ASTM	Fed. Std. –406	Other	ASTM
Tensile Strength	D638	1011	—	D229
Compressive Strength	D695	1021	—	D229
Flexural Strength	D790	1031	—	D229
Shear Strength	D732	1041	—	D732
Bearing Strength	—	1051	—	—
Constant-Strain Flexural Fatigue	D671	1061	—	D671
Izod Impact Strength (notched, ½ inch square bar)	D256	1071	—	D256
Izod Impact Strength (notched, ½ inch x thickness)	—	—	JAN-P-13[a]	—
Izod Impact Strength (unnotched, ½ inch x thickness)	—	—	L545a[b]	—
Falling Ball Impact Strength	—	1074	—	—
Abrasive Wear (loss in weight)	—	1091	—	—
Bond Strength	—	—	—	D952
Specific Gravity (displacement of water)	—	5011	—	—
Specific Gravity (weight and volume)	—	5012	—	—
Ignition Loss	—	—	L517L[b]	—
Thermal:				
Flammability (0.050 inch thick)	D635	2021	—	—
Flammability (0.050 inch thick)	D568	2022	—	—
Heat Distortion	—	—	L546a[b]	—
Thermal Conductivity	—	—	L401a[b]	—
Electrical Tests:				
Arc Resistance	—	4011	—	D495
Power Factor	—	4021	—	D150
Dielectric Constant	—	4021	—	D150
Dielectric Strength	—	4031	—	D149
Electrical Resistance (insulation, volume, surface)	—	4041	—	D257
Permanence Tests:				
Accelerated Weathering	G23	—	—	—
Colorfastness to Light	D620	6031	—	—
Outdoor Weathering	Bulletin No. 173	—	—	—
Chemical Tests:				
Chemical Resistance	D543	7011	—	—
Water Absorption	D570	7031	—	—

Note:
a. Military Joint Army-Navy.
b. Owens-Corning Fiberglas Corporation.

TABLE X. SPECIFIC STRENGTH AND SPECIFIC MODULI OF STRUCTURAL MATERIALS

Material	Specific Gravity	Modulus of Elasticity x 10^6, p.s.i (Tension)		Tensile Strength x 10^3. p.s.i (Ultimate)	
		Actual	Specific	Actual	Specific
Plastics, Unreinforced[a]	1.2	0.3	0.25	12	10
Glass-Mat Base Laminate[b]	1.5	1.5	1.0	21	15
Glass-Fabric Base Laminate[c]	1.7	3.0	1.7	46	27
Parallel Glass Strand Laminate[d]	1.9	5.7	3.0	152	80
Magnesium	1.8	6.3	3.5	52	29
Aluminum	2.7	9.7	3.6	81	30
Titanium	4.5	16.2	3.6	126	28
Steel	8.0	29.0	3.6	240	30
Glass Filaments Only	2.5	9.5	3.8	350	140

Notes:
a. These values apply especially to the polyesters.
b. Glass by volume, 30 percent.
c. Glass by volume, 45 percent.
d. Glass by volume, 60 percent.

TABLE XI. MECHANICAL PROPERTIES OF RIGID GENERAL-PURPOSE POLYESTERS REINFORCED WITH GLASS FABRIC[a]

Property	Unit	Fabric Style 112[b]		Fabric Style 143[b]		Fabric Style 164[b]		Fabric Style 181[b]	
		Dry[c]	Wet[d]	Dry[c]	Wet[d]	Dry[c]	Wet[d]	Dry[c]	Wet[d]
Specific Gravity	-	1.6-1.8	1.6-1.8	1.7-1.9	1.7-1.9	1.7-1.9	1.7-1.9	1.7-1.9	1.7-1.9
Glass Content	wt. %	53-58	53-58	62-67	62-67	60-65	60-65	60-65	60-65
Tension	1000 psi	33-45	30-45	78-86	70-86	34-44	31-44	40-48	36-48
Flexure	1000 psi	50-60	48-60	85-105	74-105	30-40	25-38	50-60	44-60
Compression	1000 psi	29-40	24-39	40-50	33-50	13-20	10-18	30-38	27-38
Tensile Modulus	10^6 psi	1.5-2.5	-	4.0-5.0	-	1.4-2.3	-	1.8-2.8	-
Flexural Modulus	10^6 psi	2.0-3.0	1.8-2.8	4.5-5.5	4.0-5.0	1.9-2.7	1.7-2.5	2.2-3.1	2.1-3.0
Shear	1000 psi	14-23	-	19-34	-	14-24	-	16-23	-
Bearing[e]	1000 psi	30-40	-	33-44	-	34-44	-	40-65	-
Impact (unnotched)	ft-lb	16-22	-	50-55	-	23-28	-	20-27	-

Notes:
a. Based on short-time tests at room temperature, tested parallel to warp, "high-performance" finish on fabric.
b. The construction of these fabrics is shown in table LVII.
c. Dry test, at normal room humidity.
d. Wet test, after 30 days immersion in water at room temperature.
e. Bearing strength – bearing stress at a deformation 4 percent of bolt diameter. Fed Std-406.
(The data on shear and bearing strengths are based on limited tests.)

TABLE XII. MECHANICAL PROPERTIES OF GENERAL-PURPOSE POLYESTERS REINFORCED WITH ROVING AND CHOPPED STRAND[a]

Property	Unit	Chopped Strand Mat or Preform		Molding Compounds		Woven Roving (square weave)		Parallel Roving[b]	
		Dry[c]	Wet[d]	Dry[c]	Wet[d]	Dry[c]	Wet[d]	Dry[c]	Wet[d]
Specific Gravity	-	1.5-1.6	1.5-1.6	1.5-1.6	1.5-1.6	1.7-1.9	1.7-1.9	1.7-1.9	1.7-1.9
Glass Content	percent of wgt.	35-45	35-45	35-45	35-45	55-75	55-75	50-70	50-70
Tension	1000 psi	15-23	13-23	5-18	4-18	35-60	30-60	80-130	74-130
Flexure	1000 psi	25-38	23-37	10-30	9-30	40-55	35-55	100-200	92-200
Compression	1000 psi	18-26	15-26	15-26	13-26	-	-	50-75	40-75
Tensile Modulus	10^6 psi	0.8-1.8	-	-	-	2.0-4.0	-	-	-
Flexural Modulus	10^6 psi	1.0-2.0	0.8-1.8	0.5-2.0	0.3-1.9	2.5-4.0	2.0-3.8	5.0-7.0	4.0-7.0
Shear	1000 psi	12-17	-	-	-	-	-	-	-
Bearing[e]	1000 psi	28-40	-	-	-	-	-	-	-
Impact (unnotched)	ft-lb	13-21	-	3-10	-	40-60	-	50-70	-

Notes:
a. Based on short-time tests at room temperature, "high-performance" finish on reinforcement.
b. Parallel roving tested in direction of roving.
c. Dry test, at normal room humidity.
d. Wet test, after 30 days immersion in water at room temperature.
e. Bearing strength – bearing stress at a deformation of 4 percent of bolt diameter. Fed STD-406.
(The data on shear and bearing strengths, and all tests on woven roving are based on limited tests.)

(2) Range of properties over a broad temperature range

TABLE XIII. BASIC MECHANICAL PROPERTIES OF EPOXY AND SILICONE RESINS REINFORCED WITH 181 STYLE GLASS FABRICS[a]

Property	Unit	Epoxy	Silicone
Specific Gravity		1.8-1.9	1.7-1.85
Glass Content	percent of weight	66-73	60-70
Tension	1000 psi	50-60	30-40
Flexure	1000 psi	65-77	32-45
Compression	1000 psi	50-70	15-21
Tensile Modulus	10^6 psi	3.0-4.0	2.0-3.0
Flexural Modulus	10^6 psi	3.0-4.0	2.5-3.5
Impact (unnotched)	ft-lb	18-25	20-25

Note:
a. Tested at room conditions, parallel to warp, reinforcements have most appropriate finish.

TABLE XIV. COMPARATIVE DATA ON THERMAL PROPERTIES FOR FIBERGLASS REINFORCED PLASTICS, STEEL, ALUMINUM and GLASS

Material	Linear Coefficient of Expansion[a] x 10^{-6} per deg. F	Specific Heat calories per gram per deg. C	Thermal Conductivity[b] at 150 deg. F., Btu per hr. per sq ft per deg. F. per inch
Mat-Polyester[c]	14-18	0.31-0.33	1.0-1.5
Mat-Polyester[d]	10-15	0.30-0.32	1.4-1.9
181 Fabric-Polyester[e]	5-6	0.26-0.28	1.5-2.5
Polyester-Type Resin	50-60	0.20	1.2
Steel	6-7	0.10-0.12	275-325
Aluminum	12-13	0.21-0.22	1200-1500
"E" Type Glass	2.8	0.20	7.2

Notes:
a. Parallel to reinforcement.
b. Perpendicular to reinforcement.
c. Glass by weight, 25 percent.
d. Glass by weight, 40 percent.
e. Glass by weight, 65 percent.

TABLE XV. ELECTRICAL AND RELATED PROPERTIES OF SOME TYPICAL FIBROUS GLASS-BASE LAMINATES[a]

		Continuous Filament Fabric Base				Staple Fiber Fabric Base			Mat Base Cut Strand	
Test	Unit	Silicone G-7	Phenolic G-3	Melamine G-9	Melamine G-5	Phenolic G-4	Phenolic G-2	Silicone G-6	Polyester	Melamine G-8
Dielectric Strength (parallel to laminations)	KV	32	-	23	23	15	30	32	-	30
Dielectric Constant	-	4.2	-	9.0	8.0	6.0	5.5	4.5	4.1	9.0
Dissipation Factor (Power Factor)	-	0.003	-	0.080	0.020	0.035	0.025	0.005	-	0.080
Arc Resistance	seconds	180	-	180	180	-	-	180	60	150
Flexural Strength:	1000 psi									
Lengthwise		20	20	33	44	22	20	18	34	19
Crosswise		18	18	28	38	18	16	16	-	19
Izod Impact:	ft-lb									
Lengthwise		6.5	6.5	9.0	7.0	5.0	4.5	6.0	19.2	4.0
Crosswise		5.5	5.5	7.0	5.5	4.0	3.5	5.0	-	4.0
Bonding Strength	lbs	650	850	1600	1570	1000	1000	800	-	1000
Water Absorption (24 hours):	percent									
1/8 inch		0.35	2.00	3.00	2.00	2.00	0.95	0.35	-	2.50
1/2 inch		0.20	1.50	2.00	1.50	1.50	0.55	0.20	0.36	2.00

Note:
a. Based on National Electrical Manufacturers' Association standards.

221. Electrical Properties. Table XV lists the minimum electrical properties of some typical fibrous glass laminates as set by the National Electrical Manufacturer's Association (NEMA).

ENVIRONMENTAL RESISTANCE OF FRP

222. General. Environmental exposure involves temperature, humidity, fungi and marine organism attack and chemicals. Many sets of conditions and many combinations of these sets have some type of effect on FRP. These conditions will often be accompanied by different mechanical stresses and shock loading conditions. Time is a very important aspect since parts and equipment may be required to have usable lifetimes for as long as twenty years. Some of this life may be spent in storage, during which general deterioration from the elements can readily occur. For the purposes of this discussion, the military environment is considered in three parts: (1) Earth Surface Environment; (2) Underseas-Environment; and (3) Space Environment. No attempts are made to relate these effects to any particular weapon or military situation, as each has its own specific requirements which must be considered as a separate design and materials selection problem.

223. Earth Surface Environment Effects.

a. Aging and Weathering Exposures. It is an unavoidable military service requirement that once an item is made, it must be stored for some extended period of time. Since the crosslinking of a thermosetting resin is a rate process, care must be taken to assure a complete cure of the laminate during fabrication. If one fails to do so, then many properties can be expected to change during subsequent storage. Such changes are certainly to be expected in both the aging and weathering of reinforced plastics, particularly of those that are room-temperature cured. As a result, there is an additional opportunity for environmental attack on a laminate before the resin has polymerized to a stable state.

Outdoor weathering is a more severe form of ordinary aging. Not only are temperature and humidity variations encountered, but ultraviolet radiation and rain exposures are also important factors. There are three main types of deterioration of FRP panels: discoloration, erosion and fiber prominence. It is often noted that one of the first signs of attack is surface resin deterioration and, in turn, exposure of the glass reinforcement. This then leads to moisture working into the laminate mass, and loss in mechanical and electrical strength. Some color changes will also be noted on those resins less resistant to ultraviolet radiation.

One important aspect of outdoor weathering is ultraviolet radiation. It is reported that only 5 percent of the radiation reaching the earth is actinic ultraviolet radiation or that capable of breaking chemical bonds. On a clear day, 95 percent of this is effective, while on a cloudy day 99 percent or more is ineffective. This radiation varies with the seasons of the year, the day, and the location. One of the first effects to be noted is that of the resin yellowing, a photochemical effect. In polyesters it is found that the carbonyl radical is formed, accounting for the yellowing of the material in the presence of atmospheric oxygen.

b. Moisture Exposure. Moisture is very important in the environmental resistance picture because of its chemical attack and/or plasticization effects on polymers. Thus, unless very special care is taken in the selection of the components for a composite and in its construction, property degradation upon moisture exposure can be expected.

One of the first areas of attack is thought to be at the coupling agent. Hence much effort has been put forth toward improving these materials, so as to provide better chemical bonding to the glass and thereby improve the wet strength retention of laminates.

A popular method of evaluating moisture resistance is the boil test, which is carried out for varying periods of time. It has been found that some types of epoxy laminates lost strength up to 50 percent after 72 hours, and up to 52 percent after 144 and 300-400 hour periods of boiling. Minimum losses were 2 percent after 72 and 144 hours, and 9 percent after 300-400 hours. The extremes in variation were traceable to resin formulation and coupling agent on the glass reinforcement. It was also found that water assists in the degradation of certain types of coupling agents.

In general, attack by water may be expected when a polymer is wetted by water. Thus, polar materials like the polyesters are easily wetted and decomposed or altered molecularly. Such attack may be listed in the following order: acetates > esters > chlorides > amides.

c. Temperature Exposure. The very chemical nature of organic resinous materials is such that they are susceptible to temperature effects and exhibit widely variable characteristics. The degree of change to be measured, as one varies from ambient conditions, is related to the polymer's glass transition temperature. If this value is low, startling property changes will occur, while if high, only slight alterations will be effected under ordinary conditions. Such changes are controlled by molecular structure, types of bonds present, atomic constituents, degree of polymerization and the presence of impurities. However, if temperatures vary too far to either extreme, other changes can take place. At low temperature, "crystallization" and embrittlement can occur. At very high temperatures, the point is reached where bond rupture takes place, and the material depolymerizes and decomposes. This decomposition is irreversible for all resin systems.

General-purpose polyesters exhibit serviceable strength to 250°F., and can be used with additional strength decline and discoloration up to 300°F. Polyester resins, in general, regain most of their room-temperature strength after exposure to 300°F., but above that temperature suffer progressive degradation. Special polyesters are serviceable up to 350°F. Phenolic-type laminates, exposed to a temperature of 500°F. for one-half hour, have been found to retain 90 percent of their original strength. Silicone type laminates show relatively little strength deterioration after being held at temperatures of 500 to 600°F.

Much research is being done on the chemistry of temperature-resistant polymers, and important new polymers such as polybenzemidazole and aromatic polyimide will extend the useful temperature range of FRP.

d. Temperature - Humidity Cycling. Temperature and humidity effects are inseparable. As a result, much testing of glass is done under established temperature - humidity cycling conditions as set forth in MIL-STD-331. It has been shown that the variance in resistance of materials is attributable to the resin-coupling agent combination. Some combinations show no deterioration, while others suffer as much as 70 percent loss of properties. Resins with high glass transition-temperatures give the best results. A good coupling agent can improve the performance of a not-so-good resin to a limited degree. Water is a necessary ingredient of any cycling program.up to temperatures of 165° F. in order to induce degradation.

e. Chemical Exposure. FRP materials are resistant to the corrosive attack of numerous chemical reagents which normally degrade or destroy other materials of construction. While many of the claims are true, the extent to which they apply must be carefully studied by screening tests at first, and those which pass can then be studied by long term exposure tests. Due to the variety of possible exposure conditions, it is suggested that the design engineer explore the literature on this subject and he will probably unearth the desired information regarding specific chemical resistances for a given application.

f. Fungus Growths. Mold and fungi will grow on laminate materials under the proper conditions. However, these growths are a surface condition and have not been found to affect the mechanical properties of reinforced plastics materials. The necessary prerequisites for growth are food and moisture. Changes in electrical properties can be correlated with the presence of moisture. The presence of fungus growth on a laminate has little,,if anything, to do with the changes.

224. Underseas Environment Effects. In the last several years, the underseas environment has become of real importance as concern reinforced plastics. Applications now have been developed requiring the use of these materials to act as structures in direct contact with sea water at various depth. Because of the newness of these applications, there is a scarcity of data on the performance of FRP in the underseas environment.

The sea has its own unique characteristics. On the average, ocean water will vary from 3.2 to 3.6 percent salinity with a low of 1.6 percent at times in the Black Sea, and a high of 4.1 percent in the Red Sea. Temperatures vary from about 34°F. to about 90°F., depending on the location and depth. With depth, pressure is a factor and reaches a maximum of 16,400 p.s.i. in one specific location. The sea is very corrosive to materials, since it contains many dissolved materials and gases. Its pH ranges from 7.58 to 8.20. Dissolved oxygen varies from 0.5 to about 6 volumes per 1000 volumes of water. Both pH and oxygen content vary with depth. In addition, there is profuse biological activity, especially in the upper layers of the sea. All of the above, along with water pollution, go to form a very complex and constantly changing environment.

When laminated materials are exposed to either fresh water or sea water, varying degrees of changes are noted. Laminate tests have shown that sea water causes some deterioration. The loss of strength was least when the laminate was well made and had a good coupling agent on the glass. It has been reported that an actual part used in sea water for five years, as a submarine structural part, lost only about 12 percent of its dry flexural strength. Limited data on high pressure water effects has indicated that 2100 hours exposure at 10,000 p.s.i. will cause a decrease in axial compressive strength of cylindrical hollow specimens of about 9 percent. Under these conditions, filament-wound cylinders appear to absorb less than 0.1 percent of moisture by weight at the maximum.

225. Space Environment Effects.

a. Vacuum Exposure. Outside the earth's atmosphere, a general vacuum condition exists. At 87 miles a free molecular state begins to exist and the pressure is down to about 6×10^{-6} torr (a torr approximates one mm of mercury). The particles found in this area are in atomic, excited or ionized states and are, therefore, more reactive chemically. Under these conditions many organic materials, expecially uncross-linked materials with double bonds, are susceptible to attack by atomic oxygen, ozone, and atomic nitrogen. In laminating resins, aromatic double bonds could be present if the formulations were improperly mixed and cured. However, these bonds are not attacked to the same degree as olefinic double bonds.

Most laminating resins have basic macro-molecular structures of low vapor pressures and, therefore, it is not likely that there would be significant losses of these materials in space. It is also probable that the major portion of such a loss would be a surface phenomena and be confined to degradation at the terminal ends of the polymer, or on pendant branches to the main polymer network.

Negligible effects on polyester, phenolic and epoxy laminates have been reported after as much as 1000 hours exposure at 10^{-6} torr at room temperature. It is also reported that if heat is involved in a vacuum test, the strengths are not reduced as much, as compared to exposure to heat alone, because of the lack of any oxidative effect.

In itself, vacuum is not a real problem. It will have an effect, however, if the material is improperly cured to give a broad spread of molecular weight, or has been affected by heat or radiation so as to produce low molecular weight volatile polymer fragments, leading to excessive outgassing. Properly made laminated materials can be expected to maintain their engineering properties in vacuum conditions.

b. Ultraviolet Radiation. The lack of atmosphere in filtering-out the energy between 3000 and 4880Å means that material in space may absorb 10 to 100 times more ultraviolet radiation than on earth. The energy per photon in the 2000 to 4000Å band exceeds the energy of the typical chemical bonds found in polymers. However, the ultraviolet degradation in vacuum is not nearly as severe on mechanical and electrical properties as it is in the presence of oxygen.

Exposure to radiation between 2000 and 6000Å at 10^{-6} torr and normal intensities for periods up to 500 hours, shows weight losses of approximately 1 percent for polyester, phenolic and epoxy laminates. The polyester first gains in flexural strength, through additional crosslinking, and then reduces to only slightly greater strength than it had originally. Both the phenolic and epoxy materials lose about 10 percent of their flexural strengths. The effects that bring about these strength changes are thought to be surface controlled. Because of the limited penetration of this radiation, 4mm (about 0.01 inch), the interior bulk of the laminate remains unchanged. At higher radiation intensities, more drastic changes are brought about and the decreasing resistance to change in flexural strength was found to be in this order: phenolic, epoxy and polyester.

c. Nuclear Radiation. There are several types of nuclear and atomic radiations: fast (epithermal) neutrons, thermal neutrons, gamma radiation, beta radiation and fission fragments. Of these, the fission fragments (protons, deuterons and alpha particles) are encountered only under very special conditions and will not be further considered. The thermal neutrons are in equilibrium with their surroundings, so they essentially diffuse through a material without transfer of mechanical energy. Fast neutrons, on the other hand, can be captured or absorbed by a nucleus which is then converted to an excited state, and may either descend to ground state or decay into a different nucleus. Eventually, through loss of energy, fast neutrons become thermal neutrons. These transfers of energy are low and inversely proportional to nuclear mass. Beta radiation or electron radiation reacts with the orbital electrons of a material. Ionization occurs and electrons are produced which in turn, if of sufficient energy, act upon the materials like a primary beta emission. Gamma radiations can act on materials by three different mechanisms, the relative contribution of each depending upon the energy of the initial ray and the nuclear mass of the absorbing material. The final result of the three mechanisms is that gamma radiation affects material identically to that of beta radiation.

Organic materials are greatly affected by radiation. Changes are mainly initiated by ionization and excitation processes; they are generally proportional to the total energy absorbed, and rarely depend upon the type and source of the radiation.

Since organics are primarily made-up of carbon and hydrogen bonds covalently bonded, these bonds are easily disrupted. Also, upon exposure to radiation, the materials become more susceptible to attack by oxygen. In the non-crosslinked polymers, degradation by scission may follow radiation. They may become sticky, lose their properties and eventually may be reduced to dust. In contrast, the crosslinked laminating resins may even be improved by some radiation because of additional crosslinking. Their resistance is further enhanced because of the presence of the benzene ring structure throughout the molecular structure. These materials will, therefore, show some initial strength increases, increased hardness, and decreased solubilities. Many times they release gases in the process, and eventually may become brittle.

Generally, the mechanical properties of laminates are not greatly affected up to dosages of 8.7×10^8 rad. However, at a dosage of 10^{10} rad all materials, except a certain phenolic type, rapidly degrade and lose as much as 50 percent of their properties. The phenolic still retains its characteristics at 10^{10} rad and temperatures up to 500° F. Between 8.7×10^8 and 8.5×10^9 rad, the order of decreasing radiation stability is: phenolic, epoxy,ppolyester, silicone, head resistant epoxy (epoxy-phenolic), and heat resistant polyester (triallyl cyanurate).

It has been stated by some investigators that none of these materials are appreciably altered in respect to their electrical properties because of nuclear radiation. However, others have indicated that some changes do occur. For example, it has been noted that the surface resistivity of cast sheet epoxy materials had decreased from 10^{16} to 10^{10} ohm-cm. It was also found that electrical insulators can develop transient charges because of free ions produced during radiation. Thus conductivity, capacitance, dissipation factor, and electric strength can vary with rate, time, and temperature of exposure. When the materials are removed from the radiation field, these effects will then decay (at an exponential rate) to constant values.

In any analysis of the radiation resistance of plastics, it should be pointed out that fillers greatly moderate the effects. The resinous part of the composite structure is the most susceptible to degradation. Glass, asbestos and carbon black are very good in improving radiation resistance. Thus, a laminate structure because of its very high reinforcement content, is less affected by radiation than unfilled resin systems.

d. Temperature Exposure. Temperature is another element of the space environment. By itself, it has the same influence on reinforced plastics as discussed previously. The principal heating effect comes from solar radiation. It is stated that a 200 mile altitude, a temperature environment of 3000°F. prevails. In the practical situation and ignoring any energy control attempt, it is estimated that the uncontrolled equilibrium surface temperature would be no greater than 716° F. Obviously, in the shadow of the earth these temperatures would drop to very low values. With thermal control materials applied to space vehicles, the temperature can be easily narrowed to a range of -100°F. to + 200°F. Under these conditions, phenolics are best, followed in decreasing order by silicones, epoxy-phenolics, triallyl cyanurates, epoxies, and polyesters. The best reinforcements are considered as asbestos and glass.

In addition to solar radiation, other heating conditions connected with space vehicle performance are ascent and reentry aerodynamic heating.

The ascent heating condition is of short duration (only a few minutes, and is limited to temperatures of about 1830°F. or less). Such conditions only affect the surface of the laminate material because of its low thermal conductivity. Even these surface effects can be largely eliminated by use of external layers of subliming organic materials.

The reentry heating condition is by far the more severe. Although of short duration, the stagnation temperature developed (about 9000°F. or more) exceed those that the material can resist. Therefore, laminates are used only where their ablation characteristics can be of advantage. In this type of application, both the reinforcement and the resin contribute to performance. As a result, very refractory fibers, as well as heat resistant resins, are needed. At present silica, glass, asbestos and graphite reinforcements are all of interest. The superior resin is considered to be a phenolic or a phenolic-nylon formulation. Such combinations of materials into laminates provide low ablation rates, low thermal conductivities, and high thermal shock resistance. Upon ablation, they form char surfaces which enhance their ability to resist the severe thermal mechanical-chemical conditions of reentry. This ability is further enhanced if the reinforcement is laid down so that it is at an angle to the flow of gases, to give a shingle effect.

Several efforts have been made to estimate the ablation resistance of plastics and other materials. However, it is still necessary to test in order to obtain the initial design data, because so little is known about the complex ablation phenomena. Much work is being done on the decomposition of resin alone. Thermo-gravimetric data gives information on the most temperature-resistant formulations. One of the simpler engineering ways of comparing composite materials is by oxyacetylene torch testing. In addition, temperature profile data and, with modified tests, effective thermal diffusivity data can be collected. A great deal of work has also been done with arc plasma jets. Some researchers have reported that phenolic and phenolic-nylon resins are among the best of the ablative reentry materials. These when combined with glass, asbestos, silica and nylon reinforcements are all useful in missile applications. For use in short-time, high-temperature environments where no materials are stable, the reinforced plastics may be the most durable materials available.

At the other extreme in space are the cryogenic temperatures. Exposures as low as -120°F. can be expected at altitudes of 50 miles. Also, some internal missile applications will require even lower temperatures. Tests have shown that there is a general increase in the strength of laminates as the temperature is lowered down to -424°F. Data has also been accumulated to show that these materials are more resistant to cyclic fatigue loadings as the environmental temperature is lowered.

TYPICAL APPLICATIONS

226. Low-Pressure Laminates. Hand layup and press molding are the two principal processes for low-pressure reinforced plastics laminating. The two options allow for a wide range of FRP possibilities, with many choices of resin mix, reinforcing materials, and molding procedure. The "low pressure" designation means exactly that. In hand layup, only atmospheric pressure is used. In low-pressure press molding, pressures run no higher than 250 p.s.i., compared to 50,000 p.s.i. or more for injection molding.

Of all plastic production methods, hand layup is the most flexible and thrifty in equipment needs. Hand layup is the fastest way to produce a prototype. While profitability of hand layup is high for low-volume production, it falls off sharply in comparison with press molding as volume increases. Therefore, hand layup is the proper choice for a single product or for a limited volume, and press molding is most economic for high-volume needs. Volume for a low-pressure press job, however, must be high enough to justify the cost of the matched dies and press operation.

Hand layup starts with a three-dimensional, full-scale pattern in the exact form and size of the product to be made. It can be the actual end product, or a wood, metal, or glass fiber mockup. From this, a female forming mold is made. Where reverse curves are involved, the mold can be of the breakaway type to permit release of the finished product without causing damage to the mold.

The process involves placing one layer of reinforcement at a time on the forming mold. The material is saturated with filled, catalyzed resin. Distribution of the resin mix is by hand or with the use of hand tools. Care must be taken in three areas: (a) reinforcing material must be included with the resin mix in every area of the mold; (b) the mix must reach thoroughly into every curve and recess in the mold; (c) no entrapped air can remain in the laminate to cause possible structural deficiencies. Cure of a hand layup form is accomplished at room temperature, or in a low-temperature oven.

Advantages of the hand layup process include: size of end product that can be made has no limitation; complexity of shape is unlimited; wide variation in physical properties is attainable; tooling costs are low.

Requirements for opacity, appearance, nonconductive ability, corrosion resistance and finish determine resin and reinforcement selection, and how they are laid up is determined by product needs. If esthetics are important, the exterior coat, applied first, can be a pigmented or nonpigmented gel.

The end product will determine the necessary number of plies. There may be just one layer of resin and reinforcement, or eight or more.

For press forming, end-use requirements also will dictate the type and number of layers of resin and reinforcement needed. Part shape, esthetic considerations, or the simple mechanics of forming will determine the arrangement of molds in the press. It takes but only a single operation of the press to form each piece.

In press molding, mating machined dies, usually heated, are made of aluminum, cast iron, or steel. Hydraulically operated presses are employed. Reinforcement can be placed on either half of the mold. Filled, catalyzed resin is poured on; closing the molds assures even distribution. High-volume production, high accuracy, and high strength are achieved by this process.

The premix method, a variation of the matched die process, affords lowest labor and material cost per part, and permits relative ease in changing complex shapes. Here the resin, reinforcement, fillers, and catalyst are mixed into a putty-like compound, and loaded into the dies as a set volume charge. Closing the press distributes the mixture evenly through the mold cavity.

In low-pressure laminating, polyesters account for almost 85% of all resins in reinforced mixtures. Polyester has a favorable balance of mechanical and electrical properties, dimensional stability, low cost, and ease of handling. Also used is epoxy, which provides good adhesion, excellent chemical resistance, minimum water absorption, and minimum shrinkage during cure.

Glass fibers are the most widely used reinforcing material for low-pressure laminates. They provide dimensional stability, high heat and electrical resistance, and moisture resistance. Other reinforcing materials are asbestos, synthetic fibers, sisal, paper, cotton, and metal.

TABLE XVI. PROPERTIES OF SOME REINFORCED PLASTICS MATERIALS FOR LOW-PRESSURE LAMINATING

Properties	Glass mat/ polyester	Glass cloth/ polyester	Glass mat/ epoxy	Glass cloth/ epoxy
Tensile strength, p.s.i.	20,000-25,000	30,000-70,000	14,000-30,000	20,000-60,000
Compressive strength, p.s.i.	15,000-50,000	25,000-50,000	30,000-38,000	58,000-70,000
Heat resistance, continuous, °F.	300-500	300-350	330-500	330-500
Flexural strength, p.s.i.		40,000-90,000	20,000-26,000	70,000-100,000
Flammability rating	Slow burn. to self-exting.	Slow burn. to self-exting.	Slow burn. to self-exting.	Slow burn. to self-exting.

227. High-Strength Composites. The term "advanced" or high-strength composites applies to the class of fiber reinforced materials with tensile moduli (Young's modulus) in excess of 10 million p.s.i. for unidirectional composites. This rather broad definition encompasses composites using commercially available high-performance graphite fibers, boron filaments, and the recently announced high-modulus organic fibers, as well as a host of developmental films, fibers, and whiskers of a variety of chemical compositions.

Initial development of high-performance composites was under the sponsorship of the Air Force with the goal of providing lighter weight, stronger, and stiffer materials. These goals have been achieved as shown in Figure 14 in which the strength and stiffness of unidirectional, high-performance composites are contrasted with the yield strength and Young's modulus of various typical metals.

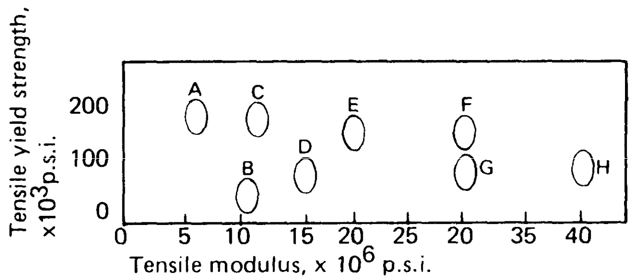

Figure 14. Comparison of tensile strength and modulus of unidirectional high-performance composites, and the yield strength and modulus of common engineering materials: S-glass/epoxy (A);aluminum(B); organic fiber/epoxy (C); titanium (D); graphite/epoxy, high strength (E); boron/epoxy (F); steel (G); graphite/epoxy, high modulus (H).

Sizable increases relative to aluminum, titanium, and steel are realized; for example, four fold increases in strength or stiffness over aluminum are possible. Combining the increases in engineering properties with the lower densities of the composites (0.050 lb./in.^{3} for organic fiber/epoxy, 0.063 lb./in.^{3} for high-modulus graphite/epoxy, and 0.72 lb./in.^{3} for boron/epoxy vs. 0.282 lb./in.^{3} for steel) provides potential improvements in specific performance (performance per pound of structure) ranging from three to six fold in both stiffness and strength.

Other benefits include 100% elastic recovery, ease of processing by a variety of methods, and the ability to tailor the properties of the component to satisfy anisotropic performance requirements, something not readily accomplished with metals. In addition the graphite members of the family contribute low coefficient of friction, near zero thermal expansion, and outstanding wear resistance under nonlubricated conditions, coupled with ease of machining.

Composites are the additive combination of a high-performance reinforcing fiber with a matrix material. The characteristics of the reinforcing fibers are discussed in detail in the individual sections dealing with fibers. The commercially available materials include boron (on tungsten) continues filament, both 4- and 5.6-mil diameter, graphite and organic fibers as continuous filament yarns and tows, woven constructions, and chopped fibers.

Producers include Avco, Celanese, CuPont, Great Lakes Carbon, Hamilton Standard, Hitco, Hercules, Polycarbon, Union Carbide, and Whitaker-Morgan in the U.S., and several foreign ones.

MATRIX

The function of the matrix is to distribute the loads throughout the composite, permitting the high performance of the fibers to be realized. Both plastic and metal matrix systems have been developed, although plastics have received the greatest attention because of desirable processing characteristics.

Three classes of plastic matrix systems have been developed in response to the aerospace community's needs—general purpose systems suitable for use to to 180°F. (83°C.), and high temperature systems for supersonic aircraft and the hot sections of engines and surrounding structure. These latter classes are characterized as for 350°F. (130°C.) maximum and above 500°F. (260°C.) service.

The characteristics desired of the matrix system are more chemical and process oriented than structural. The levels of mechanical properties are modest—300,000 to 1,000,000 p.s.i. modulus and 10,000 to 20,000 p.s.i. tensile strengths. Processing related variables are concerned with the ability to fabricate, reproducibly and simply, sound, low-void, high-fiber-content composites without resin rich or resin starved areas. Important factors include wetting characteristics, low volatiles, controlled viscosity, modest pressure requirements, short cure cycles, and, desirably, the absence of exotherms. Chemical resistance in a variety of harsh environments is often an additional requirement.

As a class, epoxy systems combine wettability, ease of processing, and desirable chemical inertness with functionality from cryogenic temperatures to near 500°F. (260°C.). Systems suitable for the 350°F. (138°C.) to 800°F. (428°C.) range include phenolics, polyimides, polybenzimidazoles (PBI), polyquinoxalines (PQ), polyimidazoquinazoline (PIQ), and other ladder polymers. With many of these, however, desirable processing characteristics are sacrificed for the higher temperature performance. For even higher service temperatures, metal systems including aluminum, steel, titanium, and nickel have been characterized.

For less demanding environments thermoset polyesters and thermoplastics such as Celcon, nylon, and others can be used.

COMPOSITE PROPERTIES

Properties of unidirectional, continuous filament reinforced plastics are quite well predicted by the rule of mixtures. The data in Figure 14 are typical tensile properties of 60 volume-per cent epoxy matrix composites. In compression, with full support for the large filaments, the strength of unidirectional boron/epoxy composites has been reported near 400,000 p.s.i. In graphite composites, with a much smaller filament diameter, compressive strengths range from 90,000 to 180,000 p.s.i.; organic fiber composites, with both small filament diameter and lower modulus, are typically in the 50,000 to 60,000 p.s.i. range.

Most applications have not only uniaxial but also shear or transverse loads and, therefore, some fibers are placed off-axis. Assistance is available to the designer through a number of computer programs that minimize material usage and maximize weight savings and performance to meet anisotropic load requirements.

In addition to composites with only one type of reinforcing fiber, hybrid systems utilizing a mixture of fibers, often with very selective orientations, have been developed.

A third general class of materials is chopped fiber systems using either a single fiber type or blends, generally with glass. Here the graphite containing systems appear to have the most promise, combining lower costs with attractive increases in modulus and ease of processing.

APPLICATIONS

Boron/epoxy composites are used on the F-14, F-15, and F-111G for primary structure, and graphite/epoxy is used on the F-111G for secondary structure. Graphite/epoxy components are in use on a number of satellite programs because of increased stiffness as well as weight savings. In nonaerospace applications, ease of fabrication, particularly with the graphite containing systems, has led to use in small precision parts with high value-in-use.

(Additional information on high-strength composites is available from Military Handbook 17A entitled – Plastics for Aerospace Vehicles – Part I. Reinforced Plastics.)

FILAMENT WINDING

228. General. The reinforced plastic industry has developed several new techniques over the years, but none can match the combined versatility and performance of the filament winding process which not only produces structures that have superior mechanical properties, but also offers possibilities for almost truly automated production lines, the lack of which has constituted one of the major drawbacks in the reinforced plastic industry to date.

Filament winding consists of winding or wrapping continuous filaments on a mandrel. A binder material is combined with the filaments, either during the winding which would be called "wet winding", or prior to winding, which would then be classified "prepreg winding", and subsequently cured to form an integral structure. The wound structure is then removed from the mandrel, and then processed through any subsequent operations required. The key to the winding process is that the filaments can be oriented in an extremely precise manner, the resin content can be controlled very accurately, and the whole process can be repeated over and over again with a great degree of reproducibility that is independent of operator technique. It is this feature of reproducibility that lends the filament winding process to both automation and high performance structures.

The ability to orient the fibers in the exact position required by the stress analyst, is one of the main reasons for making the filament-wound structure so efficient in terms of strength to weight. In the case of the simple closed-end vessel, where the load relationships are two-to-one in regard to the hoop and longitudinal forces, the fibers can be oriented in that ratio of two-to-one. This results in a truly balanced structure (rather than an over-designed vessel in either direction) where there are exactly enough fibers in both the hoop and longitudinal directions to react to the forces. In a pressure vessel fabricated from a homogeneous material such as steel, it can be shown that there is twice as much material present as needed to withstand the longitudinal forces, because the design thickness indicated by the hoop load is twice that of the longitudinal load. The filament winding process, however, does have drawbacks. These include such problem areas as end closure designs on pressure vessels where large end closure openings are required (that is,

$$\frac{\text{diameter opening}}{\text{diameter cylinder}} \geq 0.8\text{), multi opening closures,}$$

and designs requiring minimum deflection. These problems can be minimized by proper design, and the results are well demonstrated by such items as rocket motor cases with off-center nozzle or thrust reversal ports, skirts on rocket motors which must take a high degree of bending and compression, and deep submergence vehicles where high compressive loading is commonplace.

Usually, a filament-wound structure is considered as one which is composed of continuous fiberglass filaments impregnated with an epoxy resin. However, it is not limited to that system, but rather should include any continuous filament material. The materialsmay be fiberglass, metal or synthetic fibers, and any binder that can include not only most of the standard thermosetting resins, but also the thermoplastics and several new inorganic binders which hold great promise for extreme high temperature applications.

The subject of filament winding is too large to cover properly in this handbook. Therefore the following references are suggested:

1. Handbook on Fiberglass and Advanced Plastic Composites by George Lubin. Chapter 18 – Filament Winding.
2. Filament Winding, by D. V. Rosato and C. S. Grove, Jr.

CHAPTER 6

FILMS CHART AND PROPERTIES OF LAMINATIONS

TABLE XVII. FILMS CHART

Properties and commercial standards of packaging films–3 mils and under

	Cellophane							
	Lacquered	Polymer-coated	Polyethylene-coated[1]	Cellulose acetate[2]	Fluoro-halocarbon	Ionomer	Nylon (polyamide)	Nylon, cast saran-type coating one side
GENERAL								
Clarity	Transparent	Transparent	Transparent to translucent	Transparent	Transparent	Transparent	Transparent to translucent	Transparent to translucent
Yield (1 mil)	19,500	19,500	18,250 (1.1 mil)	22,000	13,000	29,200-29,500	23,500 24,500	21,200
Specific gravity	1.40-1.55	1.44	1.2	1.25-1.35	2.2	0.94-0.95	1.13-1.14	1.3
MECHANICAL								
Tensile strength, lb./sq. in. (ASTM D882)	7,000-18,000	7,000-18,000	7,000-18,000	7,000 12,000	5,000-10,000	3,000-5,000	10,000-18,000	6,000-10,000
Stretch, % (ASTM D882)	15-25	25-50	15-25	15-50	50-400	350-450	250-500	300-400
Impact strength[3], kg.-cm.	8-15	5-15	5-15	2-8	2-15	30-90	4-6	5
Tear strength (Elmendorf), gm./mil (ASTM D1922)	2-10	7-15	2-10	2-15	10-40	15-25	20-150	20-60
Stiffness, gm. (Handle-O-Meter)[4] MD / TD	37-65 / 18-31	37-65 / 18-31	40-60 / 20-40	25-40 / 25-45	20-45	5-10	5-35 / 5-40	5-30
Heat-seal range, deg. F[5]	200-350	200-350	230-300	350-450[6]	350-400	190-400	350-500[6]	250-375
CHEMICAL								
WVT, gm./24 hrs./1 sq. m. at 100 deg. F., 90% R.H. (ASTM E96 Method E1)[7]	3-15	6-14	18 and up	Very high	0.4-1.0	22-30	Very high	7-10
Gas trans., cc./mil/1 sq.m./24 hrs./1 atm./73 deg. F., 0% R.H. (ASTM D1434)	O_2 2-80[8] CO_2 15-95[8]	1-9[8] 6-9[8]	—[8]	1,800-3,100 7,700-52,000	100-300 250-750	3,500-7,500 9,700-17,800	30-110 150-390	6-15 20-30
Resistance to greases and oils	Impermeable	Impermeable	Impermeable	Excellent	Excellent	Good	Impermeable	Excellent
PERMANENCE								
Maximum use temperature, deg. F.	Begins to char at 375	Begins to char at 375	180	250	250	190	350-475	250
Minimum use temperature, deg. F.	Depends on type and R.H.	About 0	Depends on cellophane	About 0	Minus 50	Minus 50	Minus 50	-40
Dimensional change at high R.H., %	3-5	2-3	3-5	0.2-0.6% at 80% R.H.	None	None	1-3	1-3
Flammability	Same as newsprint	Same as newsprint	Slow burning	Slow burning	Nonflam.	Slow burning	Self-extinguishing	Self-extinguishing
CONVERTING CHARACTERISTICS								
Machine performance	Excellent	Excellent	Excellent	Good	Good	Fair to good	Good	Good
Printability	Excellent	Excellent	Excellent	Excellent	Good if treated	Good if treated	Good	Good
Sealing	Heat or adhesive	Heat or adhesive	Heat	Heat or solvent	All svstems	Heat	Heat or adhesive	Heat or impulse
Heat shrinkable	No	No	No	No	No	No	No	No

- * Data, unless otherwise specified, are for 1-mil (0.001 in. thickness). Properties depend on type and grade of polymer or resin used in base films or coatings.
- 1 Various coating thicknesses available; also laminated combinations. Test data assume polyethylene side toward product.
- 2 Modified acetates - cellulose acetate butyrate, cellulose propionate and cellulose triacetate–offer an additional range of properties.
- 3 See "New Pendulum Impact Tester," MODERN PACKAGING' Nov. 1956, p. 163.
- 4 For 8-in. widths ½-centi. slot, Handle-O-Meter See "Testing Films for Machinability," MODERN PACKAGING, Sept., 1967, p. 171.

Pliofilm (polyisoprene hydrochloride)	Polycarbonate	Polyester saran-type coating	Polyester (uncoated)	Polyethylene		
				Low density 0.910-0.925	Medium density 0.926-0.940	High density 0.941-0.965
Transparent to translucent	Transparent	Transparent	Transparent	Transparent to translucent	Transparent to translucent	Transparent to opaque
24,000	23,100	20,500	20,000-22,000	30,000	29,500	29,000
1.11	1.2	1.4	1.35-1.39	0.910-0.925	0.926-0.940	0.941-0.965
3,000-4,100	8,000-9,000	17,000 and higher	17,000 and higher	1,000-3,500	2,000-5,000	3,000-10,000
Yield 10-20 Ultimate 350-500	110	80-180	70-130	225-600	225-500	10-500
6-15	High	25-30	25-30	7-11	4-6	1-3
60-1,600	20-40	10-20	13-80	100-400	50-300	15-300
12-25 12-25	Stiff	40	40 40	2.5-4.5 3-7	5-10 6-14	8-16 10-20
240-300[6]	400-430	275-400	275-400[9]	250-350[6]	260-310[6]	275-310[6]
8 and higher	150	1-2	15-30	18	8-15	5-10
130-1,300 520-5,200	4,000 12,000	9-15 20-35	52-130 180-390	3,900-13,000 7,700-77,000	2,600-5,200 7,700-13,000	520-3,900 3,900-10,000
Excellent	Good	Excellent	Excellent	May swell slightly on long immersion	Good	Excellent
Softens at 200	265	Coating softens at 190	250	150 (softens at 230)	180-220	250
Depends on plasticizer	Minus 100	Minus 60	Minus 80	Minus 60	Minus 60	Minus 60
None	None	None	None	None	None	None
Self-extinguishing	Slow burning	Slow burning	Slow burning	Slow burning	Slow burning	Slow burning
Fair to good	Good	Fair to good	Good	Fair to good	Fair to good	Good
Special inks	Good	Good	Good	Good if treated	Good if treated	Good if treated
Heat	Heat	Heat or adhesive	Heat[9] or adhesive	Heat	Heat	Heat
Some types	No	Some types	Some types	Special types	Some types	Some types

5 Heat-seal range, in deg. F., shows the lowest temperature at which effective seals can be made and the upper temperature at which seals begin to show degradation. For some films, special methods or equipment may be necessary.
6 Unsupported film cannot be sealed on all types of heat sealers. Special sealing may be necessary.
7 To convert to gm. per 100 sq. in., divide gm. per sq. m. by 15.5.
8 Depends on moisture content and plasticizer.
9 Some types can be sealed only if coated.

(Continued on next page)

FILMS CHART (continued)

	Polypropylene (oriented)	Polypropylene (unoriented)	Polypropylene, balanced, oriented, stabilized, coated two sides[10]	Polystyrene (oriented)	Polyurethane	Polyvinyl alcohol	Saran[11] (polyvinyl-Idene chloride)	Vinyl (PVC and plasticized)
GENERAL								
Clarity	Transparent	Transparent	Transparent	Transparent	Transparent to translucent	Translucent	Transparent	Transparent to translucent
Yield (1 mil)	30,600	30,800	29,500	26,300	23,000	21,600	16,300	19,000-22,000
Specific gravity	0.905	0.88-0.90	.93	1.05	1.12-1.2	1.21-1.31	1.59-1.71	1.23-1.37
MECHANICAL								
Tensile strength, lb./sq. in. (ASTM D882)	25,000-30,000	3,000-6,000	15,000-30,000	9,000-12,000	7,000-12,000	5,000-9,000	8,000-20,000	2,000-19,000
Stretch, % (ASTM D882)	70-100	200-500	100	10-60	300-700	400	40-80	5-500
Impact strength[3], kg.-cm.	5-15	1-3	10-25	1-5	40	Good	10-15	12-20
Tear strength (Elmendorf). gm./mil (ASTM D1922)	4-6	40-330	5-8	4-20	High	300-500	10-20	Varies widely
Stiffness, gm. (Handle-O-Meter)[4] MD TD	5-40	11-27 11-27	20-30	50 50	Very soft	Soft	10 15	7.5-40 10-45
Heat-seal range, deg. F.[5]	Requires coating	325-400[12]	190-270	250-325[12]	300-375	375-490	280-300[12]	200-350[12]
CHEMICAL								
WVT, gm./24 hrs./1 sq. m. at 100 deg. F., 90% R.H. (ASTM E96 Method E)[7]	4	8-10	4-10[13]	100 and higher	Very high	None	1.5-5	8 and higher
Gas trans., cc./mil/1 sq. m./24 hrs./1 atm./73 deg. F., 0% R.H. (ASTM D1434)	O_2 2,400 CO_2 8,400	1,300-6,400 7,700-21,000	...[13]	2,600-7,700 10,000-26,000	Very high Very high	Very low --	8-26 52-150	77-7,500 770-55,000
Resistance to greases and oils	Excellent	Excellent	Excellent	Good	Excellent	Excellent	Excellent	Excellent
PERMANENCE								
Maximum use temperature, deg. F.	275	250	250	Shrinks at 185	220	240	Softens at approx. 290, melts at 310	Approx. 200 Depends on plasticizer
Minimum use temperature	Minus 60	—[14]	Minus 60	Subzero	Minus 40	15	Good flexibility at 0	Depends on plasticizer
Dimensional change at high R.H., %	None	None	None	Little or none	Little or none	3-5	None	None
Flammability	Slow burning	Slow burning	Slow burning	Slow burning	Self-extinguishing	Slow burning	Self-extinguishing	Self-extinguishing
CONVERTING CHARACTERISTICS								
Machine performance	Good	Fair to good	Good	Good	Fair	Fair	Fair to good	Fair to good
Printability	Good if treated	Good if treated	Good	Special inks	Special inks	Good	Special inks	Special inks
Sealing	Adhesive	Heat	Heat	Heat or adhesive	Heat or adhesive	Heat or adhesive	Heat	Heat or adhesive
Heat shrinkable	Some types	No	No	Yes	No	No	Some types	Some types

10 Coatings can be saran, acrylic or polyvinyl acetate, depending on end-use requirements.
11 Saran is a registered trademark in certain foreign countries, but not in the U. S.
12 Unsupported film cannot be sealed on all types of heat sealers. Special sealing may be necessary.
13 Varies according to composition or type and weight of coating
14 Not recommended where low-temperature durability is critical

TABLE XVIII. PROPERTIES OF LAMINATIONS*

Properties	Foil, 0.00035; wax, microcrystalline, 17-lb.; porous paper, 20-lb.[1]	Pouch paper (or glassine), 25-lb.; polyethylene, ½-mil; foil, 0.00035; polyethylene, 1-mil[2]	Polyester film, ½-mil; adhesive; foil, 0.00035; polyethylene, 2½-mil[2]	Foil, 0.00035; casein adh., 2-lb. (or polyethylene, 7-lb.); backing paper[2]	Pouch paper, 25-lb.; casein adh., 2-lb.; foil, 0.0007; heat seal coating, 3-lb.	Foil, 0.00035; adhesive; paperboard	Kraft paper; polyethylene scrim; kraft; polyethylene
GENERAL							
Forms available	Rolls	Rolls	Rolls	Rolls	Rolls, sheets	Rolls, sheets	Rolls, sheets
Thickness range, in.	0.0025-0.003	0.004-0.0045	0.003-0.0035	0.0036	0.0026-0.0032	—[6]	—[6]
Area factor, sq. in./lb.	8,350	7,225	7,000	—	7,450	—[6]	—[6]
MECHANICAL							
Tensile strength, lb./in. MD (ASTM D828 TD	21 11	23 14	15 20	19 12	24 24	High[6]	Very high
Elongation, % MD (ASTM D828) TD	3 3	3 10	24 45	1 1	2 4	—	2
Burning strength, lb./sq.in. (ASTM D774)	21	26	42	17	25	High[6]	Very high
Tearing strength, gm. MD (ASTM D689) TD	50 55	48 52	71 98	60 72	37 37	—[6]	Very high
Folding endurance, 1 kg. load MD (ASTM D643) TD	48 7	431 92	>800 >800	110 13	250 17	—[6]	Very high
CHEMICAL							
Permeability to gasses[3] (flat sheets)	Very low	Very low	Approaches zero	Very low	Very low	—	Poor
Water-vapor permeability[3] (flat sheets)	Approaches zero	Approaches zero	Approaches zero	Very low	Approaches zero	Very low	15
Resistance to greases[3] and oils	Poor	Good	Good to excellent	Fair	Good to excellent	Poor	Poor
PERMANENCE							
Resistance to heat[4]	Fair	Good	Good	Excellent	Excellent	Good	Excellent
Resistance to cold	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
Dimensional change at high R.H.	Good, slight curl	Good, slight curl	None	Good, slight curl	Good, slight curl	Good, slight curl	Good
USE PERFORMANCE							
Machine performance,[5] printability, sealing	Excellent Good dead fold	Excellent	Excellent	Excellent Good dead fold	Excellent	Excellent	Good
Typical uses	Easy sealing overwrap or carton wrap for frozen foods, other items	Pouch stock for hygroscopic products, dehydrated soups, freeze-dried foods—and in heavier form as military barrier	Pouch for items needing greater toughness or decoration—liquid, gas or vacuum packs., Drugs, etc.	Label stock; also as liner or label for spiral-wound can.	Cover stock for foil and plastic formed container unit packs. Excellent for pharmaceuticals, drink powders.	Folding cartons, trays, oven-use trays	A strong, tough wrap for industrial use

* SOURCE: The values in this chart were obtained from various authorities. Grades may be obtained with properties different from the values shown. There are many specialized combinations. Manufacturers should be consulted for additional information or for new uses for their materials.
1 An alternate construction employs an EVA blend rather than microcrystalline wax.
2 Low density polyethylene extruxion applied as a laminating agent or coating can be used in a wide range of weights.
3 Values depend on thickness of foil and/or amount and type of laminating agent or coating.

(Continued on next page)

PROPERTIES OF LAMINATIONS* (Cont'd)

Properties	Paperboard; aqueous adhesive; white or fancy paper	Glassine; wax, ½-mil; glassine	Cellophane to cellophane with polyethylene or heat combined (also cellophane to glassine)	Foil, 0.0003; waxy adhesive; tissue, 17 lb.	Foil, 0.0035; polyethylene; kraft paper hot melt	Cellophane, 250 to 195; polyethylene, ½-mil; foil, 0.00035; polyethylene, 1- to 2-mil
GENERAL						
Forms available	Rolls, sheets	Rolls	Rolls	Rolls	Rolls	Rolls
Thickness range, in.	—[6]	.004 up	.002 to .004	.002	.0045	.003 to .004
Area factor, sq. in./lb.	—[6]	9,000 up	12,500 to 4,000	13,000	7,000	8,000 to 6,000
MECHANICAL						
Tensile strength, lb./in. MD (ASTM D828) TD	Very high	35 20	15,000 up 6,000	15 8	30 20	15,000 up
Elongation, % MD (ASTM D828) TD	1	3	5-20	3	1	5-60
Bursting strength, lb./sq. in. (ASTM D774)	Very high	40	50 and up	15	40	50 and up
Tearing strength, MD gm. (ASTM D689) TD	High	50 60	20	60	6	20-50
Folding endurance, 1 kg. load MD (ASTM D643) TD	—[6]	—[6]	—[6]	50 20	·200	Good
CHEMICAL						
Permeability to gases[3] (flat sheets)	None	Low	Very low	Low	Low	Approaches zero
Water-vapor permeability[3] (flat sheets)	None	8	—[6]	4	Very low	Approaches zero
Resistance to greases[3] and oils	None	Excellent	Excellent	Fair	Poor	Excellent
PERMANENCE						
Resistance to heat[4]	Good	Fair	Good	Fair	Excellent	Good
Resistance to cold	Good	Good	Good[6]	Excellent	Excellent	Good
Dimensional change at high R.H.	Slight curl	Poor	2% plus some curl	Good, slight curl	Good	Good, some curl
USE PERFORMANCE						
Machine performance,[5] printability, sealing	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Typical uses	Folding cartons, set-up boxes, trays	Inner liners in cartons	Bags and form/fill/seal for snack foods because of fats moistureproofness	Butter and margarine wrappers, generally embossed and printed	Heat-sealed overwrapper on cartons	Form/fill/seal for nuts and snack foods because of barrier, greaseproofness and appearance

4 Limited only by melting or softening temperature of components.
5 Surface slip, weight and components must be selected for specific requirements and surface primed for printing and coating.
6 Values depend on grade and thickness of components or plies.

CHAPTER 7

CELLULAR (FOAMED) PLASTICS

GENERAL

229. Description. Cellular Plastics (called also foamed- or expanded-plastics) are of two general types as regards to structure; that is, the closed-cell type, in which each individual cell, more or less spherical in shape, is completely closed in by a wall of plastic; and the open-cell type, in which individual cells are intercommunicating. Foamed plastics can be made in a range of densities from 0.1 to 60 lb./ft.^{3}.

Both thermoplastics and thermosetting materials can be used to make rigid, semi-rigid or flexible foams. The nine general types of plastics used for foam making are: (1) cellulose acetate, (2) epoxies, (3) phenol-formaldehyde, (4) polyethylene, (5) polystyrene, (6) silicones, (7) ureaformaldehyde, (8) urethanes, and (9) vinyls.

As in the case of plastics in the conventional form, there is opportunity for selection according to the end use requirements. In some fields of use, there may be two or more from which to choose. In some other fields of use, one material may clearly excel the others. It is frequently feasible to tailor a cellular plastic to meet end-use requirements.

Commercially, cellular plastics can be produced in the form of slabs, blocks, boards, sheets, molded shapes, extruded insulation, and sprayed coatings. In addition, several can be "formed in place" or "packed in place" in an existing cavity; for example, for potting of an electrical component within a housing, and for providing thermal insulation in a building or other structure.

A cellular structure can be developed by several methods (not all of them applicable to all of the plastics in question) as follows:

(1) Air is whipped into a suspension or solution of the plastic, which is then hardened by heat or catalytic action, or both.
(2) A gas is dissolved in the mix and expands when pressure is reduced.
(3) A liquid component of the mix is volatilized by heat.
(4) Water produced in an exothermic chemical reaction is volatilized within the mass by the heat of reaction.
(5) Carbon-dioxide gas is produced within the mass by chemical reaction.
(6) A gas, such as nitrogen, is liberated within the mass by thermal decomposition of a chemical blowing agent.
(7) Tiny beads of thermoset resins, hollow or expandable hy heat, are incorporated in a plastic mix.

The uses of foamed plastics fall largely into the fields of thermal insulation, acoustical insulation, electrical insulation, structural reinforcement, shock cushioning, floats, packaging and displays.

BLOWING AGENTS

230. General. There are two general types of "blowing" or foaming agents, both functioning under the influence of heat during the preparation of cellular plastics: (1) liquids which are volatilized without chemical change; and (2) chemicals which decompose to yield gaseous products. Typical blowing agents in category (1) are: water, ether, isopropyl ethel alcohol, acetone, and fluorinated hydrocarbons. In category (2) are: ammonium carbonate, ammonium nitrate, sodium nitrate, sodium bicarbonate, n, n' - ditrosopentamethylene tetramine, diazoaminobenzene, 1, 3 diphenytriazene, azo dicarbonamide, benzene sulfanyl

hydrazide, p-tertbutylbenzolazide, n' n' dimethyl - n-n' - dinitrosoterephthalamide, and potassium and sodium borohydrides. For any specific problem, the choice of blowing agent must depend on experimentation, guided by advice of the suppliers of the blowing agents.

231. Choosing a Blowing Agent. The following properties and behavior should be considered in choosing a chemical blowing agent:

(1) It should release gas over a definite and short range of temperature.
(2) The release rate should be rapid, but controllable.
(3) The gas preferable should be non-corrosive or explosive; nitrogen is preferred, but carbon dioxide is acceptable.
(4) It should disperse and preferably dissolve in mix.
(5) It should have good storage stability.
(6) Decomposition residues should not be malodorous, colored, staining, or toxic.
(7) Agent and residues should not affect cure rate.
(8) Large amounts of exothermic heat should not be developed.
(9) It should function equally well in closed and open molds.
(10) It should be inexpensive in proportions used.

The user of blowing agents should be thoroughly familiar with their chemical behavior, activation temperature, liability to activation with other chemicals, reactivity with material being expanded, the rate of gas evolution, and the nature of decomposition products.

CELLULAR CELLULOSE ACETATE

232. Manufacture. Cellular cellulose acetate (CCA) is produced by the controlled release of pressure from superheated solvent within a dough of cellulose acetate and solvent. The nature of the cellular structure is governed by (1) incorporating into the dough a finely divided inert material, which provides nuclei for volatilization and thus influences the number and uniformity of the cells; and (2) by controlling the degree of expansion, and thus the density of the product. The addition of chopped glass fiber will contribute to the strength of the product.

The hot dough is metered under pressure to the orifice of an extruder, where the expansion takes place. The orifice is fitted with a sizing box which governs the cross-section of the expanding product. A screw extruder has been used but a four-cylinder piston-type extruder gives better results. CCA cannot be foamed in place.

233. Properties. CCA is a white rigid closed-cell foam, commercially available as boards (0.5 x 8 in., 0.75 x 6 in., 1 x 4 in., 1.25 x 4 in.) and as rods (diameter 2.25 in.). The product continuously extruded is usually cut to a length of 6 ft.

When extruded, CCA has a dense smooth skin which is usually removed in machining to the standard commercial dimensions. CCA does not tend to become brittle or frangible. Its mechanical properties are substantially constant between 77°F. and -70°F. It will tolerate temperatures as high as 350°F., and even higher temperatures for short periods.

Typical properties are shown in Table XIX.

234. Fabrication. End-use shapes are made by machining. Objects of larger than available standard cross-sections are made from blocks prepared by cementing together pieces of the CCA board. For cementing, almost any adhesive is suitable if it contains no ketone or ester solvent. Sandwich constructions with facings of, for example, sheet aluminum and polyester-impregnated glass cloth or glass mat, are made in a conventional platen press with the aid of suitable adhesive.

CCA is satisfactorily machined within close tolerances by ordinary shop equipment.

235. Applications. CCA was first developed for use as core in monocoque construction. It has found use in control surfaces of aircraft; radome housings; filler blocks under fuel cells; structural members in reinforced plastic boats; geodesic domes; panels used in house construction, containers, trailer bodies; flotation devices; X-ray and electronic equipment; etc.

TABLE XIX. TYPICAL PROPERTIES OF CELLULAR CELLULOSE ACETATE

Property	Value
Density, lbs/ft^3	6-7
Tensile Strength, psi	170
Compressive Strength, psi	125
Shear Strength, psi	140
Flexural Strength, psi	147
Impact Strength (Izod, unnotched) Ft. -lbs.	0.1
Coefficient of Linear Thermal Expansion, inches per °F	2.5×10^{-5}
Thermal Conductivity (at mean-temperature 85F) Btu/ft^2/hr/°F/in.	0.31
Rate of Burning, inches/minute	4.9
Dielectric Constant	1.1
Loss Tangent	0.002
Water Absorption	
50% RH, lb/ft^3	0.15
100% RH, lb/ft^3	0.45
Immersion (336 hrs) lb/ft^3	4.5
Reserve Buoyancy (complete immersion) Dead Weight (lb) supported by 1 cu ft	
Initial	55
After 1 day	53
After 14 days	52
After subsequent drying	55

EPOXY FOAMS

236. Manufacture. The process of foaming the epoxies involves proper balancing of the formulation and proper control of the exothermic reaction to yield the desired uniformity of structure. The hardening of the resin by cure should take place at the moment of maximum expansion; in this connection, control of temperature is important.

The presence of solvent-diluents (which modify the viscosity of the mass, and may function as auxiliary blowing agents) and of other additives, influences the thermal behavior of the mixture, as do also the initial temperature, and the size and shape of the batch.

Products currently made by foaming of epoxy resins are of rigid type: some are preponderantly of closed cell structure,aand some of open cell structure. These commercial products include: (1) prefoamed boards, sheets and rods; (2) formulated "pack-in-place" systems; and (3) formulated foams in which the epoxy resin is not itself foamed, but serves as a binder for microscopic hollow glass-filled beads of phenolic resins, urea resins, and polystyrene.

237. Properties.

Formulation Versatility – Epoxies can be cured (without formation of by-products and hence without large shrinkage) by use of large variety of curing agents and hardeners, and are compatible with many modifiers. Thus they offer a wide choice of formulations and the opportunity to achieve a desired combination of properties. Flame-retardant formulations are available.

Handling – Shelf life is indefinite and most systems can be worked at room temperature, or with only moderate heating. When feasible, the more volatile amines used as accelerators should be replaced by longer-chained amines, in order to avoid dermatitis in manufacture and use.

Dimensional Stability – Being thermoset resins, the cured epoxies are dimensionally stable up to moderately high temperatures. Their dimensions are very little affected by high humidity.

Mechanical – The foams are tough and strong and can be shaped with wood-working tools.

Adhesion – These resins adhere strongly to most metals, ceramics, fabrics, plastics and concrete. Thus the foams will bond themselves firmly in cavities in which they are produced, or to inserts. If adhesion must be avoided, a suitable release agent must be used. Preformed foams may be readily bonded to themselves or to other materials.

Resistance to Chemicals, Solvents and Water – Epoxy foams are resistant to alkalies, most acids, solvents and water.

Electrical Properties – The electrical properties of epoxies make the foams useful in electrical applications where lightness of weight is essential. Foams can be made with dielectric constants ranging from 2 to 7.

Physical Properties – Typical values for some physical properties of epoxy foams are given in Table XX.

TABLE XX. TYPICAL VALUES FOR SOME PHYSICAL PROPERTIES OF EPOXY FOAMS

Type of Foam	Prefoamed Epoxies	Pack-In-Place Systems	Foam-In-Place Systems
Form or Components	Cubes (15") Planks (1' x 6' x 1' to 2') Sheets (12" x 12" x 1", 2" or 3") Rods (12" long; dia. 1", 2", or 3")	One- and two-component systems, similar in consistency to damp sand	One-, two- and three-component systems
Heat Required for Expansion and/or Cure	None	From room temperature to 350°F	From room temperature to 225°F
Cell Structure	Closed-cell and not completely closed-cell types	Closed-cell and not completely closed-cell types	Open- and closed-cell types
Density, lb/ft^3	5-38	15-25	5-8
Compressive Strength, psi	50-6000	600-3000	82-110
Flexural Strength, psi	200-4500	500-2500	-
Coefficient of Thermal Linear Expansion, cm/cm/°C	15×10^{-6}	15×10^{-6}	-
Thermal Conductivity, $Btu/hr/ft^2/°F/in.$	<0.65	0.24-0.8	0.24
Heat Stability	to 500F	to 600F	to 300F
Dielectric Strength, volts/mil	350	300	65
Dielectric Constant	2.0-7.0	2.5-7.0	1.55
Dissipation Factor	0.005-0.030	<0.030	-

238. Applications. Current and potential use of epoxy foams include the following:

Structural and Mechanical – Used in non-corroding structures; shock-absorbing materials for automotive, gun stocks, furniture, and boats; reinforcing media for sheet-metal parts; core materials in light sandwich structures for building doors, partitions, and panels; and reinforcement for honeycombs.

Tooling – Used in lightweight higher-temperature templates, checking fixtures and models (prefoamed epoxy foams can be embedded in epoxy casting resins or foam in-place (formulations to produce integral lightweight structures.

Electrical – Used in microwave lenses, core materials in glass-fiber double-walled radomes and other antenna applications; encapsulation of intricate electronic circuit components, particularly for airborne equipment.

Flotation – Used in gear for fishing industry and marine application, boats, boat buoys, floats, pontoons, life preservers, water-sports equipment, and flotation chambers in marine equipment.

Acoustical Insulation – Used in aircraft, meeting rooms, and offices.

Thermal Insulation – Used in walls, trailers, storage vessels, refrigerator doors, cabinets, freezer lids, evaporator doors, chemical-process vessels, icehouses, and air-conditioning units.

PHENOLIC FOAMS

239. Manufacture. Phenolic foams are of two types: reactive and syntactic.

a. Reactive Foams. The reactive type foam is produced by mixing partially condensed phenol-formaldehyde with a catalyst and blowing agent. The catalyst promotes further condensation and this exothermic reaction causes liberation of gas by the blowing agent. The increasing viscosity of the mix causes entrapment of the gas and expansion of the mass. Finally, the resin sets up with a resultant rigid foam composed of some closed and some open cells. Low reactivity resins are used for making foams of high density. Highly reactive resins are used for making foams of low density. Mixtures of these resins provides the means for making intermediate density. Usually, the addition of 3 per cent of isopropyl ether to the mix in advance of pouring provides the means for blowing. Various nitrogen-liberating blowing agents are sometimes used. The two catalysts most generally used are concentrated hydrochloric acid, and a mixture of sulfuric and phosphoric acids. Concentrations range from 2.5 to 10 percent for high-to-low reactivity resins, respectively. Sulfuric acid, when used, is added very slowly to part of the isopropyl ether in a vessel immersed in an ice bath. The temperature must not rise above 50°F. Then the phosphoric acid is stirred in thoroughly. A wetting agent, such as a polyoxyalkylene derivative of hexitol anhydride partial long-chain fatty-acid ester, is added to the mix to provide mix stability, to plasticize the mix, and to promote fineness of cell structure. Final mixing of the ingredients is done at, or slightly below, room temperature. The rapidity of the reaction, once the catalyst is added, dictates the selections of effective automatic equipment.

b. Syntactic Foams. These are produced by dispersing tiny hollow spheres of phenolic resin into a phenolic, epoxy, or polyester resin which is then allowed to cure. Commercially, a kneader type mixer is used. With the machine in operation, the hardener, or catalyst is added to the resin and then the phenolic spheres are mixed in thoroughly. The putty-like mass can then be transferred to a mold, traveled onto a surface, pressed into cavities, or placed as core in a sandwich structure. Curing will take place at room temperature, but can be hastened by heating, up to 212°F.

240. Properties.

a. Reactive Foams. The prime characteristics of reactive foams are lightweight stability, heat resistance up to 250°F., high degree of flame retardance, and low cost. In appropriate densities, phenolic foam has outstanding thermal insulation and acoustical properties. Flexural, compressive, tensile and shear strengths are 300 p.s.i., 200 p.s.i., 100 p.s.i., and 75 p.s.i., respectively for foams of 10 pounds/ft^3 density. All of these properties will diminish as the density of the foam decreases.

Under standard tests, phenolic foam at room temperature is self-extinguishing, but when heated to 250°F. or higher in a confined space and then brought into open air, it ignites spontaneously and will burn. There is evidence that service temperatures can be increased above 250°F. by the use of additives. For hydrochloric acid catalyzed foams in excess of 10 lb/ft^3 density, the service temperature decreases from 250°F. to 200°F. as density increases. For all others, the top service temperature recommended is 250°F.

Foams totally immersed in water gain weight until all of the cells are filled with water. Virgin foam exposed to 50 percent relative humidity loses weight, and approaches equilibrium in about 500 hours. Weight loss is attributable to loss of water vapor and entrapped blowing gases. Rates of change are greatly reduced by the presence of a surface skin, coating, or barrier, and is dependent upon the thicknesses of such materials.

Thermal conductivity, measured at 95°F. to 105°F., is minimum at densities of 2 to 3 lbs/ft^3 with a value of 0.20 Btu/ft^2/hr/°F./in. At densities of 0.25 and 8 lbs/ft^3, the value is 0.28 Btu/ft^2/hr/°F./in.

Measurements of a foam density of 2 lb./ft.^{3} over a range 27°C. to 93°C., show little difference in values for thermal expansion parallel and perpendicular to the direction of foaming. The values range from 1 to 3 x 10^{-5}in./in./°C.

Phenolic foams below 5 lb/ft^3 are friable; above this value they become materially tougher.

Adhesion to brick, wood, plasterboard, sheet asbestos, asphalt coated surfaces, kraft paper, and asbestos-cement is excellent; whereas, adhesion to steel, copper, brass, galvanized iron, stainless steel, aluminum alloys, chromium plate, polyethylene, asphalt roofing felt, and waxed plywood is poor.

Hydrochloric acid catalyzed foams are less corrosive to other materials than those foams catalyzed with sulphuric-phosphoric mixed acids. This is attributed to the greater volatility of hydrochloric acid, which is presumed to be driven off during the manufacturing process. In any case, these foams have shown no corrosive effect on iron nails after several years contact, when used in the construction of insulated structures.

Phenolic foams are weakly toxic to insects, do not inhibit fungus growth, and show no sign of deterioration after several years of soil burial.

b. Syntactic Foams. These foams can be varied in density from 10 to 40 lb./ft.^{3}, depending on the ratio of binder to hollow phenolic resin spheres. Typical properties of some syntatic foams are shown in Table XXI.

241. Applications. The reactive foams are used chiefly in structural panels, and thermal and acoustical insulation. They are also extensively used for floral arrangements and as cores in plastic tooling. Syntactic foams are gaining in use as core material in sandwich structures used in construction of aircraft and of hulls and decks of boats, and are being investigated for use in roofing structures. In addition, they can be used for repairing various structures, such as wooden structures damaged by rot.

CELLULAR POLYETHYLENE

242. Manufacture. Cellular polyethylene is produced by mixing granules of polyethylene and a blowing agent, and then extruding the material under controlled conditions. Heat in the extruder causes the blowing agent to liberate the inert gas, but pressure within the barrel, head, and die prevent expansion of the gas prior to emergence of the material from the die. When the extruder is performing properly, the finished cellular product has a smooth surface, and the cells are of uniform size. Temperatures higher than necessary result in non-uniformity of size of cells, roughness of surface, and difficulties during cooling of the product. To establish the optimum operating temperatures for a given machine, the temperature of barrel and head should be set first at 150°C., and the specific gravity of the product measured. Then the

TABLE XXI. TYPICAL PROPERTIES OF SYNTACTIC FOAMS (PHENOLIC RESINS SPHERES DISPERSED IN POLYESTER AND EPOXY RESIN)

Binder	Density lb/ft^3	Compressive Strength psi	Specific Strength psi/sp. gr.
Polyester	10.5	52	306
Polyester	12.5	145	725
Polyester	18.7	205	685
Epoxy	8.6	86	620
Epoxy	10.7	159	930
Epoxy	14.0	218	973

TABLE XXII. TYPICAL PROPERTIES OF CELLULAR POLYETHYLENE INSULATION AND COMPARISON WITH SOLID POLYETHYLENE

Property	Solid Poly-ethylene	Cellular Poly-ethylene
Tensile Strength, psi at 23C	2180	670
Elongation, %[a]	600	310
Dielectric Strength, v/mil, ASTM D-149		
Short-time at 0.125 in.	550	220
Step-by-step at 0.125 in.	500	190
Specific Gravity, 23/23C	0.92	0.47
Mandrel Bend at -55C and 2X[b]	no failure	no failure
Dissipation Factor at 1 kc	0.00020	0.00030
10 kc	0.00020	0.00035
50 kc	0.00020	0.00035
Dielectric Constant at 1 kc	2.28	1.49
10 kc	2.28	1.49
50 kc	2.28	1.49
Compression Loading, lb/in.^{2} [c]	1550	450

Notes:
a. #14 AWG wire + 93 mils.
b. #14 AWG wire + 32 mils; coiled at twice the outside diameter of the insulation.
c. 32-mil specimen stripped from #14 AWG wire (Union Carbide Plastics).

temperature of the barrel should be raised, by small increments, until the usual specific gravity of 0.47 is achieved.

243. Properties. Cellular polyethylene comprises about equal volumes of gas and polyethylene, and hence its properties differ from those of ordinary polyethylene. Comparison of several properties are given in Table XXII.

Cellular polyethylene offers the advantage of a much lower dielectric constant (hence lower electrical losses). The composition of polyethylene (dielectric constant 2.3) and an inert gas (dielectric constant 1.0) has a dielectric constant of 1.5. In terms of electrical usage, this lower dielectric constant permits a reduction in space between inner and outer conductors without changing the characteristic impedance. Consequently, the attenuation may be reduced by increasing the size of the inner core without increasing the overall diameter, or the weight may be reduced by decreasing the overall diameter without decreasing the size of the inner conductor.

The lower density of the cellular material presents the advantages of lower cost and weight, per unit of volume. Since cellular polyethylene is of the closed-cell type structure, it has desirable low moisture permeability although it is still several fold higher than solid polyethylene.

Dielectric constant and power factor are not materially affected by changes of temperature. Increases in specific gravity will increase the dielectric constant, but the power factor of cellular polyethylene is independent of its specific gravity.

244. Applications. The ease of handling cellular polyethylene in modern wire-coating equipment, and the economies which it provides in size and weight, indicates its utility in many electrical applications. It is suitable for use in cores of coaxial cable and is valuable for use as antenna lead-in wire for UHF television, because high-frequency changes do not change the power factor and dielectric constant. It is also useful for construction of cables which will float on water. In addition, there will be many uses found for this material in the packaging field.

POLYSTYRENE FOAMS

245. Manufacture. Three types of cellular polystyrene are available for use by the fabricator, molder, or ultimate consumer: the extruded (pre-foamed) type, the expandable type, and the self-expanding type.

a. Extruded (Prefoamed) Foams. These foams are made by extruding molten polystyrene containing a blowing agent, under elevated temperature and pressure, into the atmosphere, where the mass expands into logs and planks which can be cut and shaped into many different forms by common tools. Many different sizes are available. Logs are approximately 25 in. x 33 in. x 6 ft. or 9 ft. long; planks are 7 in. x 20 in., or 10 in. x 20 in. x 9 ft. long. Boards are available from 1 to 5 in. thick, and up to 48 in. wide by 9 ft. long.

b. Expandable Foams. These foams are produced in the form of free-flowing beads containing an integral blowing agent. When exposed to heat, without restraint against expansion, these beads "puff" from a bulk density of 35 lb./ft.^{3} to as low as 0.25 lb./ft.^{3}. This very low density, however, leads to difficulty with collapse in subsequent molding; hence, the usual limit in practice is 1.0 lb./ft.^{3}. Foaming expandable polystyrene beads ordinarily comprises two separate steps: (1) pre-expansion of the virgin beads by heat; and (2) further expansion and fusion of the pre-expanded beads by heat within the shaping confines of a mold.

Continuous pre-expansion is presently being accomplished by: exposure of the beads on a moving belt or disk to infrared strip heaters; by screw-fed exposure to hot water; and most recently by introduction into a stream of steam and air, and subsequent agitation in a closed container.

c. Self-Expanding Foams. These foams are produced by combining beads of polystyrene and a thermosetting resin. The exothermic heat generated by the thermoset curing reaction provides for the

TABLE XXIII. PROPERTIES OF POLYSTYRENE FOAMS

Property	Extruded	Molded	Self-Expanded
Density Range, lb/ft^3 (D1622)[a]	1.3-4.5	1.0-10.1	5.0-10.0
Tensile Strength, psi (D1623)	35-185	20-220	-
Compressive Strength, psi (D1621)	10-140	10-200	45-120
Flexural Strength, psi	32-170	25-330	-
Shear Strength, psi (C273)	15-95	13-90	-
Thermal Conductivity, K ($Btu/in./hr/ft^2/^oF$ at 40F mean temp.) (C177)	0.24-0.33	0.24-0.27	0.24
Water-Absorption (lb/ft^2 of surface area)	0.04-0.20	0.02-0.15	0.01 max.
Water-Vapor-Transmission, perms ($grains/hr/ft^2/in./in.$ of Hg vapor pressure differential) (E96)	0.06-2.0	0.5-2.0	-
Heat-Distortion Temperature, ^oF	170	180	180
Linear Thermal Coefficient, avg. ($in./in./^oF$)	4.0×10^{-5}	4.0×10^{-5}	-
Dielectric Constant, 10^2-10^3 cps	less than 1.05	less than 1.05	-
Burning Characteristics	can be made self-extinguishing	can be made self-extinguishing	-

Note:
a. Parentheses indicate ASTM tests.

expansion of the thermoplastic beads, and forces most of the resin to the surface of the molding.

246. Properties. The three types of cellular polystyrene differ in technique of expansion and handling, but most of their properties are quite similar. Significant differences in properties are shown in Table XXIII.

247. Applications. In a number of applications, the choice of the type of cellular polystyrene depends upon economics, appearance, number of articles to be made, and the physical characteristics desired. Pre-foamed extruded boards are used extensively in low-temperature insulation. They are also used in roof and deck insulation, and as a combination of insulation and base for plaster in masonry construction of homes. Foam boards are also used as the core in sandwich panels for both residential and industrial application. Flotation docks, marker buoys and puncture-proof flotation members for small boats are all applications of the positive flotation characteristics of this closed-cell foam.

The expandable bead-type naturally follows into many similar applications. The ability of expandable polystyrene to duplicate accurately the detail of molds, led to its early and still growing use in making toys, novelties and displays. Silk-screened, dry-colored and artfully beribboned articles in this category have found large markets. Consumer, industrial and military packaging problems have been successfully solved with easily molded, shock-resistant, low-density expanded polystyrene.

SILICONE FOAMS

248. Manufacture. Silicone foams are produced in three types: premixed powder foams, room-temperature foams, and elastomeric foams.

a. Premixed Powder Foams. The premixed powder containing the resin, blowing agent, and fillers is heated above 320°F. After the resin liquifies, the blowing agent decomposes releasing nitrogen gas which expands the resin, while the amines given off act as catalysts for the condensation of the resin. Expansion and gelation are thus synchronized so that the resin gels at maximum expansion. Molds for these silicone foams may be made of metal, wood, glass, etc. The molds do not require preheating. The powder is poured into the cavity, and heat is applied by circulating air ovens, strip heaters, heat lamps, or similar equipment. To minimize shrinkage, the structure should be exposed to the expansion temperature for at least four hours. If postcuring is not required, the foam is now removed from the mold. If postcuring is required, the temperature is raised by increments of 50°F. to the temperature required to obtain certain desired properties.

b. Room-Temperature Foams. The room-temperature curing resins are a newer type, which are expanded and cured at room temperature. This type is based upon the chemical reaction between two silicone components in the presence of a catalyst. The reaction is slightly exothermic, but temperatures seldom exceed 150^{o} F. even in very large pours. Hydrogen gas is liberated as the expanding agent, but the quantity is small and has not presented any explosive hazard. However, the usual precautions should be observed when large quantities of foam are being processed. The reaction is complete within 15 minutes, and maximum strength is developed in 24 hours. These materials are supplied as liquids and are blended in a high speed mixer for 30 seconds, and then poured. Expansion of 7 to 10 times the initial volume is complete within 15 minutes, but the foam remains soft and tender for 24 hours. After 10 hours, the foam is hard enough to be cut and handled. The heat of reaction is so low that molds of cardboard or heavy paper can be used.

c. Elastomeric Foams. Lightweight elastomeric rubbery foams are still in the developmental stage. They are made in the same manner as the room-temperature foams, but they must be poured promptly since expansion begins upon blending. Negligible pressure is generated, and the articles can be removed from the molds within five minutes, at which time the foam will have developed about 80 percent of its ultimate strength. Maximum strength is developed after 24 hours.

249. Properties. Premixed powders are furnished in three types: A, B, and C. Type A can be foamed to densities ranging from 10 to 14 lb./ft.^{3}, Type B from 12 to 16 ft./lb.^{3}, and Type C from 14 to 18 lb./ft.^{3}. Types A and B may be foamed in place; Type C can be foamed satisfactorily only as a block or sheet, but it is stronger than the others, and retains more compressive strength at high temperature.

Foamed structures produced from Type A are the most resistant to thermal shock. Samples have been cycled repeatedly between room temperature and 600^{o} F. without cracking, and have withstood 700^{o} F. for 72 hours with only slight dimensional change and with a total loss of weight of less than 10 percent. When subjected to direct flame, the surface decomposes only slightly. Type B is similar to Type A in most respects, and retains a considerable amount of its compressive strength at elevated temperatures, especially if postcured for 48 hrs. at 480^{o} F. In many applications this foam will cure further, and become stronger, with use. Typical properties of silicone powder foam mixes are summarized in Table XXIV.

Properties of the room-temperature curing resins are summarized in Table XXV. Their densities usually vary between 3.5 and 4.5 lb./ft.^{3}, depending upon the geometry of the cavity. Finished foams based on these materials can be used continuously at 600^{o} F. They have excellent flame resistance, low thermal conductivity, good electrical insulation, and low water absorption.

Typical properties of elastomeric silicone foams are summarized in Table XXVI. When cast against glass cloth or paper, the foam adheres strongly. Finished pieces can be easily bonded to each other, or to metal, by appropriate silicone adhesives.

250. Applications. The original interest in silicone foams centered on their possible use as core materials in high-temperature sandwich-structures, but most of the foams developed proved too brittle to withstand the vibrations encountered in such service. However, foams based on the powdered premixes have proven useful as molded components for aircraft and as insulating materials for instruments. Resinous (room temperature cured) foams have demonstrated their convenience and effectiveness as thermal insulation on processing equipment. When the use of molding forms are not feasible, the foam mix can be applied by means of a catalytic spray gun, which sprays the two components simultaneously, through separate nozzles, so that they mix and expand on the surface to be insulated.

The elastomeric or rubber foams have been suggested for uses requiring resilience and low density such as vibrational insulation, foamed-in-place thermal insulation, and cushioning around fragile electric components for protection during encapsulation in rigid potting compounds. The rubbery foams can be processed into finished articles by a molding machine (with or without pressure), by dip coating, by continuous mixing, or by casting in place.

TABLE XXIV. TYPICAL PROPERTIES OF SILICONE POWDER FOAM MIXES

Property	Type A	Type B	Type C
Powder			
Color	tan	tan	tan
Apparent Density, lb/ft^3	45	46	46
Mesh Size, approx.	20	20	20
Melting Point, °F	120	160	200
Shelf Life, months	9		9
Expanded			
Expansion Temperature, °F	320	320	320
Density, lb/ft^3	12	14	16
Cell size, in.	0.08	0.08	0.08
Compressive strength[a], psi			
at 77F	100	175	325
after 1/2 hr at 500 F	5	25	75
after 200 hrs at 500 F	25	20	70
Loss of Weight, %			
during expansion	1.2	1.3	1.0
after 200 hrs at 480F	2.1	2.1	2.1
after 200 hrs at 570F	4.0	3.2	3.4
after 72 hrs at 700F	8.5	5.2	5.2
Water Absorption[b], % by wt after 24-hr immersion	3.2	2.3	2.1
Maximum continuous operating temp., °F	650	650	650
Flamed Resistance[c]	does not burn	does not burn	does not burn
Thermal Conductivity[d], $Btu/ft^2/hr/°F/in.$	0.3	0.3	0.3
Dielectric Constant[e] (8.5×10^9 cycles/sec)			
at 77F	-	-	1.26
at 500F	-	-	1.37
at 77F, 24 hr wet	-	-	1.27

Notes:
a. At 10% strain, FPL, 1556.
b. Fed. Spec. L-P-406B Method 7031.
c. Fed. Spec. L-P-406B Method 2023.
d. At 11.0 lbs/ft^3 density. Mean temp. of 70F, ASTM C-177
e. At 13.3 lbs/ft^3 density. All three foams have essentially the same electrical characteristics.

TABLE XXV. TYPICAL PROPERTIES OF SILICONE RESINS FOAMS (ROOM-TEMPERATURE CURED)

Property	Rigid	Semi-rigid
Density, lb/ft^3	3.5	3.5
Compressive Strength, yield[a], psi		
at room temperature	8.0	no yield
at 500F	no yield	no yield
at room temperature after 200 hr at 500F	12.0	4.0
at room temperature after 24 hr at 700F	9.0	3.0
Loss of weight after 200 hr at 500F, %	6.4	7.6
Loss of Volume after 200 hr at 500F, %	8.3	9.1
Maximum Service Temperature, continuous, °F	650	650
Water Absorption[b], lb/ft^2 surface area	0.284	0.284
Moisture-Vapor Transmission[c], perm inches	41.2	41.2
Thermal Conductivity[d], $Btu/ft^2/hr/°F/in.$ at 77°F	0.281	0.281
Flame Resistance[e]	self-extinguishing	self-extinguishing
Dielectric Constant[f] at 10^5 cps	1.09	1.10
Loss Tangent[f] at 10^5 cps	0.0028	0.0103
Per Cent Closed Cells	60 (estimated)	60 (estimated)

Notes:
a. FPL-1556.
b. Military Spec. P-16591D.
c. ASTM D-697
d. ASTM C-177.
e. LP-406 Method 2021-1.
f. ASTM D-150.

TABLE XXVI. TYPICAL PROPERTIES OF ELASTOMERIC SILICONE FOAMS

Property	Low-Density	High-Density
Physical Properties of Raw Material as Supplied		
Color	tan	tan
Specific Gravity	1.0-1.2	1.0-1.2
Viscosity, cp	4000-8000	8000-12,000
Shelf Life, minimum	6 months	6 months
Physical Properties of Foam		
Color	tan	tan
Density, lb/ft^3	7-9	13-15
Cell Structure, % closed (estimated)	20	30
Thermal Conductivity[a], $Btu/ft^2/hr/^oF/in.$ at 25C	0.31	0.36
Loss of Weight after 200 hr at 250C, %	9.4	8.6
Loss of Volume after 200 hr at 250C, %	7.5	5.9
Compression Set[b] after 22 hr at 25C, %	0.0	0.0
Compression-Deflection[c]		
25% deflection, psi	1.0	2.0
50% deflection, psi	3.0	5.0
Tear Strength[d], psi	1.0	3.0
Tensile Strength[e], psi	5.0	15.0
Elongation[e], %	40.0	45.0
Dielectric Strength[f], v/mil	50.0	59.0
Dielectric Constant[g], at 25C, 10^5 cycles per sec	1.17	1.27
Dissipation Factor[g] at 25C, 10^5 cycles per sec	0.0010	0.0013
Volume Resistivity[h] at 25C, ohm-cm	3.8×10^{12}	8.7×10^{12}
Surface Resistivity[h] at 25C, ohm-cm	1.0×10^{12}	6.2×10^{12}

Notes:
a. ASTM C-177
b. ASTM D-395
c. ASTM D-1056
d. ASTM D-624
e. ASTM D-412
f. ASTM D-149
g. ASTM D-150
h. ASTM D-257

UREA-FORMALDEHYDE FOAMS

251. Manufacture. Urea-formaldehyde foams are of two types, the open-cell and closed-cell.

a. Open-Cell Foams. Formaldehyde (30%) is condensed with urea. The resin is cooled and brought to pH 8.0. An internal plasticizer and more urea are added to bring the urea/formaldehyde ratio to 1.0/1.7.

A second solution is prepared, containing phosphoric acid and soap. The two solutions are mixed in a beater which has air blown into it, and the result is a texture like that of whipped cream. This is fed upon a moving belt, which is passed through a heated zone to affect an initial cure. The foam is then rough-cut and further cured in ovens, and finally cut to size for shipment. Present maximum size is 24 x 24 x 6 inches. Friability limits the minimum dimension to 1 inch.

b. Closed-Cell Foams. Foams consisting of microscopically small hollow spheres are made from liquid urea-formaldehyde resins by a special technique of spray drying, followed by a post treatment to improve water resistance.

252. Properties.

a. Open-Cell Foams. The open-cell foams blocks normally have a density of 0.8 $lb./ft.^3$, but they can be made over a range of 0.5 to 1.5 $lb./ft.^3$. Their thermal conductivity at a mean temperature of $10^oF.$ is 0.21, and at $70^oF.$ is 0.22 $Btu/hr./ft.^3/in./^oF.$ Exposed to 100 percent relative humidity for a long period of time, they will absorb up to 0.15 $lb./ft.^3$ of moisture. They will support a compressive load of 1.5 p.s.i. with negligible distortion. In shredded foam (particles 1/32 to 1/8 inch in size), the bulk density is 0.8 to 1.9 $ft./lb.^3$, and thermal conductivity at a mean temperature of $75^oF.$ is 0.21 to 0.23

Btu/hr./ft.^{2}/in./^{o}F. The open-cell structure provides vulnerability to entrance of water under wet conditions, unless suitably enclosed. They will not support combustion, are non-corrosive and nontoxic, and will not support the growth of mold or bacteria. Prolonged exposure at 130^{o}F. results in shrinkage, which at 300^{o}F. may be as much as 15 percent by volume.

b. Closed-Cell Foams. The closed-cell spheres range in diameter from 2 to 60 microns, and the particle density is about 18 lb./ft.^{3}. The bulk density of a mass of spheres is about 3.7 lb./ft.^{3}. The compressive strength is 30 to 50 p.s.i., determined by subjecting the spheres to pressure of nitrogen until rupture occurs. Decomposition of the spheres begins at 350^{o}F.

253. Applications. The open-cell urea-formaldehyde foams are used principally to support floral displays, and in thermal insulation. The powdery spheres were designed to be used as a floating blanket or roof on crude oil in storage, to minimize evaporation of volatile constituents. They are also used in making low density aggregates, produced by mixing the tiny spheres with thermosetting or thermoplastic binders. Such mixtures are useful in lightweight structural members, thermal insulation, potting compounds, calking compounds, etc.

URETHANE FOAMS

254. Manufacture. Urethane foams are basically the reaction products of a polyol and a polyisocyanate made to rise or foam by a blowing agent. The most commonly used polyols are polyesters and polyethers. The polyisocyanate most commonly used is the 80/20 isomeric mixture of 2.4– and 2.6– tolylene diisocyanate (TDI); more recently, n-diphenyl methane diisocyanate (MDI) has been mentioned as a possibility. Polymethylene polyphenyl isocyanate (PAPI), with high temperature characteristics, is also in use for specialty applications. The reaction of a polyol and TDI is shown below:

$$HO - R - OH \; + \; OCN - R' - NCO$$

$$HO - R - [O - \overset{\overset{O}{\|}}{C} = NH] - R' - NCO$$

URETHANE UNIT

(POLYOL) + (TDI)

The above reaction is generalized to show the simplest type of urethane structure. Actually, the terminal groups (NCO and OH) link up in linear-chain fashion to yield the urethane polymer. The bracketed portion shown above is the so-called urethane structures.

The choice of a catalyst and emulsifier will determine to a large extent the rate of reaction of polymerization and the characteristics of the resultant foam. Originally, all rigid and flexible urethane foams were blown by carbon-dioxide gas. The CO_2 was generated in situ by the reaction of water and a calculated excess of isocyanate in mixture with other components. The excess isocyanate is the amount over that needed for the reaction with the polyol to form a urethane polymer. CO_2 evolves from the reaction shown below:

$$R - N = C = O + H_2O \longrightarrow RNH_2 + CO_2 \uparrow$$

For simplicity, the isocyanate shown is a monofunctional type, not the polyfunctional type used for foam. However, it served to illustrate the principle of CO_2 production. The amine (RNH_2) reacts with the isocyanate to form a substituted urea compound that contains some active hydrogen atoms, as indicated in the formula which follows:

$$RNH_2 + R - N = C = \longrightarrow R - \overset{\overset{H}{|}}{N} - \overset{\overset{D}{\|}}{C} - \overset{\overset{H}{|}}{N} - R$$

More recently, fluorocarbon blowing agents have moved into paramount importance in the urethane foam field, especially for the rigids. In essence, these blowing agents are high molecular-weight gases that boil at low temperatures under the exothermic heat of reaction between the polyol and the isocyanate; the resulting vapor creates a cellular structure with outstanding properties and characteristics.

The reaction by which urethane foams are produced can be carried out in a single stage or in a sequence. Three methods are available: one-shot method, prepolymer method, and quasi-prepolymer method.

a. One-Shot Method. In this method, all of the ingredients (polyol, isocyanate, blowing agent, or water and catalyst) are mixed simultaneously and the resulting mixture is allowed to foam.

b. Prepolymer Method. In this method (batch mix or continuous), the polyol and isocyanate are reacted to give a prepolymer, and the catalyst (water and amine) is subsequently mixed into the prepolymer to cause foaming. Additives, such as coloring and emulsifying agents, may be added to the catalyst mix. The prepolymers can be closely controlled in viscosity, molecular structure and percentage of free isocyanate. The ratio of catalyst mix to prepolymer is about 5 to 100.

c. Quasi-Prepolymer Method. This method is a combination of the two foregoing methods. Here, a portion of the polyol is pre-reacted with an isocyanate to form a liquid prepolymer with a viscosity range suitable for pumping or metering. This component is supplied to end-users with a second premixed blend of additional polyol, catalyst, blowing agent etc. When the two components are mixed together (usually in equal proportions), foaming occurs.

255. Properties. Most commercial uses of urethane foams require densities between 2 and 30 $lb./ft.^3$ for rigid foams and between 1 and 4 $lb./ft.^3$ for flexible foams. This latter value of 1 to 4 $lb./ft.^3$ compares with latex foam rubber at an average of 5.5 $lb./ft.^3$ in commercial grades.

Most of the applications for flexible foams emphasize the material's unique compression/deflection characteristics that contribute to the intangible known as "comfort cushioning". There is no undesirable bounce-back or excessive buoyancy, as is usually associated with other foam or sponge materials.

Other advantages for the flexible foams include light weight, good chemical resistance and aging properties, shock absorbency, sound absorbency, outstanding insulating qualities, and the fact that they are non-allergenic and non-toxic, and will not absorb moisture or body odors. Low cost is another factor in their favor. To obtain comparable foam characteristics in the density range of 1.4 to 2.2 $lb./ft.^3$, latex rubber foam with a density of about 6 $lb./ft.^3$ for uncored stock or about 4 $lb./ft.^3$ for cored stock, is required. The net result is that urethane foam is 40 percent cheaper than latex foam, and about 33 to 50 percent as heavy.

A typical flexible urethane foam in use today, with a density of 2 to 2.4 $lb./ft.^3$, would have an indentation load deflection firmness of 15 to 18 lb. at 25 percent deflection. This means that in the standard test specified by ASTM D-1546-60T, a dead weight of 15 to 18 lbs. applied over an area of 50 square inches will produce a 25 percent deflection of the entire surface area, one minute after applying load.

In terms of resiliency, urethane foams are usually in the area of 40 to 50 percent. This means essentially that a small steel ball dropped from a height of 12 inches above the foam will rebound approximately 6 inches. Cushions fabricated from urethanes are neither too bouncy nor too hard.

Rigid urethane foams have much the same versatile range of properties as the flexible foams in terms of chemical resistance, outstanding resistance to moisture absorption, dimensional stability, and high compressive strength. As an engineering material, one of the prime advantages of fluorocarbon-blown rigid urethane foams (which as contrasted to flexibles, contain mainly closed-cells) is their outstandingly low K factors (representing the coefficient of thermal conductivity). This means that in many applications where it is used as an insulator, for example refrigerators or freezers, wall thicknesses can be reduced 30 to 50 percent, allowing greater interior storage space with no increase in exterior dimensions.

Most rigids perform satisfactorily in the 225 to 250^{o} range. With specialty isocyanates, such as polymethylene polyphenyl isocyanate (PAPI), rigid foams that retain up to 65 percent of their room-temperature compressive strength at 450^{o}F. are possible.

Cores of rigid urethane permit the use of thinner gage metal or skins for sandwich construction. Although ordinary wall panels are fabricated of 16- to 18-gage metal, urethane foam-filled panels require only 22- to 24-gage steel skins. Backed with foam of 2 to 2.5 lbs./ft.^{3} density, the 24-gage steel has puncture resistance equal to that of 18-gage steel without foam back-up. Compression and load tests have shown a compressive strength of almost 20,000 lbs./ft.^{2} when loads were applied to an 8 ft. by 4 ft. by 3 in. sandwich panel that incorporated a rigid urethane-foam core-construction.

A sprayed foam will adhere to most anything except polyethylene, polypropylene, fluorocarbon, stainless steel, or untreated aluminum. The rigid foam is self-supporting within minutes after spraying and will attain nearly maximum physical properties after several hours at room temperature, with top strength being reached after 24 hours.

256. Applications. Flexible foam finds six major areas of use: cushioning; bedding; automotive and truck seating; auto trim components (instrument panel padding, sun visors, arm rests, door and roof linings, etc.); textile linings (for example, garments, handbags, luggage and sleeping bags); and carpet underlays. It is also used for insulation around hot and cold processing lines and chemical storage tanks. It is expanding into the packaging field and pressure sensitive tape field. Slab stock has been adapted into such applications as inner liners for record players and for motor boat shrouds, where its sound absorption qualities play an important functional role.

Rigid foams are used in insulation for household refrigerators, freezers, beverage coolers, cream cabinets, etc., to obtain larger storage space. The thinner wall sections mean cost reductions. The adaptability of foam-in-place for production line automation means further cost reductions. In the transportation field, the material finds extensive use in refrigerated railroad cars, trailer vans and truck bodies. Rigid foam in the production of mobile homes and travel trailers is still another use. Rigid foam has enormous possibilities in the form of cores for resilient sandwich panels of all types (exterior, interior, roof and floor), as well as for curtain walls, non-residential roofs, door cores, perimeter insulation, and aluminum siding. In the marine field, reinforced plastic boats, requiring structural strengthening and added buoyancy, represent a potential market. Military and merchant vessels may well account for additional poundage for insulation of shipboard refrigeration compartments. Pipe insulation, using preformed or foam-in-place techniques, is a growing market; some of the spray-up insulations for residential housing have yet to be evaluated. Military, packaging, automotive, and other fields are starting to exploit the design feasibility inherent in rigid foams.

VINYL FOAMS

257. Manufacture. The process of manufacture of cellular vinyl products falls into two main categories: mechanical blowing; and chemical blowing (open-cell, closed-cell, and extruded).

a. Mechanical Blowing. In this process, an appropriately formulated plastisol is metered into a continuous mixing cooling unit along with gas (usually carbon dioxide) under pressure. The amount of gas absorbed by the plastisol is controlled by regulation of the mixing unit temperature. The chilled mixture is allowed to escape through a nozzle or tube, and foams as it encounters atmospheric pressure. To make molded objects, the chilled mixture is released through the tube into a mold, where expansion takes place. The filled mold is heated to the fusion temperature of the plastisol (about 360°F.) in an air-circulating oven. It is then cooled and opened for removal of the article. For slab production, the mixture is released through one or more nozzles or tubes upon a moving belt which carries the foam through a high-frequency fusion oven, and then through a conventionally heated post-fusion oven. The foam is then cooled and cut into lengths (usually 72 in.) for shipment as slab stock; or it can be sliced horizontally into sheet stock of thickness 1/6 to 4 in., which is rolled onto a core for shipment.

b. Chemical Blowing, Open-Cell. Chemically-blown open-cell foams are produced by mixing a plastisol with a blowing agent and placing the mixture in a vented mold, which is then heated and held at a decomposition temperature of the blowing agent until blowing takes place. Further heating serves to fuse the foam. The entire cycle takes from 10 to 60 minutes depending on the temperature of the oven, the nature of the plastisol, and the size and shape of the product.

c. Chemical Blowing, Closed-Cell. Chemically-blown closed-cell foams are made by introducing a plastisol-blowing agent mixture into a high-pressure (4000 to 10,000 p.s.i.) mold, and heating to decompose the blowing agent and fuse the plastisol. The mold is then cooled to below 120°F., while the pressure is maintained. Pressure is then released and the molded piece, partially expanded, is released from the mold. To fully expand the article and to set the cell structure, the piece is heated in an air-circulating oven at a temperature below that of fusion.

d. Chemical Blowing, Extruded. In this process, foams can be produced through: (1) modification with nitrile rubber, to closed-cell form; (2) low-density extrusion by post expansion; and (3) high-density extrusion, to closed-cell form.

(1) Closed-cell foams from blends with nitrile rubber are produced in a manner as typified below:

Ingredients	Parts by Weight
Dispersion-Grade Vinyl Resin	50
Medium Acrylonitrile-Grade Nitrile Rubber	50
Epoxy Plasticizer	5
Dioctyl Phthalate (Plasticizer)	50
Rubber Antioxidant	1
Barium-Cadmium Stabilizer	2
Carbon Black	70
Zinc Oxide	3

These ingredients constitute the master batch, mixed in a Banbury or rubber mill. Effective breakdown of the nitrile rubber is essential. In a Banbury, a maximum temperature of 320°F. should be used. The master batch is aged for 48 hours. Then the curing and blowing agents are incorporated on a cold mill:

Ingredients	Parts by Weight
Master Batch	100
Sulfur	1
Ultra Accelerator	1
P,P-Oxy-Biz-Benzene-Sulfonyl Hydrazide	8.5

In the laboratory, a tubing of OD 0.625 in. and ID 0.250 can be extruded from a Royle rubber extruder under the following conditions:

Temperature of Die	175°F.
Temperature of Screw	180°F.
Speed	25 r.p.m.
Temperature of Stock	190-195°F.

The extruded material is cured in two stages: 2 to 4 minutes at 265°F. and 5 to 10 minutes at 310°F. in a forced hot-air dryer. The product has a density of about 6 lb./ft.^{3}, a closed-cell structure, and a smooth skin.

It is essential that the curing of the nitrile rubber in the mixture be balanced exactly with the rate of decomposition of the blowing agent, since the rubber matrix, as it becomes cured, constitutes physical support for the growing cellular structure. Too fast a system of cure results in high density and a ruptured structure; too slow a cure results in low density and an open-cell structure.

(2) Low-density extrusion by post-expansion involves incorporating a blowing agent in a stabilized plasticized vinyl formulation, and extruding the compound from a cross-head extruder

at a temperature not exceeding 285°F. upon an axial-supporting cord or wire. Since the decomposition temperature of the blowing agent (azo dicarbonamide) is about 350°F., the extruded vinyl (with core wire) is passed through an expansion tunnel and radially heated to 370°F., where there is no physical impediment to free expansion. The product has a thin noncontinuous skin, and a mixture of closed and open cells. If wire is used for axial support of the soft vinyl compound, it can be left in place after expansion and used for fastening purposes. Nylon cord can be withdrawn if desired, but cotton cord usually becomes firmly anchored with the expanded product.

(3) High-density closed-cell vinyl foam is made by direct extrusion of a compound containing a small proportion of blowing agent, which is completely decomposed within the barrel of the extruder. Ultimate expansion occurs upon emergence of the mass from the die. The follwoing is a typical formulation:

Ingredients	Parts by Weight
Vinyl Extrusion Resin	100
Dioctyl Phthalate	40
Butyl Benzyl Phthalate	20
Basic Lead Silicate Sulfate	10
Paraffin Wax	0.5
Azo Dicarbonamide (Blowing Agent)	0.5

In the low concentration of blowing agents involved, the selection and the method of incorporation are not critical. Tumbling the blowing agent with cubed plastic, or dry blending into a mixture of powders, is satisfactory since the agent will be decomposed in the barrel and the gas will be uniformly distributed in the mass by the action of the machine.

258. Properties. The commercial success of standard products based on polyvinyl chloride resins has led naturally to the development of cellular products having similar toughness, chemical resistance, good aging properties, and ability to be heat sealed.

Plasticization by liquid or solids or, for some applications, by nitrile rubbers, produces a variety of open-cell and closed-cell structures varying from very soft to rigid.

Since the material is thermoplastic, scrap material may be easily reprocessed. Varying the amount of blowing agent from 1/10 to 10 parts per 100 parts of resin by weight, produces cellular structures that vary from extremely light foams having a gas content of 95 percent to much denser materials with only 5 percent of gas by volume. The resulting structures range in density from 4 up to 75 lb./ft.^{3}. Solid vinyls weight 75 lb./ft.^{3} and even higher for heavily loaded compounds.

Properly made foams do not oxidize, hydrolize, burn, dry out, or harden, and they are resistant to most inorganic acids and alkalis, oils, greases, aliphatic hydrocarbons, and alcohols. Careful formulation has minimized their tendency to stiffen at low temperature and soften at high temperatures.

Foams can be made in white and colors, and do not darken or fade.

259. Applications. Closed-cell vinyl foams are widely used in marine buoyancy items (for example, floats and life rings) by reason of excellent weathering resistance. Their thermal insulating properties find use in clothing, footwear, and winterization kits for the military in cold weather climates. The absence of appreciable transmission of water vapor is an advantage in such uses, and also in insulating the cabins of jet aircraft, where the passage of moisture may lead to corrosion and failure by stress fatigue. Consumer products such as ice buckets are made in many colors, by pressure molding. Molded slabs and other shapes in special grades, having unusual shock-resistance, are used in padding in boxing rings and athletic uniforms, and in some special packaging applications where stringent requirements warrant the cost. The material also finds use in many gasketing applications. Low-density foams find use in the fields of cable fillers and separators, in joint-fillers, and in fabrics or rug constructions woven and then expanded. Profiled shapes have found markets in packaging, insulation welding and weatherstripping. High-density foams may serve as primary insulation on wire, to achieve lower cost, superior electrical properties or lower total weight.

CHAPTER 8

PLASTICS MATERIALS SELECTION FACTORS

SELECTING PLASTICS MATERIALS

260. General. In earlier chapters of this handbook, properties of the various plastics have been discussed, typical applications have been presented,aand some cost data have been presented. This chapter, however, presents important aspects of this information in a form intended to help in the selection of the optimum material for a particular product.

The engineer or designer planning to bring out a new plastics item has before him many varieties to choose from. He should consider not only the physical, chemical, optical, and electrical properties, but also the cost and method of processing. Often, the question of how a product is to be made determines the type of material to be used. The key to selecting the right plastic is good communication between the designer, processor and material supplier.

The more rigid the specifications covering end-use, the easier the selection becomes. If, for instance, the prime requirement is resistance to temperatures above 250° F., the problem of selection is reduced to perhaps five plastic types. Trial and error as a means of selection is exceedingly costly and, therefore, careful study of the problem is warranted. If the specifying engineer really knows what he wants, there probably is but one material best suited to do the job.

261. Selection Factors. Plastics have good combinations of properties, rather than extremes of any single property. For example, no plastic approaches the steels in strength. No plastic is as light in solid form as most woods, as elastic as soft rubbers, as scratch-resistant or transparent as glass. Yet plastics are the only materials which can be simultaneously strong, light, flexible and transparent. In some cases plastics are applied because of a single outstanding property - tetrafluoroethylene for antistick characteristics, for example - but these are not typical. All of the tables and figures in this chapter were abstracted from "Machine Design" 1971 Plastics/Elastomers Reference Issue.

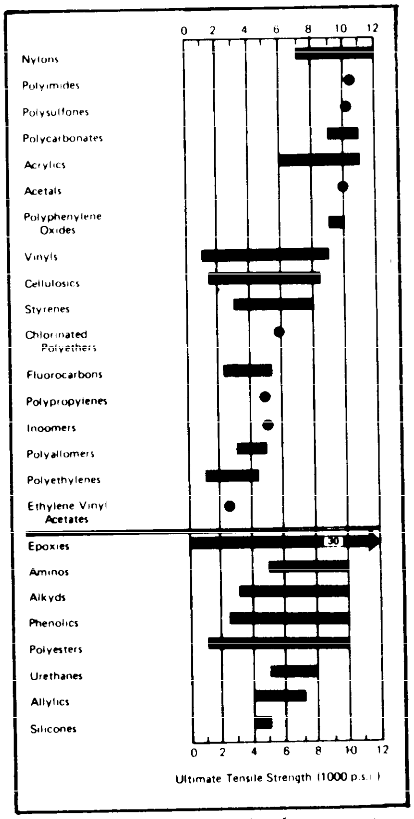

Fig. 15—Tensile strength of representative plastic materials.

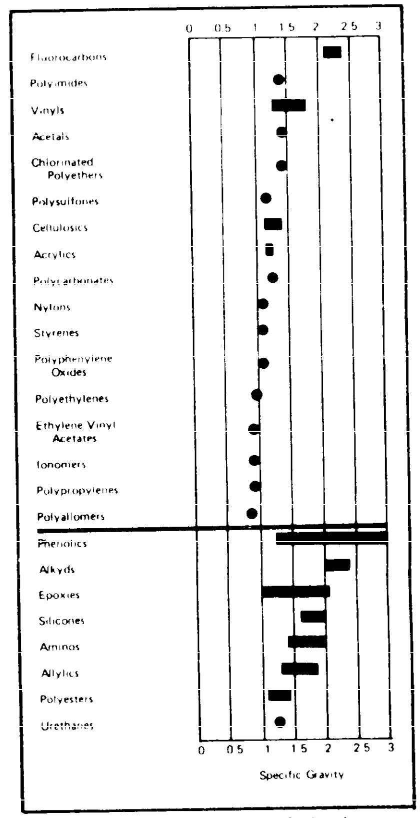

Fig. 16—Specific gravity of plastic materials.

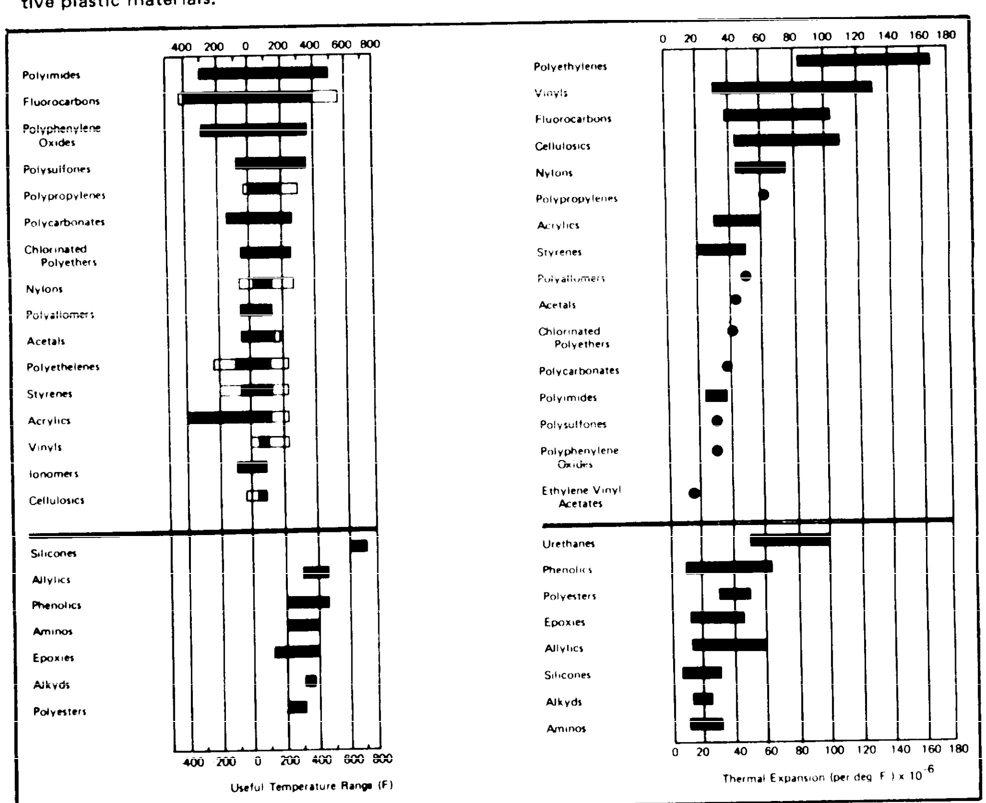

Fig. 17—Thermal properties of plastic materials.

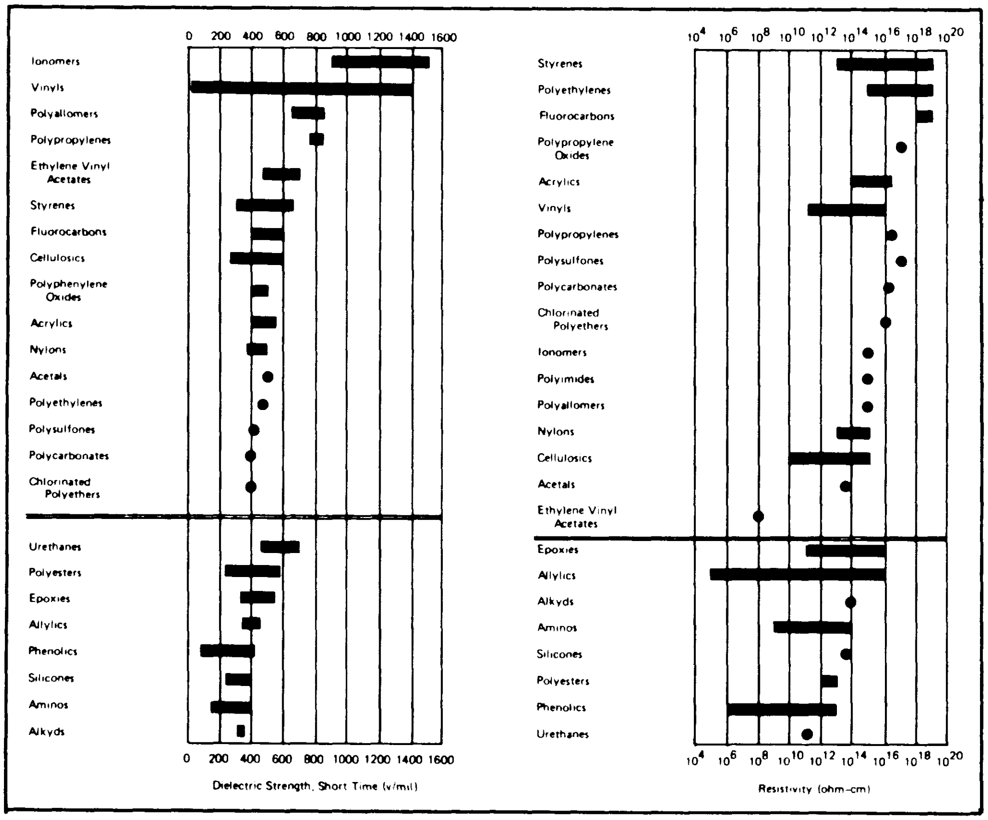

Fig. 18—Electrical properties of typical plastic materials.

TABLE XXVIII. PROPERTIES OF MATERIALS FOR LOW FRICTION APPLICATIONS— BEARINGS, BUSHINGS, SLIDES, GUIDES, VALVE LINERS, WEAR SURFACES

Properties Required: Low coefficient of friction, even when nonlubricated. High resistance to abrasion. Fair to good form stability, heat resistance, and corrosion resistance.

Suitable Plastics: Fluorocarbons (TFE and FEP), filled fluorocarbons (TFE), TFE fabrics, nylons, acetals, TFE-filled acetals, high-density and ultrahigh molecular weight polyethylenes, and self-lubricating acetals.

Other Suitable Materials: Babbitts, bronzes, cast irons, prelubricated woods, graphite, and cermets.

Consider Plastics When: 1. Corrosives or abrasives are present. 2. Lubrication might contaminate product being processed. 3. Assembly must operate above or below useful temperature of conventional lubricants. 4. Maintenance-free operation is necessary. 5. Complex lubrication systems would otherwise be required. 6. Weight is a major consideration. 7. Electrical insulation must be provided. 8. Noise must be controlled. 9. Galling and scoring must be minimized. 10. High-load, low-speed operation would squeeze out conventional lubricants. 11. Slip-stick characteristics would be objectionable.

Consider Other Materials When: 1. Service temperatures are over 500 F. 2. Heavy radial or thrust loads exist. 3. Continuous high-speed operation is required. 4. Shaft deflections must be minimal over long periods of time. 5. Wear on shaft is preferred to bearing wear.

Consider Plastics-Other-Material Combinations When: 1. Maximum heat dissipation is required. 2. Cold flow must be minimized. 3. Loadings are too high for solid plastic.

Property Summary: *Nylon* recommended for general-purpose bearings and wear surfaces. *Fluorocarbons* (especially TFE) for sliding or low-speed-rotating dry bearings, for highly corrosive service, or service in extreme temperatures (−430 to +500 F). *Acetals* for submerged or humid service, and when resistance to creep is important. *Acetals, fluorocarbons,* and *UHMW polyethylene* for valve liners or slides to eliminate jerky starts and slip-stick. *Filled fluorocarbons* for heavier loadings and high creep resistance. *Self-lubricated acetal* and *TFE-filled acetal* for heavy duty sleeve or sliding bearings. *TFE fabric* for ball-and-socket and thrust bearings; sliding bearings under heavy load, low speed. *High-density polyethylene* for lowest cost at very low speeds and loads.

	Abrasion Resistance (mg loss/1,000 cycles)	Flexural Modulus (10^5 psi)	Apparent Modulus (10^5 psi)	PV Rating, dry, continuous (× 1,000)	Deflection Temperature at 66 psi (F)	Thermal Conductivity (Btu-in./hr-ft²-°F)	Thermal Expansion (per °F) × 10^5	Water Absorption in 24 hr (%)	Slip-Stick	Coefficient of Friction: Dry	Coefficient of Friction: Lubricated	Remarks
Fluorocarbons												
TFE	7	..	0.4	1 to 2.5	250	1.7	5.5	None	No	0.04	0.04	Usable from −430 to +550 F, does not adhere to tacky materials; nongalling, absorbs abrasive particles, chemically inert.
FEP	13.2	0.95	<0.4	0.6 to 0.9	<250	1.4	4.6	<0.01	No	0.08	0.08	Readily injection molded and extruded, does not adhere to tacky materials; chemically inert.
TFE fabric	..	..	..	5 to 50	..	1.7	8	None	No	0.02 to 0.25	0.02 to 0.25	High load capacities at low speeds (50,000 psi at 0 fpm), no set under heavy static loads, requires low clearance. Not recommended for over 200 fpm, rarely used over 50 fpm.
Filled TFE	8 to 26	1.2 to 2	0.6 to 1	5 to 35	>250	1.7 to 20	3 to 9.7	None	No	0.16 to 0.28	0.06	High load capacities.
Nylons	6 to 8	1.5 to 4	1	2 to 3	340 to 360	1.4 to 2	4.6 to 7.1	0.4 to 3.3	Yes	0.15 to 0.40	0.06	Absorbs and engulfs abrasive particles, nongalling, available in massive shapes.
Acetals	6 to 20	3.1 to 4.1	2	2 to 3	316 to 338	1.6 to 1.9	4.5 to 6	0.12 to 0.41	No	0.15 to 0.35	0.1	Stiffest unfilled thermoplastic, creep resistant.
Acetal, self-lubricating	5 to 12	..	..	18	302	..	..	..	No	0.10	0.05	High *PV*, low friction, internally lubricated; injection-moldable.
Acetal, TFE-fiber-filled	..	4.14	2	7.5	329	1.7	4.6	0.6	No	0.12	0.07	High creep resistance, good wear resistance, most efficient at high loads and low speeds.
Polyethylenes, high-density	6	1.3 to 2.2	1.5	..	140 to 180	3.4	6.5 to 16.7	<0.01	Yes	0.21	0.1	Nongalling.

TABLE XXVII. PROPERTIES OF MATERIALS FOR HOUSINGS, SHROUDS, CONTAINERS, DUCTS

Properties Required: Good to excellent impact strength and stiffness. Good formability and moldability. Moderate cost. Good environmental resistance. Fair to good tensile strength and dimensional stability.

Suitable Plastics: ABS, high-impact styrene, polypropylene, high-density polyethylene, cellulose acetate butyrate, modified acrylics, polyester-glass and epoxy-glass combinations. Also, structural-foam compounds of these and other resins.

Other Suitable Materials: Formed steel, cast or stamped aluminum or magnesium, and die-cast metals.

Consider Plastics When: 1. Resonance and sound transmission must be minimized. 2. Elastic deformation is required to prevent dents and cracks from random impacts. 3. Producing complex shapes is difficult by metalworking techniques. 4. Postfabrication finishing is undesirable. 5. Integral thermal or electrical insulation must be provided. 6. Corrosion and moisture resistance are required.

Consider Other Materials When: 1. High strength and stiffness are required. 2. Lowest cost is all important.

Consider Plastics-Other-Material Combinations When: 1. Control of cold flow or warpage (metal threaded insert in plastic shroud) is required. 2. Textured housing capable of withstanding rough usage is required (metal-plastic laminates).

Property Summary: *High-impact styrene* and *ABS* recommended for general-purpose applications at lowest cost. *Polyester-glass* and *epoxy-glass* for maximum strength-to-weight ratios, stiffness and heat resistance. *Cellulose acetate butyrate* for transparent housings. *Modified acrylic and acrylic-PVC alloy* for resistance to sunlight and to staining. *Polypropylene, high-density polyethylene* and *epoxy-glass* for corrosive environments. *Polypropylene* when its high flex strength can be utilized.

	Tensile Strength (1,000 psi)		Impact Strength (ft-lb/in. of notch)		Flexural Modulus (10^5 psi)		Thermal Expansion (per °F) $\times 10^5$	Heat Resistance, continuous (F)	Flammability	Formability	Water Absorption in 24 hr (%)	Resistance To				Remarks
	Range	Typical	Range	Typical	Range	Typical						Acids	Alkalies	Solvents	Oils	
ABS	2.6 to 9	5	3 to 12	6	2.4 to 3.7	2.4	3.2 to 5.8	140 to 250	Slow	G	0.1 to 0.3	G	E	F	G	Smooth, hard surface with excellent gloss.
Styrenes, high-impact	3 to 6.8	4.3	0.5 to 3.5	1	2.3 to 5	2.3	2.2 to 5.6	126 to 165	Slow	G	0.03 to 0.2	G	E	P	F	Lowest forming temperature.
Polypropylenes	3.5 to 5.7	5.5	0.3 to 3	1	1.5 to 2.7	1.75	3.4 to 6.2	230 to 320	Slow	G	0.01 to 0.03	E	E	G	E	Sterilizable, high flex strength, resistant to stress cracking, lightest plastic.
Polyethylenes high-density	2.9 to 5.5	4.2	0.4 to 14	12	1.3 to 2.2	2	6.5 to 16.7	170 to 260	Very Slow	E	<0.01	E	E	G	G	Lighter than water, high abrasion resistance.
Cellulose Acetate Butyrates	2.6 to 6.9	5.5	0.8 to 6.3	2.1	0.6 to 1.8	1.3	6 to 10	140 to 220	Slow	E	0.9 to 2.8	P	P	P	G	Transparent.
Acrylics, modified	5 to 9	5.5	0.5 to 3	2	2.8 to 3.6	2.8	3 to 6	140 to 195	Slow	E	0.2 to 0.4	G	E	F	F	Resistant to ultraviolet light and to staining.
Acrylic-PVC alloy	..	6.5	..	15	..	4.0	3.5	165	Non-burning	E	0.06	E	E	E	E	Good thermoforming properties; tough, weather-resistant.
Polyester-Glass	8 to 55	16.5	7 to 18	15	10 to 38	15	1 to 1.4	200 to 550	Slow to nil	G	0.1 to 2	G	F	G	E	Excellent adhesion to nonmetallics, easily repaired.
Epoxy-Glass	34 to 100	36	10 to 25	12.4	20 to 50	25	0.3 to 0.6	250 to 400	Slow to nil	G	0.02 to 0.08	G	E	E	E	Tough, adheres to most surfaces.

E = Excellent   G = Good   F = Fair   P = Poor

TABLE XXXI. PROPERTIES OF MATERIALS FOR ELECTROSTRUCTURAL PARTS

Properties Required: Excellent electrical resistance in low to medium frequencies. High strength and impact properties, good fatigue resistance, and heat resistance. Good dimensional stability at elevated temperatures.

Suitable Plastics: Allylics, alkyds, aminos, epoxies, phenolics, polycarbonates, polyesters, polyphenylene oxides, and silicones.

Other Suitable Materials: Ceramics and glass.

Consider Plastics When: 1. Shock loadings are high. 2. Minimum weight is important. 3. Dimensional accuracy must be close. 4. Complex integral conductor-insulator parts are needed (printed circuitry and slip-ring assemblies).

Consider Other Materials When: 1. Service temperatures are extreme. 2. Compressive loadings are high.

Property Summary: *Polycarbonates* for transparent parts requiring high impact strength. *Cast epoxies* for encapsulating electric or electronic assemblies for maximum environmental resistance. *Molded epoxies* for uses which require dimensional stability over wide temperature ranges. *Melamines* (amino) for hardness. *Silicones* for high heat resistance. *Aminos* for low cost. *Phenolic laminates* for punched, stamped parts.

	Impact Strength (ft-lb/in. of notch)		Flexural Strength (1,000 psi)		Dielectric Strength (v/mil)		Volume Resistivity (ohm-cm)		Dissipation Factor at 60 Hz		Heat Resistance Continuous (F)		
	Range	Typical	Range	Typical	Range	Typical	Range	Typical	Range	Typical	Range	Typical	Remarks
Allylics	3 to 6	..	10 to 20	20	375 to 400	350	10^{14} to 10^{16}	10^{7}	0.002 to 0.01	0.009 to 0.017	325 to 500	..	Dielectric properties little affected by moisture; has excellent dimensional stability.
Alkyds	0.3 to 12	2.5	7 to 17	10 to 15	300 to 350	350	10^{8} to 10^{16}	10^{14}	0.003 to 0.06	0.017	275 to 300	..	Excellent dimensional accuracy and uniform, low shrinkage during cure.
Aminos	0.3 to 12	7	10 to 23	14	320 to 430	360	10^{11} to 10^{13}	10^{4}	0.033 to 0.32	0.08	170 to 400	..	Hard scratch-resistant surfaces, retains whiteness.
Epoxies	0.4 to 30	8 to 15	12 to 60	20 to 26	350 to 550	375	10^{14} to 9×10^{15}	9×10^{15}	0.01 to 0.08	..	400 to 500	..	Outstanding adhesion to metallics or nonmetallics, excellent chemical resistance, low shrinkage rate in encapsulation.
Phenolics	0.3 to 27	3.4	10 to 45	..	300 to 425	300	10^{11} to 10^{11}	5×10^{11}	0.005 to 0.50	0.18	300 to 550	400	Available in casting or molding compounds.
Polycarbonates	12 to 16	11	11 to 13	12	400 to 440	410	0.9 to 2.1×10^{16}	2×10^{16}	0.0007 to 0.001	0.0009	250 to 270	260	Transparent.
Polyesters	1.5 to 24	..	6 to 25	13 to 20	345 to 420	..	10^{12} to 10^{15}	....	0.008 to 0.041	..	250 to 350	..	Available in rigid or flexible forms readily colorable, transparent to radio waves of radar frequency.
Polyphenylene Oxides	1.5 to 1.9	..	..	14 to 15	400 to 500	..	..	10^{14}	..	0.35	..	380	Electrical properties remain stable over wide temperature and frequency range; good chemical resistance.
Silicones	0.3 to 10	6.5	7 to 18	12	350 to 400	350	3.4×10^{14} to 10^{14}	....	0.006 to 0.03	0.022	300 to 700	475	Retains strength and electrical properties after prolonged exposure to heat.

TABLE XXXII. PROPERTIES OF MATERIALS FOR LIGHT-TRANSMISSION COMPONENTS, GLAZING, MODELS

Properties Required: Good light transmission in transparent or translucent colors. Good to excellent formability and moldability. Shatter resistance. Fair to good tensile strength.

Suitable Plastics: Acrylics, polystyrenes, cellulose acetates, cellulose butyrates, ionomers, rigid vinyls, polycarbonates, and medium-impact styrenes.

Other Suitable Materials: Glass.

Consider Plastics When: 1. Shatter resistance is required. 2. Vibration resistance is important. 3. Flexibility is required. 4. Colored transparency is desired. 5. Maximum strength-to-weight ratios are required. 6. Translucency must be obtained within the material rather than by surface treatment. 7. Ease of forming in complex shapes is required. 8. Hand fabrication of prototypes is required.

Consider Other Materials When: 1. Maximum chemical resistance is required. 2. Abrasive conditions are present. 3. Service temperatures are high. 4. Maximum dimensional stability over wide range of temperatures is needed. 5. Imperviousness to moisture is required.

Property Summary: *Acrylics* recommended for general-purpose applications, especially for optical, decorative, and outdoor use. In sheet stock, *cast acrylic* has greater strength and transparency; *extruded acrylic* costs less (especially in thin members) and has better formability. *Polycarbonates* for maximum strength, as in explosion shields. *Butyrates* for excellent impact resistance, and deep formability. *Vinyls* for maximum formability and printability. *Acetates* and *vinyls* for flexible glazing and guards. *Medium-impact styrene* and *rigid vinyls* for lowest-cost translucent lighting applications. *Polystyrene* for lowest-cost molded transparent parts.

	Tensile Strength (1,000 psi)	Impact Strength (ft-lb/in. of notch)	Flexural Modulus (10^5 psi)	Heat Resistance continuous (F)	Light Transmission (%) Range	Light Transmission (%) Typical	Haze (%) Range	Haze (%) Typical	Effect of Ultraviolet	Formability	Resistance To: Acids	Alkalies	Solvents	Oils	Remarks
Acrylics	5.5 to 10.5	0.4 to 0.5	3.5 to 5	150 to 225	91 to 93	92	1 to 3	1	None	G to E	G	F	F	F	Highest reflectance (sparkles in reflected light) of transparent plastics, pipes light, excellent low-temperature properties.
Polystyrenes	5 to 9	0.25 to 0.4	4 to 5	150 to 175	75 to 93	..	>3	..	Slight to crazes	P	G	E	P	F	High reflectance, pipes light, excellent low-temperature properties, brittle, machines poorly, stress-crazes.
Styrenes, medium-impact	3.5 to 6.8	0.6 to 3	3 to 7.5	155 to 180	10 to 55	30	..	..	Slight	G	G	E	G	G	Translucent only.
Acetates	1.9 to 11	1.2 to 5.8	1.1 to 4	180 to 200	75 to 95	89	2 to 15	9	Slight	G	P	P	F	G	Hand formable.
Cellulose Acetate Butyrates	2.6 to 6.8	0.8 to 6.3	0.6 to 1.8	140 to 220	80 to 92	88	1 to 4	3	Slight to none	P	P	P	G	E	Takes extremely deep draws.
Vinyls, rigid	5.5 to 9	0.25 to 1.2	3.8 to 5.4	150 to 220	..	89	3 to 4	4	Slight	G to E	G	E	G	G	Good abrasion resistance; excellent dielectric; printable.
Polycarbonates	9 to 10.5	12 to 16	3.2 to 3.8	250 to 270	75 to 85	89	>10	..	Fades	E	E	G	G	F	High creep resistance and creep stability.
Ionomers	5	5 to 14	0.4	160	..	95	..	3	......	..	G	E	G	E	Tough, excellent clarity.

TABLE XXIX. PROPERTIES OF MATERIALS FOR HEAVILY STRESSED MECHANICAL COMPONENTS – GEARS, CAMS, RACKS, COUPLINGS, AND ROLLERS

Properties Required: High-tensile plus high-impact strength. Good fatigue resistance and stability at elevated temperatures. Machinable or moldable to close tolerance.
Suitable Plastics: Nylons, TFE-filled acetals, polycarbonates, and fabric-filled phenolics.
Other Suitable Materials: Cast iron, brasses, and steels.
Consider Plastics When: 1. Weight reduction is important. 2. Ambient conditions are gritty, abrasive, or corrosive. 3. Part is subjected to flexing. 4. Noise or vibration must be minimized. 5. Combined functions are desired.
Consider Other Materials When: 1. Low inertia and high starting speeds are required. 2. Cost is all important. 3. Loadings are heavy. 4. Service temperatures are high.
Consider Plastic-Other-Material Combinations When: 1. Low cost and flex resistance are required. 2. High impact resistance is required.
Property Summary: *Nylons* are recommended for general-purpose gears and other mechanical components. *Acetals* for maximum fatigue life, for highly accurate parts, or exposure to extremely humid conditions. *Phenolic-fabric laminates* for low-cost thin, stamped gears or parts. *Polycarbonates* for intermittent, very high impacts (not recommended for applications involving repeated cyclical stress). *TFE-filled acetals* for heavy-duty applications.

	Tensile Strength (1,000 psi)	Impact Strength (ft-lb/in. of notch)	Abrasion Resistance (mg loss/1,000 cycles)	Fatigue Endurance Limit (1,000 psi)	Flexural Modulus (10^5 psi)	Deflection Temperature (F) 66 psi	Deflection Temperature (F) 264 psi	Resistance To Acids	Resistance To Alkalies	Resistance To Solvents	Resistance To Oils	Machinability	Remarks
Nylons	7.1 to 12.6	0.6 to 4	6 to 8	3	1.5 to 4	340 to 360	140 to 165	F	E	E	E	E	Vibration damping, nongalling available in massive shapes, low friction.
Acetals	8.8 to 10	1.2 to 1.4	6 to 20	5	3.7 to 4.1	316 to 338	230 to 255	P	E	E	E	E	Creep resistant, excellent low-temperature strength, low friction, low moisture absorption.
Acetal, TFE-fiber filled	6.9	0.86	..	..	4.11	329	212	P	P	E	E	E	Self-lubricating, low friction, excellent wear life, creep resistant.
Polycarbonates	9 to 10.5	12 to 16	7 to 24	2	3.2 to 3.8	283 to 293	270 to 280	E	G	G	F	E	Extremely creep resistant, transparent, excellent low-temperature strength, low moisture absorption, high dimensional stability.
Phenolics, fabric-filled	9 to 16	1 to 2.5	..	..	8 to 14	320	>320	F	F	E	E	F to E	Hard, extremely creep resistant.

TABLE XXX. PROPERTIES OF MATERIALS FOR CHEMICAL AND THERMAL EQUIPMENT

Properties Required: Resistance to temperature extremes and/or chemicals. Minimum moisture absorption. Fair to good strength.
Suitable Plastics: Fluorocarbons, chlorinated polyether, polyvinylidene fluoride, polypropylene, high-density polyethylene, epoxy-glass, phenolics, furanes, polyimides, aromatic polyesters.

Other Suitable Materials: Stainless steels, titanium, columbium, and other premium metals.

Consider Plastics When: 1. Cost is a primary consideration. 2. Ultimate in corrosion resistance is required. 3. Abrasives may be present in combination with corrosives. 4. Minimum maintenance is desired. 5. Thermal insulation is a requirement.

Consider Other Materials When: 1. Maximum strength properties are needed. 2. Service temperatures exceed 550 F. 3. Dimensional stability must be good over wide or fluctuating temperature ranges.

Consider Plastics-Other-Material Combinations When: 1. Optimum strength properties and maximum corrosion resistance are required. 2. Intense heats are involved and the plastic ablates slowly, preventing heat from damaging the metal.

Property Summary: *TFE fluorocarbons* for general-purpose chemical and high-temperature applications. *Polyimides* and *aromatic polyesters* for strength at temperatures to 600 F. *Aromatic polyesters* for high wear resistance. *Polypropylene* and *high-density polyethylene* for plating and less severe chemical exposures. *Chlorinated polyether, PVF* and *CTFE fluorocarbon* for extreme resistance in combination with mechanical strength and stiffness. *CTFE* for transparency. *Epoxy-glass* for greatest mechanical strength and for large structures.

	Tensile Strength (1,000 psi)	Impact Strength (ft-lb/in. of notch)	Brittle Point (F)	Heat Resistance (F) Range	Heat Resistance (F) Continuous	Deflection Temperature at 66 psi (F) Range	Deflection Temperature at 66 psi (F) Typical	Flammability	Effect Of Strong Acids	Effect Of Strong Alkalies	Effect Of Solvents	Remarks
Fluorocarbons												
TFE & FEP	1.5 to 4.5	2.5 to >16	−420	400 to 550	..	160 to 260	250	None	None	None	None	Good mechanical properties over wide temperature range, low friction, zero moisture absorption. FEP can be injection-molded.
CTFE	4.6 to 5.6	3.1 to 7.3	−400	..	400	196 to 391	265	None	None	None	Very slight	Transparent, injection moldable, zero moisture absorption, resistant to radiation and creep.
Chlorinated Polyether	6	0.4	10 to −20	..	290	..	300	Self-ext	Very slight	None	Very slight	Good abrasion resistance.
Polyvinylidene Fluoride	7	..	<−80	..	300	..	300	Self-ext non-drip	Very slight	None	Very slight	Injection moldable and extrudable.
Polypropylenes	3.3 to 5.7	0.3 to 3	0	230 to 320	275	215 to 240	210	Slow	Very slight	Very slight	Slight	Lightest of plastics; excellent resistance to creep and stress cracking.
Polyethylenes, high-density	2.9 to 5.5	0.4 to 14	−76 to −200	170 to 260	250	140 to 180	175	Very slow	Slight	Very slight	Slight	Good abrasion resistance; lighter than water.
Polyimides	10.5	0.9	..	500 to 900	500	..	>470	Non-burning	Attack	Attack	None	Good mechanical and physical properties in a wide temperature range; excellent ionizing radiation resistance. High cost.
Polyphenylene Oxide	11.6	1.3	..	..	250	..	355	Self-ext nondrip	Very slight	Very slight	None	Good overall properties, even at high temperatures.
Epoxy-Glass	34 to 100	10 to 25	..	250 to 400	250 to 300	300 to 550	350 to 375	Slow to none	Slight	Slight	None	Readily applied by hand layup to large areas, adheres tightly to most substances, easily patched.
Phenolics, Furanes	3.0 to 8.0	0.20 to 0.36	..	..	300	300 to 500*	..	None	Slight†	Attack	Slight	Various formulations available for specific resistance characteristics.

*At 264 psi. †For nonoxidizing acids; decomposed by oxidizing types.

CHAPTER 9

REFERENCE MATERIAL

PLASTICS REFERENCE MATERIAL

262. General. The following sources will be useful to the user of this Handbook who is interested in standardization documents on plastics issued by the U. S. Government. Such documents include specifications, standards and handbooks. The sources given below tabulate these documents.

World Index of Plastics Standards, edited by L. H. Breden, and published by the National Bureau of Standards as NBS Special Publication 352, December 1971. Available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Order as SD Catalog No. C13.10:352 at $5.50.

This computer-produced hard-cover index of 458 pages contains the printed titles of more than 9,000 national and international standards on plastics and related materials, including adhesives and elastomers, which were in effect as of the end of December 1970. These standards are published by technical societies, trade associations, government agencies and military organizations. The title of each standard can be found under all the significant key words which it contains. These key words are arranged alphabetically down the center of each page, together with their surrounding context. A total of 124 standardization agencies are listed.

List of Voluntary Product Standards, Commercial Standards, and Simplified Product Recommendations, published by the National Bureau of Standards, U. S. Department of Commerce, Office of Engineering Standards, Washington, D. C. 20234, as NBS List of Publications 53, Revised April 1973 (Published semi-annually).

This brief (13-page) publication, obtainable on a no-charge basis from NBS, is intended to assist all interested parties in obtaining copies of the listed standardization documents published by the Department of Commerce. It contains subject and numerical indexes of the standards available and instructions for ordering them. Basically, the documents cited are those prepared by industrial or trade aasociations and published by the U. S. Government. They are not actually Government specifications or standards, however, but are listed here because of their possible interest to the reader.

Department of Defense Index of Specifications and Standards (DODISS), published by the U. S. Department of Defense. Part I. Alphabetical Listing. Part II. Numerical Listing, and (Unnumbered) Federal Supply Classification. Parts I and II are available at $20.00/year, including supplements and quarterlies, from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. The FSC Listing is available from the same source at $10.00/year.

This massive loose-leaf publication is published yearly. It lists the unclassified Federal, Military and Departmental specifications, standards and related standardization documents, and those Industry documents which have been coordinated for DOD use.

Index of Ordnance Specifications and Weapons Specifications, published by Naval Ordnance Systems Command, Washington, D. C. as NAVORD OS O. This document of over 400 pages is issued annually. Supplements listing additions, changes and cancellations are issued each mid-year. Requests for copies of this Index, documents listed therein, or requests that contractors or activities be placed on distribution list for this Index, should be addressed to: Commander, Naval Ordnance Station, Central Documents Office, Louisville, Kentucky 40214, ATTN: Code 80121.

This publication provides a list of NAVORD OS (Ordnance Specifications) and WS (Weapons Specifications), descriptions and requirements, using materials, articles, devices, explosives, parts or assemblies, and processes used by the Naval Ordnance Systems Command.

Government Specifications and Standards for Plastics, Covering Defense Engineering Materials and Applications (Revised, Final), by N. E. Beach, published by the Plastics Technical Evaluation Center, Picatinny Arsenal, Dover, N. J. as PLASTEC Note 6C, May 1973. Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Va. 22151 at $3.00. Order as AD 771 008.

This report lists the specifications for those plastic materials which are considered to be of interest to engineers concerned with the design, development, production, and handling of defense hardware. Included are the major specifications pertaining to molding, extrusion, films, foams, and laminates: sheets, rods, tubes and shapes.

This area is now being covered by another Government agency (The National Bureau of Standards and its "World Index of Plastics Standards"), and PLASTEC Note 6C will be the final report in this series.

Index of Federal Specifications and Standards, published by the General Services Administration, Federal Supply Service, as FPMR 101-29.1 (41CFR 101-29.1). Published as of January 1 each year. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Subscription price is $7.50/year, including the basic Index and monthly cumulative supplements.

The reader should be able to find any relevant documents on Federal specifications and standards in the DODISS described above, but the Federal Index, with its larger type, is much easier to read.

NASA Specifications and Standards, published by the National Aeronautics and Space Administration, Scientific and Technical Information Division, Washington, D. C. as NASA SP-9000, May 1967. Available to organizations registered with NASA to receive documents without charge through the NASA Scientific and Technical Information Facility, P. O. Box 33, College Park, Md. 20740. Others may purchase copies at $3.00 per year from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22151.

This volume is the first attempt to assemble in one publication an up-to-date listing of all specifications and standards originated by NASA, its Centers and the Jet Propulsion Laboratory (JPL) through December 1966. It is intended to help determine what specifications and standards have been generated, where they were developed, and the organizational component responsible.

APPENDIX A
TRADEMARKS AND BRAND NAMES

All trademarks and brand names listed below have been represented to us as having been registered, but the inclusion or exclusion of any should not be taken as evidence of its registration status. The publishers assume no responsibibility in this connection.

ABCITE, Abrasion-resistant sheet, Du Pont de Nemours, E. I. & Co.
ABEX, Emulsion polymerization surfacants, Alcolac Inc.
ABLAPHENE, Formophenolic resins, Plastimer, S. A.
ABLE-STIK, Pressure-sensitive labels, Kimball Systems, Div. Litton Industries
ABLEX, Plastic compounds, Action Plastics Div., Dart Industries, Inc.
ABOGLAS, Asbestos-fiberglass combination, Natvar Corp.
ABSAFIL, Fiberglass reinforced ABS, Fiberfil Div., Dart Industries, Inc.
ABSELEX, Extruded ABS sheeting, British Celanese Ltd.
ABSINOL, ABS, Allied Resinous Products, Inc.
ABSON, ABS resins & compounds, Goodrich, B. F., Chemical Co.
ACCRALINE, Instruments for indicating & controlling variables, Barber-Colman Co., Industrial Instruments Div.
ACCU-CAST, Shaw castings in all tool steels, Manco Products, Inc.
ACCUFLEX, Timer/counter, Eagle Signal, a Systems Div. G. & W. Industries
ACCUFLOW, Sheet & flat film dies, Davis-Standard/Goulding/Hobbs Divs., Crompton & Knowles Corp.
ACCUNIP, Squeezer roll assembly, Hunt, Rodney, Co.
ACCU RAY, Process management systems, Industrial Nucleonics Corp.
ACELON, Cellulose acetate film, May & Baker, Ltd.
ACETAMINE, Synthetic organic dyes, Du Pont de Nemours, E. I. & Co.
ACETOPHANE, Cellulose acetate film, UCB-Sidac
ACETOSOL, Solvent soluble dyes, Sandoz Colors & Chemicals
ACLAR, CTFE film, Allied Chemical Corp., Plastics Div.
ACLAR, CTFE fluorohalocarbon films, Allied Chemical Corp., Fibers Div., Plastic Film Dept.
ACME, Plastic sheet welders, Stanelco Ltd.
ACPOL, Polyester resin, Freeman Chemical Corp., Div. H. H. Robertson Co.
ACRALEN, Styrene-butadiene latex, Farbenfabriken Bayer AG
ACRAMATIC, Solid state logic control for plastics machinery, Cincinnati Milacron Co., Process Controls Div.
ACRAPLATE, Molding press, Patterson Industries Inc.
ACRAWATT, Electrical heating elements, Acra Electric Corp.
ACRAWAX, Lubricant, Glyco Chemicals, Inc.
ACROCUT, Engraved steel stamps, Acromark Co.
ACRODIE, Marking dies, Acromark Co.
ACROLEAF, Hot stamping foil, Acromark Co.
ACRONAL, Acrylate polymers & copolymers, Badische Anilin- & Soda-Fabrik AG
ACRONAL, Copolymer acrylic ester dispersions, BASF Wyandotte Corp.
ACROPRINTER, Printing machine, Acromark Co.
ACROTYPE, Marking type, Acromark Co.
ACRYLADOR, Enamel, Bee Chemical Co.
ACRYLAFIL, Fiberglass reinforced styrene-acrylonitrile, Fiberfil Div., Dart Industries, Inc.
ACRYLIGLAS, Acrylic-coated glass fabric, Natvar Corp.
ACRYLITE, Acrylic molding compounds; cast acrylic sheet, American Cyanamid Co., Industrial Chemicals & Plastics Div.
ACRYLOID, Acrylic modifiers for PVC; coating resins, Rohm & Haas Co.
ACRYSOL, Thickeners, Rohm & Haas Co.
ACTAFOAM, Activator-stabilizers for PVC, Polychem Dept., Stepan Chemical Co.
ACTIFRESH, Bacteriostat & fungicide, Sanitized Sales Co. of America, Inc.
ACU-THERM, Heat-measuring instrument, Electronic Development Laboratories, Inc.
ADAMAC, Coatings system catalyst, Commercial Solvents Corp.
ADIMOLL, Adipate plasticizers, Farbenfabriken Bayer AG
ADJUST-A-FLOW, Vibrating feeders, Carman Industries, Inc.
ADJUST-O-FEEDER, Metering pump, B I F, a Unit of General Signal
ADMEX, Specialty plasticizers, Ashland Chemical Co., Div. Ashland Oil, Inc.
ADOGEN, Fatty nitrogen & quaternary ammonium compounds, Ashland Chemical Co., Div. Ashland Oil, Inc.
ADRUB RTV, Flexible mold-making rubber, Adhesive Products Corp.
ADVABRITE, Brighteners, Cincinnati Milacron Chemicals, Inc.
ADVACAT, Polyester promoter, Cincinnati Milacron Chemicals, Inc.
ADVACIDE, Fungacides & bacteriostats, Cincinnati Milacron Chemicals, Inc.
ADVALITE, Stabilizers for vinyl coatings, Cincinnati Milacron Chemicals, Inc.
ADVASPERSE, Pigment dispersant, Cincinnati Milacron Chemicals, Inc.
ADVASTAB, PVC stabilizers for heat & light, Cincinnati Milacron Chemicals, Inc.
ADVASTAT, Antistatic agents, Cincinnati Milacron Chemicals, Inc.
ADVAWAX, Internal & external lubricants, Cincinnati Milacron Chemicals, Inc.
ADVAWET, Wetting agents, Cincinnati Milacron Chemicals, Inc.
AERO, Metallic stearates, American Cyanamid Co., Organic Chemicals Div.

Trademarks and brand names (Cont'd)

AERO-PAK, In-plant blow molding systems, Plastic Forming Co.
AERO-SHAFT, Pneumatic shaft, Dietzco, Div. Entwistle Co.
AERO-VIBE, Vibrating screens, Allis-Chalmers
AEROBOND, Adhesives, Adhesive Engineering Co.
AEROFLEX, Polyethylene extrusion, Anchor Plastics Co.
AEROSTAT, Blower static eliminators, Simco Co.
AEROTUF, Polypropylene extrusions, Anchor Plastics Co.
AFFLAIR, Flake pigments, Du Pont de Nemours, E. I. & Co.
AIR DOCTOR, Negative ion generators, Simco Co.
AIRNETICS, Bin discharge cone, Monitor Mfg. Inc., Aeration Products Group
AIR OUT, Air release, Isochem Resins Co.
AIRSLIDE, Gravity conveyor, Fuller Co.
AIRVEYOR, Pneumatic conveying equipment, Fuller Co.
AJAX-ANKERSEN, Salt bath furnaces, Ajax Electric Co.
AJAX FIREBALL, Salt bath furnaces, Ajax Electric Co.
AJAX-HULTGREN, Salt bath furnaces, Ajax Electric Co.
AJICOAT, Polyamino acid, Ajinomoto U. S. A., Inc.
AJICURE, Epoxy curing agent, Ajinomoto U. S. A., Inc.
AKROLAM, Acrylic laminant cement, 7-K Color Corp.
AKULON, Polyamide 6, 6/6, Akzo Plastics bv
AL-SIL-ATE (SERIES), Clays, Freeport Kaolin Co.
ALAESTAT, Antistatic agents, Alcolac Inc.
ALATHON, Polyethylene resins, Du Pont de Nemours, E. I. & Co.
ALBACAR, Precipitated calcium carbonate, Pfizer Minerals, Pigments & Metals Div.
ALDO, Glyceryl esters, Glyco Chemicals, Inc.
ALFANE, Thermosetting epoxy resin cement, Atlas Minerals & Chemical Div., ESB Inc.
ALFOL, Straight-chain primary alcohol series, Conoco Chemicals, Div. Continental Oil Co.
ALFONICS, Ethoxylated straight-chain primary alcohols, Conoco Chemicals, Div. Continental Oil Co.
ALGOFLON, Polytetrafluoroethylene resins, Montedison S. p. A.
ALIPAL, Wetting agents, GAF Corp.
ALKATERGE, Surface active agents, Commercial Solvents Corp.
ALKATHENE, Low density polyethylene polymers & compounds; EVA copolymers, Imperial Chemical Industries Ltd., Plastics Div.
ALKOR, Furane resin cement, Atlas Minerals & Chemicals Div., ESB Inc.
ALKYDAL, Alkyd resins, Farbenfabriken Bayer AG
ALLISPEDE, Adjustable speed drive, Allis, Louis, Div., Litton Industrial Products, Inc.
ALMOLD 20, Mold steel, Allegheny Ludlum Steel Corp., Div. Allegheny Ludlum Industries, Inc.
ALPEROX, Organic peroxide catalysts, Lucidol Div., Pennwalt Corp.
ALSIBRONZ, Wet ground muscovite mica, Franklin Mineral Products Co.
ALSTEELE, Plastics granulator or pelletizer, Composite Materials & Mfg. Div., Entoleter, Inc.
ALSYNITE, Reinforced Plastic panels, Reichhold Chemicals, Inc.
ALTOROTO, Rotogravure inks, Gotham Ink & Color Co.
ALUMASHEEN, Printing ink, Sun Chemical Corp., General Printing Ink Div.
ALUMATUFF, Printing ink, Sun Chemical Corp., General Printing Ink Div.
AMBERLAC, Modified alkyd resins, Rohm & Haas Co.
AMBEROL, Phenolic resins, Rohm & Haas Co.
AMBIT, Solid state control circuit, Ingersoll-Rand/IMPCO & Negri Bossi Divs.
AMER-PLATE, PVC sheet material, Ameron Corrosion Control Div.
AMER-SIL, Microporous plastic sheet, Amerace Corp., Microporous Products Div.
AMINCO SUPERPRESSURE, High pressure valves, fitting, etc., American Instrument Co., Div. Travenol Laboratories, Inc.
AMINOCEL, Urea-formaldehyde resins, Montedison S.p.A.
AMINOLAC, Melamine-formaldehyde-butyl, Plastimer S.A.
AMINOX, Antioxidant, Uniroyal, Inc.
AMPLI/CATOR, Amplifier/indicator, Tensitron, Inc.
AMPOL, Cellulose acetates, American Polymers, Inc.
AMRES, Thermosetting liquid resins, Pacific Resins & Chemicals, Inc.
AMSCO-RES, Synthetic polymer emulsions, AMSCO Div., Union Oil Co. of Calif.
AMSCOMATIC, Unitized conveyor/sealers, Amsco Packaging Machinery, Inc.
ANALYTE, Color comparators, Crown Engineering & Sales Co.
ANCHOR, Dial filler paints, Perry & Derrick Co.
ANCORENE, High impact styrene extrusions, Anchor Plastics Co.
ANCOREX, ABS extrusions, Anchor Plastics Co.
ANHYDROL, Solvents, Union Carbide Corp., Chemicals & Plastics
ANTAROX, Low foaming wetting agent, GAF Corp.
ANTIBLAZE, Organic phosphorus flame retardants, Mobil Chemical Co., Industrial Chemical Div.
ANVYL, Vinyl extrusions, Anchor Plastics Co.
APEX, Clay, Thompson, Weinman & Co.
AQUA-MATE, Scale control instrument, Mokon Div., Protective Closures Co.

Trademarks and brand names (Cont'd)

AQUAMAC, Copolymer latex, Commercial Solvents Corp.
AQUAMETER, Titrating moisture analyzer, Beckman Instruments, Inc.
AQUANAXOL, Hydrosoluble alkyd resins, Convert, Ets. G.
AQUASUN, Printing ink, Sun Chemical Corp., General Printing Ink Div.
AQUATRON, Controlled waterproof porosity process, American Combining Corp.
ARALDITE, Epoxy resins & hardeners, CIBA-GEIGY Corp., Plastics & Additives Div.
ARANOX, Antioxidant, Uniroyal, Inc.
ARATHENE, Synthetic paper, UCB-Sidac
ARC EASE, Lubricant, release agent, American Resin Corp.
ARC KLEER, Adhesives, American Resin Corp.
ARclad, Pressure-sensitive adhesive materials, Adhesives Research, Inc.
ARKOLUBE, Antistatic agent & lubricant, Arkansas Co.
ARMID, High molecular weight amide, Armak Co., Polymer Additives Dept.
ARMITE, Vulcanized fibre, Spaulding Fibre Co.
ARMODUR, Rigid PVC sheets, May & Baker, Ltd.
ARMOR LINE, AC motors, Allis, Louis, Div., Litton Industrial Products, Inc.
ARMORBOND, Vinyl bonded to metal tubing, Lakeland Plastics, Inc.
ARMORPLATE, Pulverizing & crushing apparatus, Jeffrey Mfg. Co.
ARMOSLIP, Anti-slip agents, Armak Co., Polymer Additives Dept.
ARMOSTAT, Antistatic agent, Armak Co., Polymer Additives Dept.
ARNITE, PETP & PTMT thermoplastic polyesters, Akzo Plastics bv
AROCHEM, Modified phenolic resins, Ashland Chemical Co., Div. Ashland Oil, Inc.
AROFENE, Phenolic resins, Ashland Chemical Co., Div. Ashland Oil, Inc.
AROFLINT, Polyester-epoxy resins, Ashland Chemical Co., Div. Ashland Oil, Inc.
ARON ALPHA, Cyanoacrylate adhesive, Vigor Co., Div. B. Jadow & Sons
ARONTITE, Anacrobic sealants, Vigor Co., Div. B. Jadow & Sons
AROPLAZ, Alkyd resins, Ashland Chemical Co., Div. Ashland Oil, Inc.
AROPOL, Unsaturated polyester resins, Ashland Chemical Co., Div. Ashland Oil, Inc.
AROSET, Acrylic resins, Ashland Chemical Co., Div. Ashland Oil, Inc.
AROSURF, Emulsifiers, Ashland Chemical Co., Div. Ashland Oil, Inc.
AROTHANE, Polyester resin, Ashland Chemical Co., Div. Ashland Oil, Inc.
ARSONAX, Fire retardant, Humphrey Chemical Corp.
ARTFOAM, Rigid urethane foam, Strux Corp.
ARYLON, Polyarl ether compounds, Uniroyal, Inc.
ASCOT, Coated spunbonded polyolefin sheet, Appleton Papers
ASHDEE, Curtain coater, Koch, George, Sons, Inc.
ASTRA-TONE, Oleophilic montmorillonite, Georgia Kaolin Co.
ASTRADUR, Extruded PVC sheets, Dynamit Nobel, A.G.
ASTRADUR, High impact vinyl copolymer sheets, Dynamit Nobel of America Inc.
ASTRAGLAS, Plasticized pressed PVC sheets, Dynamit Nobel of America Inc.
ASTRAGLAS, Plasticized PVC sheets, Dynamit Nobel, A.G.
ASTRALIT, Vinyl copolymer sheets, Dynamit Nobel of America Inc.
ASTRALON, PVC sheets, Dynamit Nobel, A.G.
ASTRALON, Vinyl & vinyl copolymer sheets, Dynamit Nobel of America Inc.
ASTRAPRINT, PVC copolymer sheets, Dynamit Nobel, A.G.
ASTRATHERM, Rigid PVC film, Dynamit Nobel, A.G.
ASTREL 360, Polyarylsulfone thermoplastic, 3M Co.
ATEPAS, Viscosity depressant for plastisols, Bohme, Dr. Th., KG
ATLAC, Polyester resins, ICI America Inc.
ATLAS, Coal tar dyes, Kohnstamm Co.
ATLAS, Pitment colors, Kohnstamm, H., & Co.
ATMER, Surface active agents, ICI America Inc.
ATOMITE, Calcium carbonate, Thompson, Weinman & Co.
ATTAGEL, Thickening agent, Engelhard Minerals & Chemicals Corp., Minerals & Chemicals Div.
AUDREY, Dielectric curometer, Brabender, C. W., Instruments, Inc.
AUDREY, Automatic dielectrometer, Tetrahedron Associates, Inc.
AURORA, PVC sheeting, Crespi, Giovanni, S.p.A.
AUTAC, Noncontact temperature controls, Walco Systems Inc.
AUTO-BIN-DICATOR, Bulk material level control, Bin Dicator Co.
AUTO-TENSIONEER, Automatic tension indicator & control, Dusenbery, John, Co.
AUTOCOAT, Automatic plastic coating machines, Plastic Coatings Ltd.
AUTOCOATER, Coating system, Zicon Corp.
AUTOCOLOR, Loader meters & mixes in color, Conair, Inc.
AUTODRYER, Infra-red drying oven, Zicon Corp.
AUTOFROTH, Polyurethane production equipment, Olin Corp.
AUTOGRAM, Laboratory balance, Ohaus Scale Corp.
AUTOSONIC, Ultrasonic multicomponent mixing system, Sonic Corp., Div. of General Signal
AUTOWELD, Friction welder, Brown Machine, Div. Koehring Co.

Trademarks and brand names (Cont'd)

AZDEL, Glass fiber reinforced thermoplastic sheets, G. R.T. L. Co.
AZOCEL, Azodicarbonamide blowing agent, Fairmount Chemical Co.

BAKCAR, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
BAKELITE, Polyethylene, ethylene copolymers, Epoxy, phenolic, polystyrene, phenoxy & vinyl resins, Union Carbide Corp., Chemicals & Plastics
BALDWIN, Test Instruments, SATEC Systems, Inc.
BANBURY, Intensive, internal batch mixer, Farrel Co., Div. USM Corp.
BANC-LOK, Inserts for post-molding, Boots Aircraft Nut Div., Townsend Co.
BANGERTER, Machines for film & foil conversion, Polytype Ltd.
BANTAM, Bulk material level control, Bin Dicator Co.
BARDEN, Kaolin clay, Huber, J. M., Corp.
BAREX, Acrylic barrier resin, Vistron Corp., Sub. The Standard Oil Corp. of Ohio
BARFILEX, Film-strip line, American Barmag Corp.
BARFILEX, Extrusion line, Barmag Barmer Maschinenfabrik A.G.
BARGE, Resin-based adhesive, National Adhesives Div., National Starch & Chemical Corp.
BARIMITE, Barium sulfate, Thompson, Weinman & Co.
BAROFLEX, Coextrusion line, American Barmag Corp.
BAROFLEX, Extrusion line, Barmag Barmer Maschinenfabrik A.G.
BARRYMOUNT, Vibration attenuating mount, Barry Div., Barry Wright Corp.
BATCH-MASTER, Centrifugal, Ametek/Process Equipment
BATCH-O-MATIC, Centrifugal, Ametek/Process Equipment
BAYCRYL, Acrylic dispersions, Farbenfabriken Bayer AG
BAYDUR, Skinned molded rigid polyurethane foam, Farbenfabriken Bayer AG
BAYGAL, Polyester for casting resins, Farbenfabriken Bayer AG
BAYLON, Low density polyethylene, Farbenfabriken Bayer AG
BAYMIDUR, Isocyanates, Farbenfabriken Bayer AG
BAYSILONE, Silicones, Farbenfabriken Bayer AG
BEETLE, Urea molding compounds, American Cyanamid Co., Industrial Chemicals & Plastics Div.
BELTRAC, Belt guiding systems, Knox, Inc., Controls Div.
BENCHMASTER, Benchtop test chamber, Tenney Engineering, Inc.
BENTONE, Gelling agent, Kronos Titan GmbH
BENVIC, Polyvinyl chloride compounds, Solvay & Cie S.A.
BENZOFLEX, Ester plasticizer, Velsicol Chemical Corp., Resin Products Div.
BESTFLEX, Extruded sheet, BQP Industries
BETALUX, TFE-filled acetal, Westlake Plastics Co.
BETAMIKE, Thickness and/or density measuring system, Taylor Instrument Process Control Div., Sybron Corp.
BETAMIKE, Basis-weight, thickness measurement, Taylor Instrument Industrionics Div.
BIN-EYE, Bin or container level indicator, Jeffrey Mfg. Co.
BIN-FLO, Aerator to produce flow of dry powders, Bin Dicator Co.
BLACK PEARLS, Pelleted carbon black, Cabot Corp., Special Blacks Div.
BLACK SHIELD, Carbon black dispersions, CDI Dispersions
BLAK-STRETCHY, Cold molding compound, Perma-Flex Mold Co.
BLAK-TUFY, Cold molding compound, Perma-Flex Mold Co.
BLANCOPHOR, Fluorescent brightener, GAF Corp.
BLANEX, Cross-linked polyethylene compounds, Reichhold Chemicals, Inc.
BLAPOL, Polyethylene compounds & color concentrates, Reichhold Chemicals, Inc.
BLAST-MASTER, Steam cleaners for molds, Clayton Mfg. Co.
BLAVIN, Vinyl extrusion compounds & color concentrates, Reichhold Chemicals. Inc., Blane Div.
BLENDEX, ABS resins for modifying PVC, Specialties, Borg-Warner Chemicals, Borg-Warner Corp.
BLENDMASTER, 2 component proportioning, mixing & dispensing system, Hull Corp.
BLEND TROL, Digital blending systems, Foxboro Co.
BLO, Solvent, catalyst for polymers, GAF Corp.
BLU-SIL, Silicone cold molding compound, Perma-Flex Mold Co.
BODMER, Orbital headforming for plastic studs, Taumel Noiseless Riveters Inc.
BOLTA FLEX, Vinyl sheeting & film, General Tire & Rubber Co., Chemical/Plastics Div.
BOLTA QUILT, Quilted plastic films, General Tire & Rubber Co., Chemical/Plastics Div.
BOLTA THENE, Rigid olefin sheets, General Tire & Rubber Co., Chemical/Plastics Div.
BOLTATRON, ABS or PVC rigid plastic sheets, General Tire & Rubber Co., Chemical/Plastics Div.
BOMB-LUBE, Mold lubricant, Price-Driscoll Corp.
BONADUR, Organic Pigments, American Cyanamid Co., Pigments Div.
BOND ZALL, Filler compounds, Schramm Fiberglass Products Div., High Strength Plastics Corp.
BONDAID, Teflon etchant, Shamban, W. S., & Co.
BONDMASTER, Industrial adhesive, National Adhesives Div., National Starch & Chemical Corp.
BONDSTRAND, Filament wound fiberglass reinforced plastics, Ameron Corrosion Control Div.
BONYL, Biaxxially-oriented nylon film, Kohjin Co.
BORONOL, Polyolefins with Boron, Allied Resinous Products, Inc.
BOSTIK, Adhesives; specialty polymers, Bostik Div., USM Corp.
BRITE SORB, Synthetic magnesium silicate, Philadelphia Quartz Co.

Trademarks and brand names (Cont'd)

BRONCO, Supported vinyl or pyroxylin, General Tire & Rubber Co., Chemical/Plastics Div.
BRONZELESS GOLD, Metallic coating, Bee Chemical Co.
BRUX, Bimetallic cylinders, Brookes (Oldbury) Ltd.
BUDENE, Polybutadiene, Goodyear Tire & Rubber Co., Chemical Div.
BUHLER MATIC, Electronic equipment for injection molding machinery, Buhler Brothers
BURKS, High temperature pumps, Burks Pumps-Decatur Pump Co.
BUSAN, Flame-retardant microbicide, Buckman Laboratories, Inc.
BUSORB, Ultraviolet absorber, Buckman Laboratories, Inc.
BUSPERSE, Deaerator for reinforced plastics, Buckman Laboratories, Inc.
BUTANOX, Polyester curing agents, Akzo Chemie Nederland bv
BUTAPRENE, Styrene-butadiene latexes, Firestone Plastics Co., Div. Firestone Tire & Rubber Co.
BUTOFAN, Styrene-butadiene copolymers, Badische Anilin- & Soda-Fabrik AG
BUTVAR, Polyvinyl butyral resins, Monsanto Co.
BZQ-50, Organic peroxide catalyst, U. S. Peroxygen Div., Witco Chemical Corp.

CAB-O-SIL, Fumed silica, Cabot Corp.
CABULITE, Cellulose acetate butyrate film & sheets, May & Baker, Ltd.
CACHALOT, Mold release agent, Michel, M., & Co.
CADCO, Plastic rod, sheet, tubing, film; resins, glass fibers, glass strand, Cadillac Plastic & Chemical Co.
CADET, Organic peroxides, Noury Chemical Corp.
CADMERE, Cadmium-mercury pigments, Kohnstamm, H., & Co.
CADMOLITY, Lithopone-type cadmium pigments, Glidden Pigments & Colors, SCM Corp.
CADMOPUR, Cadmium pigments, Farbenfabriken Bayer AG
CADOX, Organic peroxides & mixtures, Noury Chemical Corp.
CADOX, Polymerization catalysts, Akzo Chemie Nederland bv
CAIROX, Potassium permanganate, Carus Chemical Co.
CAL STAT, Temperature controller, ITT Vulcan Electric
CAL-STIX, Polyester pressure-sensitive labels, Topflight Corp.
CALANDRETTE, Film calendering equipment, Kleinewefers Industrie-Companie GmbH
CALCOFLUOR, Fluorescent whitening agent, American Cyanamid Co., Organic Chemicals Div.
CALEN-AID, Internal lubricants, Purethane Div., Easton RS Corp.
CALROD, Electrical resistance heaters, General Electric Co., Industrial Sales Div.
CALTHANE, 2-Component urethanes & epoxies, Cal Polymers, Inc.
CALWHITE, Calcium carbonate, Georgia Marble Co., Calcium Products Div.
CAMBRIDGE SYSTEMS, Dew point analyzers, EG&G, Environmental Equipment Div.
CAMEL-CARB, Calcium carbonate, Campbell, Harry T., Sons' Corp.
CAMEL-KOTE, Calcium carbonate, Campbell, Harry T., Sons' Corp.
CAMEL-TEX, Calcium carbonate, Campbell, Harry T., Sons' Corp.
CAMEL-WITE, Calcium carbonate, Campbell, Harry T., Sons' Corp.
CAPACITROL, Instruments for indicating & controlling variables, Barber-Colman Co., Industrial Instruments Div.
CAPRAN, Nylon 6 film, Allied Chemical Corp., Plastics Div.
CAPRAN, Nylon films & sheet, Allied Chemical Corp., Fibers Div., Plastic Film Dept.
CAPROCYL, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
CAPRON, Nylon copolymer, Allied Chemical Corp., Plastics Div.
CAR-BAN, Microbiostats, Cincinnati Milacron Chemicals, Inc.
CARBAMAC, Oil-modified urethanes, Commercial Solvents Corp.
CARBASOL, Modified rosin ester, Osborn, C. J., Chemicals, Inc.
CARBITOL, Solvents, Union Carbide Corp., Chemicals & Plastics
CARBO-SPHERES, Hollow carbon sphere filler, Versar Inc., General Technologies Div.
CARBO ZINC II, Inorganic zinc protective coating, Carboline Co.
CARBOMASTIC, Epoxy coal tar coating, Carboline Co.
CARBOPOL, Water-soluble resins, Goodrich, B. F., Chemical Co.
CARBOSET, Alkali-soluble coating resins, Goodrich, B. F., Chemical Co.
CARD-O-TIMER, Time cycle controllers, Taylor Instrument Process Control Div., Sybron Corp.
CAROLUX, Filled urethane foam, flexible, North Carolina Foam Industries, Inc.
CARSTAB, Urethane foam catalysts, Cincinnati Milacron Chemicals, Inc.
CARSTAB (SERIES), Antioxidants; stabilizers, Cincinnati Milacron Chemicals, Inc.
CASTETHANE, Castable molding urethane elastomer system, Upjohn Co., CPR Div.
CASTOMER, Urethane elastomer chemicals, Witco Chemical Corp., Organics Div.
CASTOMER, Urethane elastomer systems, Baxenden Chemical Co.
CAT-A-CUTTER, Rotary knife cut-off machines, Gatto Machinery Development Corp.
CAT-A-PULLER, Extrusion take-off equipment, Gatto Machinery Development Corp.
CATANAC, Antistatic agent, American Cyanamid Co., Organic Chemicals Div.
CELACOL, Water-soluble cellulose ethers, British Celanese Ltd.
CELANAR, Polyester film, Celanese Plastics Co.
CELANEX, Thermoplastic polyester, Celanese Plastics Co.
CELANTHRENE, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
CELASTOID, Sliced cellulose acetate sheet, British Celanese Ltd.
CELATRON, High-impact polystyrene sheet, British Celanese Ltd.

Trademarks and brand names (Cont'd)

CELCON, Acetal copolymer resins, Celanese Plastics Co.
CELERON, Molded, laminated phenolics, Budd Co./Polychem Div.
CELGARD, Microporous polypropylene film, Celanese Plastics Co.
CELLASTINE, Extruded acetate sheeting, tubes, rods, British Celanese Ltd.
CELLIDOR, Plastified cellulose esters, Farbenfabriken Bayer AG
CELLIT, Unplastified cellulose esters, Farbenfabriken Bayer AG
CELLOFOAM, Polystyrene foam board, United States Mineral Products Co.
CELLOKOTE, Wax-coated cellulose laminate, UCB-Sidac
CELLOLAM, Wax-laminatedccellulose film, UCB-Sidac
CELLONEX, Cellulose acetate sheets, Dynamit Nobel, A.G.
CELLOSIZE, Hydroxyethyl cellulose, Union Carbide Corp., Chemical & Plastics
CELLOTHENE, Polyethylene-coated cellulose film, UCB-Sidac
CELLU-CUSHION, Low density polyethylene foam, Cellu Products Co.
CELLULINER, Resilient expanded polystyrene foam, Gilman Brothers Co.
CELLULITE, Expanded polystyrene foam, Gilman Brothers Co.
CELMAR, Polypropylene/Glass fiber fabric laminate, British Celanese Ltd.
CELOGAN (SERIES), Blowing agents, Uniroyal, Inc.
CELPAK, Rigid polyurethane foam, Dacar Chemical Products Co.
CELRAMIC, Glass nodules, Pittsburgh Corning Corp.
CELTHANE, Rigid polyurethane foam, Dacar Chemical Products Co.
CEM-ALL, Catalysts & driers for plastics resins, Mooney Chemicals, Inc.
CENT-O-GRAM, Laboratory balance, Ohaus Scale Corp.
CENTRAFLEX, Flexographic press, Kidder-Stacy Co.
CENTRI-BOND, Bimetallic cylinders, Wisconsin Centrifugal, Inc.
CENTRIDYNE, Particle reduction, classification equipment, Composite Materials & Mfg. Div., Entoleter, Inc.
CENTRIFIELD, Air pollution control systems, Composite Materials & Mfg. Div., Entoleter, Inc.
CENTRIMIL, Particle reduction equipment, Composite Materials & Mfg Div., Entoleter, Inc.
CENTRY, Process control instrumentation, Leeds & Northrup Co.
CENTURY, Laboratory flowmeters, Fischer & Porter Co.
CERAMO, Ceramic insulated thermocouple element, Thermo Electric
CERAMOCOUPLE, Thermocouples, Thermo Electric
CERTIMESH, Woven wire mesh, Pall Corp.
CHAPMAN, Static eliminators, Portland Co.
CHARGEMASTER, Static charge generators, Simco Co.
CHEL, Chelating agent, CIBA-GEIGY Corp., Plastics & Additives Div.
CHEM CARB, Calcium carbonate, Engelhard Minerals & Chemicals Corp., Minerals & Chemicals Div.
CHEM-GUARD, Chemical resistant laminate, Woodall Industries, Inc.
CHEM-O-FEEDER, Metering pump, B I F, a Unit of General Signal
CHEM-o-SEAL, Rubber-based emulsions, Chemical Products Div., CPL Corp.
CHEM-o-SET, Crosslinked PVC dispersion, Chemical Products Div., CPL Corp.
CHEM-o-SOL, PVC plastisol, Chemical Products Div., CPL Corp.
CHEM-o-THANE, Polyurethane elastomer casting compounds, Chemical Products Div., CPL Corp.
CHEM-SEAL, Decorative chemical resistant laminate, Woodall Industries, Inc.
CHEM VAC, Portable pneumatic conveyor, Dunbar Kapple, Inc.
CHEMACOIL, Synthetic drying oils, Commercial Solvents Corp.
CHEMCERAM, High-temperature ceramic binder & foam, Whittaker Corp., R & D Div.
CHEMEX, Expansion joints, Uniroyal, Inc.
CHEMFLUOR, Fluorocarbon plastics, Chemplast, Inc.
CHEMFOAM, Plastic foams, Toyad Corp.
CHEMGLAZE, Polyurethane-based coating materials, Hughson Chemicals, Lord Corp.
CHEMGRIP, Epoxy adhesives for TFE, Chemplast, Inc.
CHEMICAT, Polyethylene-imine, Alcolac Inc.
CHEMIQUAT, Quaternized polyethylene-imine, Alcolac Inc.
CHEMLINK, Polyfunctional acrylic & methacrylic monomers, Ware Chemical Corp.
CHEMLOK, Adhesives, Hughson Chemicals, Lord Corp.
CHEMPOL, Protective coatings & polyurethane foam resins, Freeman Chemical Corp., Div. H. H. Robertson Co.
CHEM SHEAR, High shear impeller, Chemineer, Inc.
CHERATOLO, Straight phenol resins, Montedison S.p.A.
CHILSONATOR, Densifying equipment for powders, Fitzpatrick Co.
CHLOREZ, Resin chloroparaffins, Dover Chemical Corp.
CHLOROWAX, Chlorinated paraffins, Diamond Shamrock Chemical Co., Plastic Div.
CHLORPARAFFINE, Chlorinated paraffines, Farbwerke Hoechst AG
CHROMA-PAC, Color-matching computer programs, Applied Color Systems, Inc.
CHROMACYL, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
CHROMALOX, Heaters, dries, oven equipment, controls, etc., Wiegand, Edwin L., Div. Emerson Electric Co.
CHROMAR, Metallized plastics film, Kurz-Hastings, Inc.
CHROMTEX, Metallized plastics transfer film, Kurz-Hastings, Inc.
CIMGLAS, Fiberglass-reinforced polyester moldings, Cincinnati Milacron, Molded Plastics Div.
CINEMOID, Cellulose acetate sheet, British Celanese Ltd.

Trademarks and brand names (Cont'd)

CIRCUIT PAK, Hydraulic power units, Mr. D. W. Van Auker, Publications Manager
CIRCULATIC, Steam generators, Vapor Corp., Va-Power Div.
CLAR/ESCENT, Fluorescent pigments, Claremont Polychemical Corp.
CLARECHEM, Vinyl stabilizers, Claremont Polychemical Corp.
CLARIFOIL, Cast cellulose acetate film, British Celanese Ltd.
CLARION, Acid azo red pigment, American Cyanamid Co., Pigments Div.
CLARITEX, Wire-reinforced cellulose acetate sheeting, British Celanese Ltd.
CLEAN WIZ, Mold cleaners, Axel Plastics Research Laboratories, Inc.
CLEAR-PAK, Blister sealing machine, Abbott Machinery Div., U. S. Packaging Corp.
CLIDERITE, Potting compound, Thermo Cote, Inc.
CLIMATE LAB, Environmental control chambers, cabinets, American Instrument Co., Div. Travenol Laboratories, Inc.
CLOCEL, Rigid urethane foam systems, Baxenden Chemical Co.
CLOPANE, PVC film & tubing, Clopay Corp., Plastic Film Div.
CLOUDFOAM, Polyurethane foam, International Foam Div., Holiday Inns, Inc.
CO-MER-7, Polyamide ester, Nypel, Inc.
CO-REZYN, Polyester resins & gel coats; pigment pastes, Interplastic Corp., Commercial Resins Div.
COBOCELL, Cellulose acetate butyrate tubing, Cobon Plastics Corp.
COBOFLOW, Teflon tubing, Cobon Plastics Corp.
COBONOL, Polyethulene tubing, Cobon Plastics Corp.
COBOTHANE, Ethylene-vinyl acetate tubing, Cobon Plastics Corp.
COLANYL, Pigment preparations, Farbwerke Hoechst AG.
COLANYL, Pigment dispersions, American Hoechst Corp., Dyes & Pigments Div.
COLLACRAL, Acrylic polymers & copolymers, Badische Anilin- & Soda-Fabrik AG
COLMONOY, Hard-surfacing & brazing alloys, Wall Colmonoy Corp.
COLOR-O-METER, Color proportioner, Wilson Products Co.
COLORATOR, Indicating filter, Marvel Engineering Co.
COLORFLOW, Control valves, Parker-Hannifin Corp.
COLORGARD, Reflectometer/colorimeter, Gardner Laboratory Inc.
COLORIT, Pigment stamping foil, Kurz-Hastings, Inc.
COLORMATCH, Pigment dispersions, Plasticolors, Inc.
COLORMATE 2000, Color measuring instrument, Neotec Corp.
COM-BIN FEEDER, Rotating bin feeder, Pulva Corp.
COMET, Thermoforming machines, Comet Industries, Inc.
COMPACT, Continuous flow screen changer, Beringer Co.
COMPLEXIFORM, Large hollow extrusions, Anchor Plastics Co.
COMPO-DESMA, Injection molding machines, Compo Industries, Inc., IVC Div.-Industrial
COMPO-FIT, High frequency flow molding machinery, Compo Industries, Inc., IVC Div.-Industrial
COMPUTER COLOR, Computerized color matching process, Reed Plastics Corp.
COMPUTREATER, Laboratory & pilot line for cord & strand impregnation & treating, Litzler, C. A., Co.
CON-STA-FLO, Continuous flow automatic filter, Beringer Co.
CONACURE, Curing agents, Conap, Inc.
CONAFORM, Vacuum dryer, Patterson Industries Inc.
CONATHANE, Polyurethane casting, potting, tooling & adhesive compounds, Conap, Inc.
CONCRESIVE, Adhesives, Adhesive Engineering Co.
DONDUX, Electrical conductive elastomers, Hardman, Inc.
CONE-VERTICAL, Mixer, Atlantic Research Corp.
CONOFLEX, Flexible decorative laminate, Conolite Div., Woodall Industries, Inc.
CONOLITE, Polyester laminate, Woodall Industries, Inc.
CONOLITE, Flexible plastic laminate, Conolite Div., Woodall Industries, Inc.
CONSOTROL, Pneumatic, electronic instrumentation, Foxboro Co.
CONTROLPAC, Sequential & programmable control systems, Eagle Signal, a Systems Div. G. & W. Industries
CONVELOADER, Hardness tester, Shore Instrument & Mfg. Co.
CONVEYANSCREEN, Electromagnetic screens for materials separating, Jeffrey Mfg. Co.
CONVIMETER, Rotational process viscometer, Brabender, C. W., Instruments, Inc.
COPAR, Adhesive base resin, Velsicol Chemical Corp., Resin Products Div.
COPPERCONE, Silicone rubber dies, sheet, rollers, Gladen Enterprises Div., Hayes-Albion Corp.
COPY CAST, Molding compounds, Schramm Fiberglass Products Div., High Strength Plastics Corp.
CORDO, PVC foam & films, Ferro Corp., Composites Div.
CORDOGLAS, Coated fabrics, Ferro Corp., Composites Div.
CORDOPREG, Pre-pregs, Ferro Corp., Composites Div.
CORLITE, Reinforced foam laminate, Snark Products, Inc.
CORO-FOAM, Urethane foam systems, Cook Paint & Varnish Co.
CORRDUCT, Corrugated tubing, OEM Corp.
CORRDUIT, Corrugated tubing, OEM Corp.
CORRTUBE, Corrugated tubing, OEM Corp.
CORVEL, Fusion bond finishes, Polymer Corp.
CORVIC, Vinyl polymers & copolymers, Imperial Chemical Industries Ltd., Plastics Div.
COSMIC BLACK, Fine bone black pigment, Ebonex Corp.

Trademarks and brand names (Cont'd)

COSMO-CHROME, Heat sealing machines, Cosmos Electronic Machine Corp.
COSMOLINE, Rust preventitives, Houghton, E. F., & Co.
COURLOSE, Water-soluble cellulose ethers, British Celanese Ltd.
COVERLIGHT, Coated nylon fabric, Reeves Brothers, Inc.
COVICOL, Vinyl compounds, Colcarburo S. A.
CPF SYSTEM, Continuous polymer filter, Fluid Dynamics, Div. Brunswick Corp.
CRESPOR, Poromerics, Crespi, Biovanni, S.pA.
CRESTAPOL, Polymeric plasticizers, Scott Bader Co.
CRILAT, Acrylic polymer solutions & emulsions, Montedison S.p.A.
CROFON, Light guides, Du Pont de Nemours, E. I., & Co.
CROMOPHTAL, Organic pigments, CIBA-GEIGY Corp., Plastics & Additives Div.
CROSS PLASTIC, Oriented HDPE film laminate, Van Leer Plastics (U.S.A.) Inc.
CRYORAP, Packaging material, Cryovac Div., W. R. Grace & Co.
CRYSTIC, Unsaturated polyester resins, Scott Bader Co.
CUMAR, Coumarone-indene resins, Neville Chemical Co.
CURASTAT, Electronic static eliminator, Herbert Products, Inc.
CURENE, Organo tin compounds, Anderson Development Co.
CURITHANE (SERIES), Polyaniline polyamine, tertiary amines, Upjohn Co., Polymer Chemicals Div.
CURON, Polyurethane foam, Reeves Brothers, Inc.
CYAGARD, Flame retardant, American Cyanamid Co., Organic Chemicals Div.
CYAN, Phthalocyanine pigments, American Cyanamid Co., Pigments Div.
CYANADUR, Organic pigments, American Cyanamid Co., Pitments Div.
CYANAPRENE, Polyurethane, American Cyanamid Co., Organic Chemicals Div.
CYANOLIT, Cyanoacrylate adhesive, Leader, Denis, Ltd.
CYASORB, Light absorber, American Cyanamid Co., Organic Chemicals Div.
CYCL-FLEX, Reset timer/counter, Eagle Signal, a Systems Div. G. & W. Industries
CYCLO BLOWER, Positive displacement blower, Gardner-Denver Co.
CYCLO-JET, Single-unit rotating anvil-jet mill, Fluid Energy Processing & Equipment Co.
CYCLO/PHRAM, Metering pumps, Yarway Corp.
CYCLOMATIK, Straight knife cutter, Maimin, H., Co.
CYCLON, Round knife cutter, Maimin, H., Co.
CYCLONOX, Polyester curing agents, Akzo Chemie Nederland bv
CYCLOLAC, ABS resins, Plastics, Borg-Warner Chemicals, Borg-Warner Corp.
CYCLOLOY, Alloys of synthetic polymers with ABS resins, Plastics, Borg-Warner Chemicals, Borg-Warner Corp.
CYCOPAC, ABS resins, Packaging Resins, Borg-Warner Chemicals, Borg-Warner Corp.
CYCOVIN, Self-extinguishing ABS graft polymer blends, Plastics, Borg-Warner Chemicals, Borg-Warner Corp.
CYGLAS, Glass-filled polyester molding compound, American Cyanamid Co., Industrial Chemicals & Plastics Div.
CYMEL, Melamine molding compounds; crosslinking agents, American Cyanamid Co., Industrial Chemicals & Plastics Div.

D-FILM, Packaging material, Cryovac Div., W. R. Grace & Co.
DABCO, Triethylenediamine, Air Products & Chemicals, Inc., Chemical Additives Div.
DACOVIN, PVC compounds, Diamond Shamrock Chemical Co., Plastic Div.
DAIFLON, CTFE molding powders, pellets, dispersions, Daikin Kogyo Co.
DALAMAR, Pigment dyestuff, Du Pont de Nemours, E. I. & Co.
DALTOFLEX, Urethanes, ICI America Inc.
DAPON, Diallyl phthalate resins, FMC Corp., Organic Chemicals Div.
DARAN, Polyvinylidene chloride emulsion coatings, Grace, W. R., & Co., Organic Chemicals, Dewey & Almy Chemical Div.
DARATAK, Polyvinyl acetate homopolymer emulsions, Grace, W. R., & Co., Organic Chemicals, Dewey & Almy Chemical Div.
DAREX, Styrene-butadiene latices, Grace, W. R., & Co., Organic Chemicals, Dewey & Almy Chemical Div.
DARVIC, PVC sheet, Imperial Chemical Industries Ltd., Plastics Div.
DAUBOND, Epoxy, urethane & elastomer adhesives, Daubert Chemical Co.
DAVENITE, Wet ground mica, Hayden Mica Co., Div. Franklin Mineral Products
DAXAD, Pigment dispersants, Grace, W. R., & Co., Organic Chemicals, Dewey & Almy Chemical Div.
DAXCEL, Adhesive, Dacar Chemical Products Co.
DAXCEL FOAMASTIK, Adhesive & vapor barrier, Dacar Chemical Products Co.
DAXCEL FOAMGUARD, Protective coatings for foams, Dacar Chemical Products Co.
DAYMAX, Disperser, Day, J. H., Co.
DEBRON (SERIES), Coatings, de Beers Laboratories, Inc.
DEC-O-GRAM, Laboratory balance, Ohaus Scale Corp.
DECANOX, Organic peroxide catalysts, Lucidol Div., Pennwalt Corp.
DECHLORANE, Fire retardant additive, Hooker Chemicals & Plastics Corp.
DECOLA, Melamine decorative laminates, Sumitomo Bakelite Co.
DECOLAR, Printed decorative laminate, Rexham Corp.
DECOLITE, Reinforced plastic panels, Reichhold Chemicals, Inc.
DECONYL, Nylon coating powders, Plastic Coatings Ltd.
DEE-TAC, Detackifiers, Polychem Dept., Stepan Chemical Co.

Trademarks and brand names (Cont'd)

DEECY, Vinyl plasticizers, Reichhold Chemicals, Inc.
DEKOR, Multi-color heat transfers, Kurz-Hastings, Inc.
DEKORON, Plastic extrusions, Moore, Samuel, & Co.
DELRIN, Acetal resin, Du Pont de Nemours, E. I., & Co.
DELTADYNE, Gauges, indicators, Pall Corp.
DENFLEX, PVC plastisols, primers; polyurethanes; PVC powders; epoxies, Dennis Chemical Co.
DENSITROL, Liquid density recording, indicating, controlling instrument, Princo Instruments Inc.
DEPLASTOL, Viscosity depressant/deaerating agent, Henkel International GmbH
DERAKANE, Vinyl ester resins, Dow Chemical Co.
DERAKANE, Thermoset-reinforced plastics, Dow Chemical Co.
DEROTON, Polyester molding compound. Imperial Chemical Industries Ltd., Plastics Div.
DESCOVIL, Supported PVC sheeting, Crespi, Giovanni, S.p.A.
DESMOCOLL, Polyurethane resins, Mobay Chemical Co., Div. Baychem Corp.
DESMODUR, Isocyanates for polyurethane foam, Farbenfabriken Bayer AG
DESMODUR, Polyisocyanates, Mobay Chemical Co., Div. Baychem Corp.
DESMOFLEX, Polyurethane casting resin, Farbenfabriken Bayer AG
DESMOPAN, Thermoplastic polyurethane elastomer, Farbenfabriken Bayer AG
DESMOPHEN, Polyesters & polyethers for polyurethane foam, Farbenfabriken Bayer AG
DESMORAPID, Promoters for polyurethanes, Farbenfabriken Bayer AG
DEWCEL, Humidity sensing element, Foxboro Co.
DEXEL, Cellulose acetate molding powders, British Celanese Ltd.
DIAKON, Acrylic polymers & compounds, Imperial Chemical Industries Ltd., Plastics Div.
DIAL-O-GRAM, Laboratory balance, Ohaus Scale Corp.
DIALLOY, Diamond coated bandsaws, Dia-Chrome, Inc.
DIARON, Melamine resins, Reichhold Chemicals, Inc.
DIE-DRAULIC, Hydraulic fluid stamping cushioning, Pall Corp.
DIELUX, Acetal, Westlake Plastics Co.
DIENITE, Polybutadiene thermosetting resin, Firestone Synthetic Rubber & Latex Co.
DIGIMITE, Digital pyrometer, Thermo Electric
DIOFAN, Copolymer PVDC, BASF Wyandotte Corp.
DIOFAN, Vinylidene chloride copolymers, Badische Anilin- & Soda-Fabrik AG
DIOLEN, Polyester, Akzo Plastics bv
DION, Polyester resins, Diamond Shamrock Chemical Co., Plastic Div.
DISFLAMOLL, Phosphate plasticizers, Farbenfabriken Bayer AG
DISPERSONIC, Ultrasonic homogenizing mixer, Sonic Corp., Div. of General Signal
DISTRIBUT-AIR, Compressed air distribution system, Gardner-Denver Co.
DODGE, Expansion insert, Heli-Coil Products, Div. Mite Corp.
DORVON, Molded polystyrene foam, Dow Chemical Co.
DORYL, Dephenol oxide resin, Westinghouse Electric Corp./Industrial Plastics Div.
DOT WELDER, Machine for repair of mold defects. Mid-States Welder Mfg. Co.
DOUBLE/BUBBLE, Disposable packages for two-part reactive liquids, Hardman, Inc.
DRACCO, Dust collecting equipment, Fuller Co.
DRAKEOL, White mineral oil, Penreco, Div. Pennzoil Co.
DRAPEX, Epoxy plasticizers for PVC, Argus Chemical Corp., Sub. Witco Chemical Corp.
DRI-LITE, Expanded polystyrene, Poly Foam, Inc.
DRIKALITE, Calcium carbonate, Thompson, Weinman & Co.
DRY-O-LITE, Desiccant, Van-Air Inc.
DRYCA-FLO, Dry ground calcium carbonates, Sylacauga Calcium Products Co.
Du-COLOR, Color difference meter, Neotec Corp.
DUAL-TROL, Recycling timer control devices, Industrial Timer Corp., A Unit of Esterline Corp.
DUCO, Lacquers, Du Pont de Nemours, E. I., & Co.
DUCTROLENE, Thermoplastic tubular shapes, Sipler Plastics, Inc.
DUCTRON, Reinforced tubular shapes, Sipler Plastics, Inc.
DUO-MIX, 2-component material mixer, Pyles Industries, Inc.
DUOL, Lithol rubine, Du Pont de Nemours, E. I., & Co.
DUOROTO, Rotogravure inks, Gotham Ink & Color Co.
DUPLIMATIC, Insert molding machines, Reed-Prentice Div., Package Machinery Co.
DURA BEAUTY, Decorative laminate, Consoweld Corp.
DURAFRESH, Bacteriostat & fungicide, Sanitized Sales Co. of America, Inc.
DURAGENIC, Bacteriostat & fungicide, Sanitized Sales Co. of America, Inc.
DURAGOLD, Bronze powders, Claremont Polychemical Corp.
DURAL, Acrylic-modified rigid PVC compounds, Alpha Chemical & Plastics Corp.
DURAMAC, Oil-modified alkyds, Commercial Solvents Corp.
DURAMITE, Calcium carbonate, Thompson, Weinman & Co.
DURAPLEX, Alkyd resins, Rohm & Haas Co.
DURATHON, Polybutylene resins, Witco Chemical Corp., Polymer Div.
DURATRON, Polymers, Shell Chemical Co.
DURELENE, PVC flexible tubing, Auburn Plastic Engineering, Div. Plastic Warehousing Corp.

Trademarks and brand names (Cont'd)

DURETHAN, Nylon 6, Farbenfabriken Bayer AG
DURETHENE, Polyethylene film, ARCO Polymers, Inc.
DURIBBON, Sealants, National Adhesives Div., National Starch & Chemical Corp.
DURO-LOK, Resin-based adhesive, National Adhesives Div., National Starch & Chemical Corp.
DUROCALIBRATOR, Durometer calibrator, Shore Instrument & Mfg. Co.
DUTRAL-CO, Ethylene-propylene elastomers, Montedison S.p.A.
DUTRAL-TER, Ethylene-propylene-diene elastomers, Montedison S.p.A.
DYALON, Urethane elastomer material, Thombert, Inc.
DYLAN, Low- & medium-density polyethylene, ARCO Polymers, Inc.
DYLARK, Styrene copolymer, ARCO Polymers, Inc.
DYLENE, Polystyrene resin & oriented sheet, ARCO Polymers, Inc.
DYLEX, Latex, ARCO Polymers, Inc.
DYLITE, Expandable polystyrene beads, extruded sheet, etc., ARCO Polymers, Inc.
DYMETROL, Continuous precision forms, Du Pont de Nemours, E. I., & Co.
DYNA-SWITCH, Overload prevention device, Dillon, W. C., & Co.
DYNAC, Injection molding control system, Dynisco
DYNADUR, Unplasticized PVC tubes, sheets, rods, Dyanmit Nobel, A.G.
DYNAFORM, Metal dies for heat sealing, Guild Electronics, Inc.
DYNAGUIDE, Web guide controller, GPE Controls
DYNAGUIDER, Guide rolls for web control, GPE Controls
DYNALEN, Polyethylene tubes, Dynamit Nobel, A.G.
DYNALLOY, Stainless fiber filter media, Fluid Dynamics, Div. Brunswick Corp.
DYNALOG, Recorder/potentiometer, Foxboro Co.
DYNAPLAN, Sheets; decorative laminates, Dynamit Nobel, A.G.
DYNAPOL, Polyethylene terephthalate copolymers, Dynamit Nobel, A.G.
DYNATHERM, Sealing machines, Guild Electronics, Inc.
DYNATROL, Measurement & control equipment, Automation Products, Inc.
DYNOS, Vulcanized fibre sheets & bars, Dynamit Nobel, A.G.
DYNOS, Vulcanized fibre, Dynamit Nobel of America Inc.

E-COL-O-FLO, Dip coatings, Armitage, John L., & Co.
E-COL-O-GARD, Roller coating coating, Armitage, John L., & Co.
E-COL-O-HIDE, Coatings, Armitage, John L., & Co.
E-COL-O-TEX, Textured coatings, Armitage, John L., & Co.
E-Z OUT, Material handling equipment, Jeffrey Mfg. Co.
EASTOBOND, Solvents, Eastman Chemical Products, Inc., Sub. Eastman Kodak Co.
EASTONAIR, Deodorant systems, Purethane Div., Easton RS Corp.
EASTOZONE, Antiozonants, Eastman Chemical Products, Inc., Sub. Eastman Kodak Co.
EASY-KOTE, Fluorocarbon release compound, Borco Chemicals, Inc.
EASY RELEASE, Chromium-fluorocarbon release finish, Mirror Polishing & Plating Co.
EASY RELEASE, Chromium/fluorocarbon release finish, Plasma Coatings, Inc., Div. Mirror Polishing & Plating Co.
EASYPOXY, Epoxy adhesive kits, Conap, Inc.
ECCOBOND, Adhesives, Emerson & Cuming, Inc.
ECCOCERAM, Ceramic dielectrics, Emerson & Cuming, Inc.
ECCOCOAT, Surface coatings, Emerson & Cuming, Inc.
ECCOFLO, Powders & fluid dielectrics, Emerson & Cuming, Inc.
ECCOFOAM, Plastic, ceramic, silicone foams, Emerson & Cuming, Inc.
ECCOGEL, Plastic gel, Emerson & Cuming, Inc.
ECCOMOLD, Molding compounds, Emerson & Cuming, Inc.
ECCOSEAL, Impregnating resins, Emerson & Cuming, Inc.
ECCOSIL, Silicone resins, Emerson & Cuming, Inc.
ECCOSORB, Microwave absorber, Emerson & Cuming, Inc.
ECCOSPHERES, Hollow glass, ceramic, plastic spheres, Emerson & Cuming, Inc.
ECCOSTOCK, Plastic rod & sheet, Emerson & Cuming, Inc.
ECONO FLO, 2-component meter-dispenser, Pyles Industries, Inc.
ECONOFILM, Blown film extrusion system, Hobbs-Williams Machinery Ltd.
ECONOFILM, Blown film extrusion system, Davis-Standard/Goulding/Hobbs Divs., Crompton & Knowles Corp.
ECONOMASTER, Extruder, Davis-Standard/Goulding/Hobbs Divs., Crompton & Knowles Corp.
ECONOSHOT, Limited shot meter dispenser, Pyles Industries, Inc.
ECONOSONIC, Ultrasonic homogenizing mixer, Sonic Corp., Div. of General Signal
EDENOL, Primary & secondary plasticizer, Henkel International GmbH
EDILAC, Polyvinyl acetate copolymer dispersions, Montedison S.p.A.
EDISOL M, Edible, water-soluble film, Polymer Films, Inc.
EDISTIR, Polystyrene, Montedison S.p.A.
EDIVIL, Polyvinyl acetate homopolymer dispersions, Montedison S.p.A.
EDOLITE, Phenolics, Mitsubishi Gas Chemical Co.
EKAVYL, Polyvinyl chloride, Plastimer, S. A.

Trademarks and brand names (Cont'd)

EKTASOLVE, Solvents, Eastman Chemical Products, Inc., Sub. Eastman Kodak Co.
EL REXENE, Polyethylene, polypropylene, polystyrene & ABS resins, Rexene Polymers Co., Div. Dart Industries, Inc., Chemical Group
ELAPRIM-AR, Chlorine-free acrylic elastomomers, Montedison, S.p.A.
ELAPRIM-D, Butadiene-acrylonitrile copolymers, Montedison S.p.A.
ELAPRIM-S, Butadiene,acrylonitrile elastomers, Montedison S.p.A.
ElastaCAST, Liquid urethane process, Acushnet Co.
ELASTOLUR, Urethane elastomer coatings, BASF Wyandotte Corp.
ELASTONATE, Isocyanate prepolymers, BASF Wyandotte Corp.
ELASTONEL, Urethane curvatives, BASF Wyandotte Corp.
ELASTONOL, Polyester Polyols, BASF Wyandotte Corp.
ELASTOSIL, Silicone sealants, Wacker-Chemie GmbH
ELECTRA-SCREW, Helical screw air compressor, Gardner-Denver Co.
ELECTRO, Treated calcium carbonate, Calcium Carbonate Co.
ELECTRO CUT, Flying die extrusion cutters, Automatic Electronic Machines Corp.
ELECTROCAL, Multi-color imprinting, Noble & Westbrook, Div., The Bristol Brass Corp.
ELECTROGLAS, Cast acrylic sheet, rod, tube, Glasflex Corp.
ELECTROGRIP, Diamond plated wheels & tools, Engis Corp.
ELECTROMAX, Signaling controllers, Leeds & Northrup Co.
ELECTROMESH, Wire mesh heating elements, Electrofilm, Inc.
ELECTROSOL, Antistatic agents, Alframine Corp.
ELFTEX, Fluffy furnace carbon black, Cabot Corp., Special Blacks Div.
ELPH, Digital thermocouple indicator, Thermo Electric
ELTEX, High density polyethylene, Solvay & Cie S.A.
ELVACE, Acetate-ethylene copolymers, Du Pont de Nemours, E. I., & Co.
ELVACET, Polyvinyl acetate emulsions, Du Pont de Nemours, E. I., & Co.
ELVACITE, Acrylic resins, Du Pont de Nemours, E. I., & Co.
ELVAMIDE, Nylon resins, Du Pont de Nemours, E. I., & Co.
ELVANOL, Polyvinyl alcohols, Du Pont de Nemours, E. I., & Co.
ELVAX, Vinyl resins; acid terpolymer resins, Du Pont de Nemours, E. I., & Co.
EM PEE, Flame-retardant plastics, Monmouth Plastics, Inc.
EMBAFILM B, Cellulose acetate butyrate film, May & Baker, Ltd.
EMFAB, Coated/impregnated fabrics, Pallflex Products Corp.
EMSODUR, Abrasive finishing media, Emser Werke A.G.
EMTAL, Talc & serpentine bearing talc, Engelhard Minerals & Chemicals Corp., Minerals & Chemicals Div.
ENKA PERLON, Polyamide 6, Akzo Plastics bv
ENKALON, Polyamide 6, Akzo Plastics bv
ENPLATE, Processes for plating on plastics, Enthone, Inc., Sub American Smelting & Refining Co.
ENSOCOTE, PVC lacquer coating, Uniroyal, Inc.
ENSOLITE, Cellular plastic sheet material, Uniroyal, Inc.
ENVIROSTAT, Area static eliminators, Simco Co.
EPI-CURE, Curing agents for epoxy resins, Celanese Resins, Div. Celanese Coatings Co.
EPI-REZ, Basic epoxy resins, Celanese Resins, Div. Celanese Coatings Co.
EPI-TEX, Epoxy ester resins, Celanese Resins, Div. Celanese Coatings Co.
EPIBOND, Adhesives, Furane Plastics, Inc.
EPIKOTE, Epoxy resin, Shell Chemical Co.
EPILINK, Epoxy curing agent, Akzo Chemie, Interstab Dept.
EPO-TEK, Epoxies, Epoxy Technology, Inc.
EPOCAP, Two-part epoxy compounds, Hardman, Inc.
EPOCAST, Epoxies, Furane Plastics, Inc.
EPOCEL, Filter cartridges, Pall Corp.
EPOCRETE, Two-part epoxy materials, Hardman, Inc.
EPOCRYL, Epoxy acrylate resin, Shell Chemical Co.
EPOCURE, Epoxy curing agents, Hardman, Inc.
EPODITE, Epoxy resin, Showa Highpolymer Co.
EPOLAST, Two-part epoxy compounds, Hardman, Inc.
EPOLENE, Low-molecular-weight waxes, Eastman Chemical Products, Inc., Sub. Eastman Kodak Co.
EPOLITE, Epoxy compounds, Hexcel Corp., Rezolin Div.
EPOMARINE, Two-part epoxy compounds, Hardman, Inc.
EPON, Epoxy resin; hardener, Shell Chemical Co.
EPONOL, Lincar polyether resin, Shell Chemical Co.
EPOSET, Two-part epoxy compounds, Hardman, Inc.
EPOTUF, Epoxy resins, Reichhold Chemicals, Inc.
EPOWELD, Two-part epox compounds, Hardman, Inc.
EPOXER, Dispensing equipment for catalized resins, Kenics Corp.
EPOXI-PATCH, Adhesive, Hysol Div., Dexter Corp.
EPOXICAL, Formulated epoxy resins, United States Gypsum Co.
EPOXOL, Plasticizers, stabilizers, Swift Chemical Co., Div. Swift & Co.

Trademarks and brand names (Cont'd)

ERAMIDE, Slip & anti-block agent, Fine Organics, Inc.
ERVADIOL, Unsaturated polyester resins, Plastimer, S.A.
ERVAMIX, Polyester molding compound, Plastimer, S.A.
ERVAPHENE, Phenolic resins, Plastimer, S.A.
ERVAPON, Polyester resins, Plastimer, S.A.
ERVAPREG, Polyester pre-pregs, Plastimer, S.A.
ESPEROX, Organic peroxide catalysts, U. S. Peroxygen Div., Witco Chemical Corp.
ESTABEX, Heat/light stabilizers, Akzo Chemie Nederland bv
ESTABEX (SERIES), Fungicides, bacteriocides & secondary plasticizers, Akzo Chemie, Interstab Dept.
ESTANE, Polyurethane resins & compounds, Goodrich, B. F., Chemical Co.
ESTOLAN, Polyesters for urethanes, Lankro Chemicals Ltd.
ETHAFOAM, Polyethylene foam, Dow Chemical Co.
ETHALIN, Flexographic inks, Gotham Ink & Color Co.
ETHOCEL, Ethyl cellulose resin, Dow Chemical Co.
ETHOFIL, Fiberglass reinforced polyethylene, Fiberfil Div., Dart Industries, Inc.
ETHYLUX, Polyethylene, Westlake Plastics Co.
EURO-MATIC, Blow molding machines, Euro-Matic, European Plastic Machinery Mfg. A/S
EVATANE, Ethylene/vinyl acetate copolymers, Imperial Chemical Industries, Ltd., Plastics Div.
EVAZOTE, Expanded EVA foam, Bakelite Xylonite Ltd.
EVEN-TEMP, Platen with uniform temperature, Custom Engineering Co.
EVENFLO, Anilox rolls, Pamarco, Inc.
EVENGLO, Polystyrene resin, ARCO Polymers, Inc.
EVERFLEX, Polyvinyl acetate copolymer emulsions, Grace, W. R., & Co., Organic Chemicals, Dewey & Almy Chem. Div.
EVERGOLD, Bronze powder, Atlantic Powdered Metals, Inc.
EXALIN, Flexographic inks, Gotham Ink & Color Co.
EXCELITE, Polyethylene tubing, Thermoplastic Processes, Inc.
EXCELLO WHITE, Micronized calcium carbonate, Tammus Industries Co.
EXCELON, Vinyl tubing, Thermoplastic Processes, Inc.
EXPANDEX, High temperature foamer, Polychem Dept., Stepan Chemical Co.
EXPANDOMATIC, pH measuring instruments, Beckman Instruments, Inc.
EXTREL, Plastic films, Exxon Chemical Co. U. S. A.
EXTREN, Glass fiber-reinforced polyester shapes, Morrison Molded Fiber Glass Co.
EXTRU-BOARD, Corrugated polypropylene sheet, Extrudyne, Inc.
EXTRU-FOAM, Rigid PVC foam extrusions, Extrudyne, Inc.
EXTRU-GLAZ, Rigid PVC corrugated sheet, Extrudyne, Inc.
EXTRUD, Extrusion simulation program, Scientific Process & Research Inc.
EXTRUSIOGRAPH, Modular extrusion instrument, Brabender, C. W., Instruments, Inc.

FABMAT, Chopped & woven glass reinforcement, Fiber Glass Industries, Inc.
FADE-OMETER, Light fastness tester, Atlas Electric Devices Co.
FASSGARD, Vinyl coating on nylon, Fassler, M. J. & Co.
FASSLOID, Laminates film to fabric, Fassler, M. J., & Co.
FASSLON, Vinyl coating, Fassler, M. J., & Co.
FASSLUX, Vinyl coating, Fassler, M. J., & Co.
FASSOPAQUE, Acrylic coating, Fassler, M. J., & Co.
FASSTIC, Vinyl coating, Fassler, M. J., & Co.
FASSWELD, Plastic laminations, Fassler, M. J., & Co.
FEEDOWEIGHT, Conveyor weigh-feeder, Merrick Scale Mfg. Co.
FELOW, Nylon filaments, Du Pont de Nemours, E. I., & Co.
FERRO-TIC, Steel bonded, machinable carbide, Sintercast Div., Chromalloy Corp.
FERROFILTER, Magnetic separator, Frantz, S. G., Co.
FERROTRON, Ferromagnetic plastic induction hardening material, Polypenco Ltd.
FERROTRON, Ferromagnetic materials, Polymer Corp.
FIBERCORE, Premix molding compounds, Plumb Chemical Corp.
FIBERMASTER, Extruder for fibers, Davis-Standard/Goulding/Hobbs Divs., Crompton & Knowles Corp.
FIBR-SAVR, Web trimming collection system, Rando Machine Corp.
FILAWOUND, Glass filament windings, Spaulding Fibre Co.
FILESTER, Melt-soluble colorant for polyester, CIBA-GEIGY Corp., Plastics & Additives Div.
FILMPRINTER, Flexographic press, Kidder-Stacy Co.
FILOMAT, Glass thermal blanket, Fiber Glass Industries, Inc.
FILON-STRIPES, Multicolored FRP panels, Filon Div., Vistron Corp.
FILOPLATED, Gel-coated FRP panels, Filon Div., Vistron Corp.
FIREBRAKE ZB, Flame retardant synergist, U. S. Borax & Chemical Corp.
FIRECAL, Polyester pressure-sensitive labels, Topflight Corp.
FIREMASTER (SERIES), Flame retardants, Michigan Chemical Corp.
FIREROD, Electric cartridge heater, Watlow Electric Mfg.,Co.
FITZ-MILL, Pulverizing & granulation equipment, Fitzpatrick Co.

Trademarks and brand names (Cont'd)

FLAIR, Patterned plastic sheets, Rohm & Haas Co.
FLAKEGLAS, Foliated glass, Owens-Corning Fiberglas Corp.
FLAKELINE, Flake reinforced polyester coating, Ceilcote Co.
FLAMEOUT, Fire rated FRP panels, Filon Div., Vistron Corp.
FLAMITHANE, Flame retardant for polyurethane, Raychem Corp.
FLAMOLIN, Flame-retardant polyolefins, U. S. Industrial Chemicals Co., Div. National Distillers & Chemical Corp.
FLEX CAL, Polyester pressure-sensitive labels, Topflight Corp.
FLEX-CORE, Cellular core honeycomb, Hexcel
FLEX-DRUM, Abrasive brush, Merit Abrasive Products, Inc.
FLEX-LIP, Film & sheet extrusion die, Johnson Plastics Machinery Div., Leesona Corp.
FLEX-O-FILM, Plastic sheets, Flex-O-Glass, Inc.
FLEX-O-MATIC, Air couplers, Lincoln St. Louis, Div. McNeil Corp.
FLEX-O-PANE, Rigid plastic film & sheeting, Flex-O-Glass, Inc.
FLEX STRICTOR, Flexible lip sheet die, Johnson Plastics Machinery Div., Leesona Corp.
FLEXABEAM, Reverse roll coater, Egan Machinery Co.
FLEXALIN, Flexographic inks, Gotham Ink & Color Co.
FLEXAMATIC, Foam Machines, Sweets, Martin, Co.
FLEXAMINE, Antioxidant, Uniroyal, Inc.
FLEXAPORT, Mixing heads, Sweets, Martin, Co.
FLEXATHERM, Heater-coolers, Sweets, Martin, Co.
FLEXI-BRASS, Metal-like laminated extrusion, Anchor Plastics Co.
FLEXI-COPPER, Metal-like laminated extrusion, Anchor Plastics Co.
FLEXI-GOLD, Metal-like laminated extrusion, Anchor Plastics Co.
FLEXI-KROME, Metal-like laminated extrusion, Anchor Plastics Co.
FLEXICHEM, Metallic stearates, Swift Chemical Co., Div. Swift & Co.
FLEXICLOTH, Fiber reinforced plastic sheet, Flex-O-Glass, Inc.
FLEXIFEEDER, Flexible mechanical conveyor, Automatic Industrial Machines, Inc.
FLEXITORQ, Motors & generators, Allis, Louis, Div., Litton Industrial Products, Inc.
FLEXOCEL, Flexible urethane foam systems, Baxenden Chemical Co.
FLEXOL, Plasticizers, Union Carbide Corp., Chemicals & Plastics
FLEXOPRINTER, Flexographic press, Kidder-Stacy Co.
FLEXRICIN, Castor oil esters & plasticizers, NL Industries, Inc., Industrial Chemicals Div.
FLEXTOOTH, Pulverizers and crushers, Jeffrey Mfg. Co.
FLEXZONE, Antioxidant & antiozonant, Uniroyal, Inc.
FLITE-LESS, Injection screws IMS Co.
FLORANIER, Cellulose for cellulose esters, ITT Rayonier, Inc.
FLOTRAC, Pressure, temperature & transfer ram displacement instrumentation, Hull Corp.
FLOTUBE, Extruded tubing, Natvar Corp.
FLOWRATOR, Variable-area flowmeter, Fischer & Porter Co.
FLUIDAIRE, Fluidizing tanks for coating powders, Plastic Coatings, Ltd.
FLUOKEM, Teflon spray, Bel-Art Products
FLUON, PTFE powders & dispersions, Imperial Chemical Industries Ltd., Plastics Div.
FLUON, TFE resin, ICI America Inc.
FLUORGLAS, PTFE-coated & impregnated woven glass fabric, tapes, belting, Dodge Flourglas, Dodge Industries, Inc., Oak Materials Group, OAK Industries, Inc.
FLUOROBLACK, Compounds of TFE, Peabody Dore'
FLUOROBLUE, Compounds of TFE, Peabody Dore'
FLUOROBROWN, Compounds of TFE, Peabody Dore'
FLUOROCOMPS, Fluorocarbons fortified with glass or other fillers, LNP Corp.
FLUOROCORD, Fluorocarbon material, RM Friction Materials Co., Div. Raybestos-Manhattan, Inc.
FLUOROETCH, Fluoroplastics etchant, Acton Associates
FLUOROFILM, Cast Teflon films, Dilectrix Corp.
FLUOROGLIDE, Dry-film lubricant of TFE, Chemplast, Inc.
FLUOROGREEN, Compounds of TFE & FEP, Peabody Dore'
FLUORORAY, Filled fluorocarbon, RM Friction Materials Co., Div. Raybestos-Manhattan, Inc.
FLUORORED, Compounds of TFE, Peabody Dore'
FLUORORING, Molding powder, LNP Corp.
FLUOROSEAL, Pipe lubricant, Industrial Plastic Fabricators, Inc.
FLUOROSINT, TFE-fluorocarbon base composition, Polymer Corp.
FLUOROSINT, Mica-filled PTFE, Polypenco Ltd.
FLUOSITE, Phenol-formaldehyde molding powders, Montedison S.p.A.
FLYING-WEDGE, Metering, mixing & dispensing machine, Advanced Machine Planning, Inc.
FOAMASTER, Defoamers, Nopco Chemical Div., Diamond Shamrock Chemical Co.
FOAMASTER, Extruder for PVC foam, Hobbs-Williams Machinery Ltd.
FOAMASTER, Extruder for foamed plastics profiles, Davis-Standard/Goulding/Hobbs Divs., Crompton & Knowles Corp.
FOAMBOARDER, Equipment for producing cellular plastic board, Kornylak Corp.
FOAMGRAB, Adhesive, Dacar Chemical Products Co.

Trademarks and brand names (Cont'd)

FOILMARKER, Hand hot stamp tool, Service Tectonics, Inc.
FOME-BONDS, Adhesion promoters, Swift Chemical Co., Div. Swift & Co.
FOMECOAT, Spray coating for foams, Plastic Coatings Ltd.
FOMREZ, Urethane foam chemicals, Witco Chemical Corp., Organics Div.
FORMACOLOR, Color concentrate, Ametek/Westchester Plastics Div.
FORMADALL, Polyester premix compound, Woodall Industries, Inc.
FORMALDAFIL, Fiberglass reinforced acetal, Fiberfil Div., Dart Industries, Inc.
FORMAT, Bonded glass mat, Fiber Glass Industries, Inc.
FORMREZ, Urethane elastomer chemicals, Witco Chemical Corp., Organics Div.
FORMVAR, Polyvinyl formal resins, Monsanto Co.
FORTIFIED POLYMERS, Glass-reinforced thermoplastics, LNP Corp.
FORTIFLEX, Polyethylene resins, Celanese Plastics Co.
FOSTA, Molding & extrusion grade nylon, Foster Grant Co.
FOSTA-NET, Polystyrene foam extruded mesh, Foster Grant Co.
FOSTA-SOL, Vinyl toluene, Foster Grant Co.
FOSTA TUF-FLEX, High impact polystyrene, Foster Grant Co.
FOSTACRYL, Thermoplastic polystyrene resins, Foster Grant Co.
FOSTAFOAM, Expandable polystyrene beads, Foster Grant Co.
FOSTALENE, Plastic materials, Foster Grant Co.
FOSTALITE, Light-stable polystyrene molding powder, Foster Grant Co.
FOSTARENE, Polystyrene molding powder, FosterGrant Co.
FOSTORIA, Infrared equipment, Fostoria Industries Inc.
FOSTROL, Power controls, Fostoria Industries Inc.
FOTOPANEL, Thermostatic control, Powers Regulator Co.
FOURNIER, Woodgrain stamping foil, Kurz-Hastings, Inc.
FPC, PVC resins, compound, Firestone Plastics Co., Div. Firestone Tire & Rubber Co.
FRANPLAS, Sheets, rods, tubes, fabricated parts, Franklin Fibre-Lamitex Corp.
FREE WHEELING, Expander, Mount Hope Machinery Co.
FRESH-PAK, High density polyethylene film, UCB-Sidac
FRESHGARD, Bacteriostat & fungicide, Sanitized Sales Co. of America, Inc.
FRIGEN, Foaming agent, Farbwerke Hoechst AG.
FRIGID MIDGET, Chiller, Haake, Inc.
FROST-OFF, Frost preventive, Merix Chemical Co.
FULSCOPE, Pneumatic controllers, recorders, Taylor Instrument Process Control Div., Sybron Corp.
FULTON 404, TFE-lubricated acetal, LNP Corp.
FUNGITROL, Fungicide, Tenneco Chemicals, Inc., Organics & Polymers Div.
FYBEROID, Fishpaper, Wilmington Fibre Specialty Co.
FYROL, Flame retardants, Stauffer Chemical Co., Specialty Chemical Div.

G-WHITE, Ground calcium carbonate, Calcium Carbonate Co.
GABRASTER, Polyester resins, Montedison S.p.A.
GABRITE, Urea-formaldehyde molding powders, Montedison S.p.A.
GAFAC, Surfactants, GAF Corp.
GAFSTAT, Antistatic agents, GAF Corp.
GALVO/CORDA, Galvanometer/recorder, Tensitron, Inc.
GAMA-SPERSE, Calcium carbonate, Georgia Marble Co., Calcium Products Div.
GAMACO, Calcium carbonate, Georgia Marble Co., Calcium Products Div.
GANTREZ, Synthetic polymers, GAF Corp.
GARALEASE, Mold release agent, Ram Chemicals.
GARALYST, Peroxide catalyst, Ram Chemicals
GARDENIA, PVC sheeting, Crespi, Giovanni, S.p.A.
GARDLITE, Metal-reinforced plastic panels, Reichhold Chemicals, Inc.
GARDSMAN, Temperature controls, Measurement & Control Systems Div., West Instrument, Gulton Industries, Inc.
GAROX, Peroxide catalyst, Ram Chemicals
GEAR-PAK, Variable speed drive, Philadelphia Gear Corp.
GELVA, Polyvinyl acetate resins, Monsanto Co.
GELVATOL, Polyvinyl alcohol resins, Monsanto Co.
GEMA, Electrostatic powder coating equipment, Interrad Corp.
GEMCO, Mixers & blenders, General Machine Co. of N. J., Inc.
GEMCOMATIC, Drum loaders & dumpers, General Machine Co. of N. J. Inc.
GEN-FLO, Synthetic polymeric latices, General Tire & Rubber Co., Chemical/Plastics Div.
GENAL, Injection moldable thermosetting compound, General Electric Co., Engineering Polymers Products Dept.
GENTHANE, Polyurethane rubber, General Tire & Rubber Co., Chemical/Plastics Div.
GENTRO, Styrene butadiene rubber, General Tire & Rubber Co., Chemical/Plastics Div.
GEON, Vinyl resins, compounds, latexes, Goodrich, B. F., Chemical Co.
GIL-FOLD, Polyethylene sheet, Gilman Brothers Co.
GIL-MOLD, Resilient, flexible sheet, Gilman Brothers Co.

Trademarks and brand names (Cont'd)

GILCO, Rigid plastic sheet, Gilman Brothers Co.
GILLAB, Laminated chemically resistant material, Gill, M. C., Corp.
GILLCIAD BALSA, Lightweight sandwich panels, Gill, M.C., Corp.
GILLCOAT, Decorative laminates, Gill, M.C., Corp.
GILLFAB, Laminated plastic sheet & molded parts, Gill, M.C., Corp.
GILLINER, Fiberglass polyester laminate, Gill, M.C., Corp.
GILLITE, Laminated panels, Gill, M.C., Corp.
GLAMOURAMA, Core envelopment, Dimensional Plastics Corp.
GLAMOURGLAS, 3-Dimensional reinforced panel, Dimensional Plastics Corp.
GLAS SHOT, Glass bead abrasive, Microbeads, Cataphote Div., Ferro Corp.
GLASDRAMATIC, Fiberglass rods & tubes, Polygon Co., Div. Plas-Steel Products, Inc.
GLASKYD, Alkyd molding compounds, American Cyanamid Co., Industrial Chemicals & Plastics Div.
GLASPLY, Woven fiberglass tube, SGL Industries, Inc.
GLASROD, Glass-reinforced rod, Glastic Corp.
GLASSFORM, Glass-reinforced, self-extinguishing laminate, Century Plastics, Inc.
GLASSMATE, Dual extrusions, Crane Plastics, Inc.
GLASSPAK, Glass-reinforced rigid foam, Conolite Div., Woodall Industries, Inc.
GLASTRUDER, Continuous reinforced plastics profile machine, Glastrusions, Inc.
GLASTRUDER, Dielectric pultrusion machine, Goldsworthy Engineering, Inc.
GLASTRUSION, Pultrusions, Glastrusions, Inc.
GLASURETHANE, Reinforced cellular plastics, Artfiber Corp.
GLASWOOD, Plastic panels, Reichhold Chemicals, Inc.
GLENDION, Polyether resins, Montedison, S.p.A.
GLITEX, Vinyl tubing, Genesee Laboratory, Inc.
GLITTERFOIL, Hot stamping foil, Swift, M., & Sons, Inc.
GLOMAX, Anhydrous aluminum silicate, Georgia Kaolin Co.
GLOSSGARD, Portable glossmeters, Gardner Laboratory Inc.
GLUE DOCTOR, Adhesives, Schramm Fiberglass Products Div., High Strength Plastics Corp.
GLUE GIANT, Adhesives, Schramm Fiberglass Products Div., High Strength Plastics Corp.
GLUFIL, Nut shell flour fillers, Agrashell, Inc.
GLUSINE, Adhesives, 7-K Color Corp.
GLY-CEL, Diglycidyl ester resin, Celanese Resins, Div. Celanese Coatings Co.
GLYCOLUBE, Lubricants, Glyco Chemicals, Inc.
GLYCOMUL, Sorbitan esters, Glyco Chemicals, Inc.
GLYCOSPERSE, Sorbitan esters, Glyco Chemicals, Inc.
GLYPTAL, Alkyd solution, General Electric Co., Insulating Materials Dept.
GO-TAPE, Pigmented roll leaf, Gottscho, Adolph, Inc.
GOLD KAST, PVC film, Continental Plastic Co., Div. CPI, Inc.
GOOD-RITE, Plasticizers, latexes & antioxidants, Goodrich, B. F., Chemical Co.
GORDON SUPERDENSE, Polystyrene in pellet form, Hammond Plastics, Inc.
GORDON SUPERFLEX, Impact polystyrene in granular or pellet form, Hammond Plastics, Inc.
GORDON SUPERFLOW, Polystyrene in granular or pellet form, Hammond Plastics, Inc.
GORE-TEX, Expanded TFE film, tubes, rods, Fore, W.L., Associates, Inc.
GOTHALIN, Flexographic inks, Gotham Ink & Color Co.
GRA-TUFY, Cold molding compound, Perma-Flex Mold Co.
GRACON, PVC compounds, Grace, W. R., & Co., Elm Coated Fabrics Div.
GRANU-GRINDER, Grinder for thermoplastics, Brabender, C. W., Instruments, Inc.
GRANU-TIZER, Laboratory pelletizer, Brabender, C. W., Instruments, Inc.
GRAPHTOL, Organic pigments, Sandoz Colors & Chemicals
GRAVIMERIK, Weigh-feeder, Merrick Scale Mfg. Co.
GravoFLEX, ABS sheet, Hermes Plastics, Inc.
GravoPLY, Acrylic sheets, Hermes Plastics, Inc.
GRIL-tex, Copolyamide-based adhesives, Emser Werke A.G.
GRILAMID, Polyamide-12 resin, Emser Werke A.G.
GRILONIT, Epoxy resins, Emser Werke A.G.
GRIND-O-FLEX, Abrasive flap wheel, Merit Abrasive Products, Inc.
GRIPTITE, Single-roll type crushers, Jeffrey Mfg. Co.
GYROVISC, Viscosity control, Gyromat Corp.

HALAR, ECTFE resin, molding compounds, film, Allied Chemical Corp., Plastics Div.
HALLCO, Modifiers & additives, Hall, C. P., Co.
HALLCOMID, Fatty acid amides, Hall, C. P., Co.
HALON, TFE molding compounds,,Allied Chemical Corp., Plastics Div.
HALOPONT, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
HAMATROL, One-coat hammer vehicles, Commercial Solvents Corp.
HANNIFIN, Presses, Parker-Hannifin Corp.
HARD-TEX, Printing ink, Sun Chemical Corp., General Printing Ink Div.
HARTIG, Plastic processing systems, Midland-Ross Corp., Hartig Plastic Machinery Div.

Trademarks and brand names (Cont'd)

HARTMOLTOPREN, Rigid polyurethane foam, Farbenfabriken Bayer AG
HASTA, Wax-coated cellulose film, UCB-Sidac
HATCOL, Plasticizers, Grace, W. R., & Co., Hatco Chemical Div.
HAYSITE, Polyester laminates, Synthane-Taylor Corp., an Alco Standard company
HEAT-BLO, Portable electric heat gun, Milwaukee Lock & Mfg. Co.
HEAT-LES, Driers, Pall Corp.
HEAT-O-SEAL, Heat-seal labels, Tolas Corp., Div. Tompkins' Label Service
HEAT-SEAL-O-SCOPE, Heat seal inspection instrument, Precision Machine & Development Co.
HELI-FEEDER, Feeder for pre-expanders, Artisan Industries, Inc.
HELICONE, Agitator configuration, Atlantic Research Corp.
HEROX, Nylon filaments, Du Pont de Nemours, E. I., & Co.
HET ACID, Intermediate, Hooker Chemicals & Plastics Corp.
HETERO-CAVITY, Multiple insert or modular type molding operation, Security Plastics, Inc.
HETROFOAM, Fire-retardant urethane foam systems, Durez Div., Hooker Chemical Corp.
HETROLAC, Coating lacquer, Durez Div., Hooker Chemical Co.
HETRON, Fire-retardant polyester resins, Durez Div., Hooker Chemical Corp.
HEX-CEM, Catalyst & driers for plastics resins, Mooney Chemicals, Inc.
HI-CHAR, Pre-pregs, Ferro Corp., Composites Div.
HI-CURL, Epoxy laminated decorative sheet, Hitachi Chemical Co.
HI-CUT, Abrasive finishing mills, SWECO, Inc.
HI/D, High-temperature films, Technical Fluorocarbons Engineering, Inc.
HI-FAX, Polyethylene, Hercules Incorporated
HI-FLOW, Control valves, Taylor Instrument Process Control Div., Sybron Corp.
HI-POINT 180, Organic peroxide catalyst, U. S. Peroxygen Div., Witco Chemical Corp.
HI-Q, Organic & inorganic plastic colorants & gel coats, Ferro Corp., Color Div.
HI-R-TEMP, Liquid phase heaters, Vapor Corp., Va-Power Div.
HI-RAY, Infra-red heating equipment, Herbert Products Inc.
HI-REZ, Cyclic hydrocarbon resin, Mitsui Petrochemical Industries, Ltd.
HI-SIL, Amorphous silica powders & pellets, PPG Industries, Inc., Chemical Div.
HI-STYROLUX, High-impact polystyrene, Westlake Plastics Co.
HI-TUFF, Thin gauge sheeting, tubing; molded products, Stevens Molded Products Co., Dept. J. P. Stevens & Co.
HI-VIZ, Fluorescent pigment, Lawter Chemicals, Inc.
HI-WHITE, Kaolin clay, Huber, J. M., Corp.
HI-ZEX, High-density polyethylene, Mitsui Petrochemical Industries, Ltd.
HIDACID, Acid dyes, Hilton-Davis Chemical Co.
HIDACO, Basic dyes, Hilton-Davis Chemical Co.
HILEX, High-density polyethylene sheet, British Celanese Ltd.
HILTAMINE, Optical brighteners, Hilton-Davis Chemical Co.
HIRAY, Irradiated polyethylene film & tapes, Hitachi Chemical Co.
HITAFRAN, Furane resin, Hitachi Chemical Co.
HITALAC, Maleic modified resin, Hitachi Chemical Co.
HITALEX, Polyethylene film, Hitachi Chemical Co.
HITALOID, Acrylic resin, Hitachi Chemical Co.
HITAMIDE, Polyamide resin, Hitachi Chemical Co.
HITANOL, Phenolic resin, Hitachi Chemical Co.
HITTERLITE, Melamine laminated decorative sheet, Hitachi Chemical Co.
HOBE, Unexpanded honeycomb, Hexcel
HOMALITE, Cast CR 39 sheet, SGL Industries, Inc.
HONEY FOAM, Urethane-honeycomb fusion, Dimensional Plastics Corp.
HONEYCOMBE, Rotary dehumidifiers, Cargocaire Engineering Corp.
HORSE HEAD, Titanium dioxide, zinc oxide, zinc dust, New Jersey Zinc Co.
HOSTADUR, Polyethylene terephthalate; linear polyester, Farbwerke Hoechst AG
HOSTADYE, Spirit soluble dyestuffs, American Hoechst Corp., Dyes & Pigments Div.
HOSTAFLEX, PVC copolymer resin, Farbwerke Hoechst AG
HOSTAFLON, Polytetrafluoroethylene, Farbwerke Hoechst AG
HOSTAFORM, Acetal copolymer, Farbwerke Hoechst AG
HOSTALEN (SERIES), Polyethylenes; polypropylene, Farbwerke Hoechst AG
HOSTALIT (SERIES), PVC plastisols, suspensions, emulsions compounds, etc., Farbwerke Hoechst AG
HOSTALUX, Optical brighteners, American Hoechst Corp., Dyes & Pigments Div.
HOSTALUX KCB, Brightener, Farbwerke Hoechst AG
HOSTAPERM, Organic pigments, American Hoechst Corp., Dyes & Pigments Div.
HOSTAPERM, Pigments, Farbwerke Hoechst AG
HOSTAPRINT, PVC pigment preparations, American Hoechst Corp., Dyes & Pigments Div.
HOSTAPRINT, Pigment preparations, Farbwerke Hoechst AG
HOSTASET, Melamine, phenolic, polyester, urea molding compounds, Farbwerke Hoechst AG
HOSTASOL, Fluorescent soluble dyes, American Hoechst Corp., Dyes & Pigments Div.
HOSTAVINYL, PVC pigment dispersions, American Hoechst Corp., Dyes & Pigments Div.

Trademarks and brand names (Cont'd)

HOSTAVINYL, Pigment preparations, Farbwerke Hoechst AG
HOSTYREN (SERIES), Polystyrene; polystyrene foam, Farbwerke Hoechst AG
HuGLUE, Adhesives, Hughes Chemical Co.
HUM-MER, Electrically vibrated screen, Tyler, W. S., Inc.
HumiSEAL, Coatings, Columbia Technical Corp., Humiseal Div.
HY-DRY, Printing ink, Sun Chemical Corp., General Printing Ink Div.
hy-E, High modulus unidirectional prepeg. molding compound & tapes, Fiberite Corp.
HY-POWER, Portable hydraulic power tools, Parker-Hannifin Corp., Hannifin Press Div.
HYBON, Fiber glass reinforcement, PPG Industries, Inc./Fiber Glass Div.
HYCAR, Rubber & latex, AKU-Goodrich, B. V. Chemische Industrie
HYDRAFLEX, Printing ink, Sun Chemical Corp., General Printing Ink Div.
HYDRAL, Hydrated alumina, Aluminum Co. of America
HYDRALIGN, Web guiding systems, Knox, Inc., Controls Div.
HYDREPOXY, Water-based epoxies, Acme Chemicals Div., Allied Products Corp.
HYDRITE, Hydrous aluminum silicate, Georgia Kaolin Co.
HYDRO-ICDAL, Water-soluble alkyds, Dynamit Nobel, A.G.
HYDRO-MAX, Printing ink, Sun Chemical Corp., General Printing Ink Div.
HYDRO-SUN, Printing ink, Sun Chemical Corp., General Printing Ink Div.
HYDROCAL, Gypsum cement mold material, United States Gypsum Co.
HYDROFAST, Printing ink, Sun Chemical Corp., General Printing Ink Div.
HYDROGAUGE, Liquid level measurements, Statham Instruments, Inc.
HYDROGUARD, Thermostatic control, Powers Regulator Co.
HYDROSET, Printing Ink, Sun Chemical Corp., General Printing Ink Div.
HYDROSPENSER, Metering & dispensing machines, Automatic Process Control, Inc.
HYDROTHERM, Heating/cooling systems, American Hydrotherm Corp.
HyDRY, Printing ink, Sun Chemical Corp., General Printing Ink Div.
HyFORCE, Induction heaters, Stanelco Ltd.
HYGRODYNAMICS, Humidity & temperature measurement & control devices, American Instrument Co., Div. Travenol Laboratories, Inc.
HYONIC (SERIES), Biodegradable emulsifier; viscosity depressant; mold cleaning compounds, Nopco Chemical Div., Diamond Shamrock Chemical Co.
HYPO-X, Adhesives, Schramm Fiberglass Products Div., High Strength Plastics Corp.
HYPRENAL, Water-thinnable melamine resins, Cassella Farbwerke Mainkur AG
HYPROCEL, Self-adhesive polishing discs, Engis Corp.

ICEBERG, Anhydrous aluminum silicate, Burgess Pigment Co.
ICECAP K, Anhydrous aluminum silicate, Burgess Pigment Co.
IGEPAL, Wetting agent dispersant, GAF Corp.
IGETALEIM, Urea adhesive, Sumitomo Bakelite Co.
IHCO, Band heaters, Industrial Heater Co.
IMIDALLOY, Polyimide products, Tokyo Shibaura Electric Co.
IMIDITE, Polybenzimidazole, Whittaker Corp., R & D Div.
IMOLUCK, Additives for molding, Shinetsu Chemical Co.
IMPLEX, Acrylic molding powder, Rohm & Haas Co.
IMPOLENE, Stabilized polypropylene tubing, Imperial-Eastman
IMPULSE, Steam traps, Yarway Corp.
IMSIL, Micronized amorphous silica, Illinois Minerals Co.
INDUCTOHEAT, Pre-extruder heater, Syncro Machine Co.
INFRASCAN, Infrared scanning camera, Infrared Industries, Inc., Electronics
INJECTAMATIC, Screw-ram injection molding unit for thermosets, Hydratecs, Inc.
INSTANT-LOK, Hot melt adhesives, National Adhesives Div., National Starch & Chemical Corp.
INSTAWELD, Hot melts, National Adhesives Div., National Starch & Chemical Corp.
INSTEEMATIC, Steam cleaners/pressure washers for molds, Clayton Mfg. Co.
INSTUBE, Vinyl tubing, PLEXCO
INSUL F, Thermosetting urethane compounds, Purethane Div., Easton RS Corp.
INSULGRIP, Heat shrink tubing, Insul-Tab, Inc.
INSULON, Tubing, Insul-Tab, Inc.
INSULSTRUC, Glass reinforced polyester, Cincinnati Development & Mfg. Co.
INSUROK, High pressure laminates, Spaulding Fibre Corp., Insurok Div.
INSUROK, Laminated plastic, Spaulding Fibre Co.
INSUROK, High pressure laminated rods, sheets, tubes, Richardson Co.
INTAMIX, Rigid PVC compounds, Diamond Shamrock Chemical Co., Plastic Div.
INTERCIRC. Electronic control system for injection molding machines, Buhler Brothers
INTERFUSE, Thermoplastic coating, Fassler, M. J., & Co.
INTERMIX, Internal mixers, Shaw, Francis, & Co.
INTERSTAB (SERIES), Stabilizers, antioxidants, lubricants, etc., Akzo Chemie, Interstab Dept.
INTRAPLAST, Solvent-soluble dyes, Crompton & Knowles Corp., Industrial Products Div.
INTRAWITE, Optical brightener, Crompton & Knowles Corp., Industrial Products Div.

Trademarks and brand names (Cont'd)

ION-O-VAC, Sheet & web cleaner, Herbert Products Inc.
IONOL, Antioxidant, Shell Chemical Co.
IPORKA, Foamable urea resin, Badische Anilin- & Soda-Fabrik AG
IROGEL, Liquid thixotropic thickeners, Lubrizol Corp.
IRGACET, Solvent-soluble dyes, CIBA-GEIGY Corp., Plastics & Additives Div.
IRGALITE, Organic pigments, CIBA-GEIGY Corp., Plastics & Additives Div.
IRGANOX, Antioxidants, CIBA-GEIGY Corp., Plastics & Additives Div.
IRGAROL (SERIES), Thixotropic thickeners; fungicides & bactericides; catalysts for drying, Ciba-GeigyMarienberg GmbH
IRGASAN, Bacteriostats, CIBA-GEIGY Corp., Plastics & Additives Div.
IRGASTAB, Stabilizers for PVC, Ciba-Geigy Marienberg GmbH
IRGASTAB, Light stabilizer, CIBA-GEIGY Corp., Plastics & Additives Div.
IRGASTAT, Antistatic agents, Ciba-Geigy Marienberg GmbH
IRGAWAX, Lubricants, Ciba-Geigy Marienberg GmbH
IRGAZIN, Organic pigments, CIBA-GEIGY Corp., Plastics & Additives Div.
IRRATHENE, Irradiated polyethylene, General Electric Co., Insulating Materials Dept.
IRVINIL, PVC resins & compounds, Great American Chemical Corp.
ISAPLAST, Sulphonamide plasticizer, Bohme, Dr. Th., KG
ISAROL, Pigment pastes for polyurethanes, Bohme, Dr. Th., KG
ISOCON, Diisocyanates for urethane foams, Lankro Chemicals Ltd.
ISODERM, Urethane rigid & flexible integral skinning foam, Upjohn Co., CPR Div.
ISODYNAMIC, Magnetic separator, Frantz, S. G., Co.
ISOL, Coated cellulose film, UCB-Sidac
ISOLASTANE, Isocyanate elastomer-coated glass fabric, Natvar Corp.
ISOMIN, Melamine formaldehyde molding compounds, Ferguson, James, & Sons, Ltd.
ISONATE, Diisocyanates & urethane systems, Upjohn Co., CPR Div.
ISONATE (SERIES), Isocyanates; diisocyanates, Upjohn Co., Polymer Chemicals Div.
ISONOL (SERIES) Propoxylated aniline; polyfunctional polyol, Upjohn Co., Polymer Chemicals Div.
ISOPLANIC, Reinforced matched mold-making process, Ringler-Dorin, Inc.
ISOPLEX, 3-layer glass/polyester-resin combination, Natvar Corp.
ISOTERAGLAS, Isocyanate elastomer-coated Dacron-glass fabric, Natvar Corp.
ISOTHANE, Flexible polyurethane foams, Bernel Foam Products Co.
ISOTHENE, Packaging film, UCB-Sidac
IUPILON, Polycarbonate, Mitsubishi Gas Chemical Co.
IXAN, Vinylidene chloride copolymers, Solvay & Cie S.A.

JACMOUNT, Adjustable vibration damping machine mount, Air-Loc Div., Clark-Cutler-McDermott Co.
JANBRAU, Presses for thermosetting materials, Construcciones Margarit S.L.
JET-AIR, Pneumatic conveying equipment, Vac-U-Max
JET CLEANER, Cleaning device, Beringer Co.
JET-O-DRIER, Dryer for solids & slurries, Fluid Energy Processing & Equipment Co.
JET-O-MIZER, Jet grinding mill. Fluid Energy Processing & Equipment Co.
JET TEMP, Thermocouples, General Electric Co., Industrial Sales Div.
JETFOAM, Polyurethane foam, International Foam Div., Holiday Inns, Inc.
JETRAN, Folding plastic tubing, SLM Mfg. Corp.
JUPITER, Thermoforming machines, Comet Industries, Inc.

K-PRENE, Urethane cast material, Di-Acro, Div. Houdaille Industries, Inc.
K-RESIN, Butadiene styrene polymer, Phillips Petroleum Co., Chemical Dept., Plastics Div.
KADY MILL, High-speed dispersion mill, Kinetic Dispersion Corp.
KadyZOLVER, High-speed mixer, Kinetic Dispersion Corp.
KALAR, Elastomeric compounds, Hardman, Inc.
KALENE, Elastomeric compounds, Hardman, Inc.
KALEX, Two-part polyurethane elastomers, Hardman, Inc.
KALLODOC, Acrylic polymer, Imperial Chemical Industries, Ltd., Plastics Div.
KALMAC, Calcium carbonate, Georgia Marble Co., Calcium Products Div.
KALSPRAY, Rigid urethane foam systems for spray application, Baxenden Chemical Co.
KAMBEROLLER, Web guide, Fife Corp.
KANAFLEX, Flexible PVC hose, Totaku Industries, Inc.
KAOBRITE, Coating & filler clay, Thiele Kaolin Co.
KAOFILL, Coating & filler clay, Thiele Kaolin Co.
KAOGAN, Olcophilic aluminum silicate, Georgia Kaolin Co.
KAOGLOSS, Coating & filler clay. Thiele Kaolin Co.
KAOPAQUE, Delaminated aluminum silicate, Georgia Kaolin Co.
KAOWHITE, Coating & filler clay, Thiele Kaolin Co.
KAP, Injection presses, Aviaplastique, S.A.
KASTEL, Ion-exchange resins, Montedison S.p.A.
KAURAMIN, Melamine resin, Badische Anilin- & Soda-Fabrik AG
KAURESIN, Phenolic resin, Badische Anilin- & Soda-Fabrik AG

Trademarks and brand names (Cont'd)

KAURIT, Urea formaldehyde resin, Badische Anilin- & Soca-Fabrik AG
KEENSERTS, Threaded inserts, Tridair Industries, Fastener Div.
KEMAT, Bonded glass mat, Fiber Glass Industries, Inc.
KEMID, Polyimide rod & sheet, Chemplast, Inc.
KEMPORE, ABFA foaming agents, Polychem Dept., Stepan Chemical Co.
KEN-MIX, Pigment paste dispersions, Kenrich Petrochemicals, Inc.
KEN PLAST, Plasticizers, Kenrich Petrochemicals, Inc.
KENCOLOR, Silicone/pigments dispersion, Kenrich Petrochemicals, Inc.
KENFLEX, Hydrocarbon resins, Kenrich Petrochemicals, Inc.
KENSOL, Hot stamping & heat transfer equipment, Kensol-Olsenmark, Inc.
KESSCO, Organic esters, Armak Co., Polymer Additives Dept.
KEYSITE (SERIES), Organosols, plastisols, protective coatings, Soc-Co Plastic Coating Co.
KINAMATIC, Electric motors & generators, General Electric Co., Industrial Sales Div.
KINATROL, Adjustable speed drives, General Electric Co., Industrial Sales Div.
KLEARMOUNT, Clear acrylic syrup, Vernon-Benshoff Co.
KNU-VISE, Clamps, etc., Lapeer Mfg. Co.
KO-KNEADER, Continuous mixing machine, Baker Perkins, Inc.
KODACEL, Cellulosic film & sheeting, Eastman Chemical Products, Inc., Sub. Eastman Kodak Co.
KODAFLEX, Monomeric & polymeric plasticizers, Eastman Chemical Products, Inc., Sub. Eastman Kodak Co.
KODIS, Dispersible pigments, Kohnstamm Co.
KOHINOR, Vinyl resins & compounds, Pantasote Co.
KOHJIN-KORAP, Biaxially-oriented shrinkable polypropylene film, Kohjin Co.
KOL-FO-LAC, Predispersed dyes, 7-K Color Corp.
KOLDMOUNT, Acrylic for embedment, Vernon-Benshoff Co.
KOLORS, Wipe-on decorating paints, Keeler & Long, Inc.
KOMBIPLAST, Continuous compounding systems for rigid PVC, Werner & Pfleiderer Corp.
KOOLGAP, Cooling auxiliary for laminating press, Wabash Metal Products Co.
KOR-LOK, Thermosetting emulsion adhesive, National Adhesives Div., National Starch & Chemical Corp.
KORACRYL H, Acrylic copolymer sheet, Koro Corp.
KORAD, Acrylic film, Rohm & Haas Co.
KOSTAT, Color for plastics, Kohnstamm, H., & Co.
KOSTAT, Pigments for plastics, Kohnstamm Co.
KOSTIL, Styrene-acrylonitrile copolymers, Montedison S.p.A.
KRALASTIC, ABS high-impact resin, Uniroyal, Inc.
KRALON, High-impact styrene & ABS resins, Uniroyal, Inc.
KRATON, Styrene-butadiene polymers, Shell Chemical Co.
KRENE, Plastic film & sheeting, Union Carbide Corp., Chemicals & Plastics
KRIEGROBOND, Adhesives, 7-K Color Corp.
KRIEGROCINE, Colorants, 7-K Color Corp.
KRIEGRODIP, Dip dyes for plastics, 7-K Color Corp.
KRIEGROMINE, Wetting & antistatic agent, 7-K Color Corp.
KRINKLGLAS, Multi-faceted reinforced panel, Dimensional Plastics Corp.
KROLOR, Pigments, Du Pont de Nemours, E. I., & Co.
KROMAPLAST, Dry colorants for thermoplastics, Ampacet Corp.
KROMARED, Precipitated red iron oxide, Pfizer Minerals, Pigments & Metals Div.
KROMAROON, Precipitated maroon iron oxide, Pfizer Minerals, Pigments & Metals Div.
KRONITEX, Plasticizer, FMC Corp., Organic Chemicals Div.
KRONOS, Titanium dioxide white pigment, Kronos Titan GmbH
KRONOX, Plasticizer, FMC Corp., Organic Chemicals Div.
KRYSTAL, PVC sheet, Allied Chemical Corp., Fibers Div., Plastic Film Dept.
KRYSTALTITE, PVC shrink films, Allied Chemical Corp., Fibers Div., Plastic Film Dept.
KYDEX, Acrylic/PVC sheets, Rohm & Haas Co.
KYNAR (SERIES), Polyvinylidene fluoride, Pennwalt Corp., Fluorochemicals Div.

L-FILM, Packaging material, Cryovac Div., W. R. Grace & Co.
LACELL, Polyurethane discontinuous adhesive film, Goodrich, B. F., Chemical Co.
LAKOLENE, Lake colors, Kohnstamm, H., & Co.
LAMAL, Alcohol-reducible laminating adhesive, Polymer Industries, Inc.
LAMELITE, Straight melamine resins, Montedison S.p.A.
LAMILON, Wheels, Fairbanks Co.
LAMINAC, Polyester resins. American Cyanamid Co., Industrial Chemicals & Plastics Div.
LAMITEX, Laminated plastics, Franklin Fibre-Lamitex Corp.
LANCER, Adjustable frequency drive, Allis, Louis, Div., Litton Industrial Products, Inc.
LANKROFLEX, Plasticizers & epoxies, Lankro Chemicals Ltd.
LANKROTHANE, Urethane coatings & adhesives, Lankro Chemicals Ltd.
LARODUR, Acrylate coating resin, Badische Anilin- & Soda-Fabrik AG
LAROMID, Hardener for epoxies, Badische Anilin- & Soda-Fabrik AG
LAROMIN, Hardener for epoxies, Badische Anilin- & Soda-Fabrik AG

Trademarks and brand names (Cont'd)

LAST-A-FOAM, Plastic foam, General Plastics Mfg. Co.
LATECOLL, Acrylate salts, Badische Anilin- & Soda-Fabrik AG
LAUROX, Polymerization catalysts, Akzo Chemie Nederland bv
LAURYDOL, Polymerization catalysts, Akzo Chemie Nederalnd bv
LAY ON AIR, Air flotation dryers for webs, Vits Maschinenbau GmbH
LECTRO-BLOX, Electroplating stop off coating, Perry & Derrick Co.
LEGUVAL, Unsaturated polyester resin, Farbenfabriken Bayer AG
LEHIGH, Industrial fans, Fuller Co.
LEKUTHERM, Epoxy resins, Farbenfabriken Bayer AG
LENCOSOL, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
LEUCOPURE, Fluorescent whitener for polymers, Sandoz Colors & Chemicals
LEVAPREN, Polyethylene-vinyl acetate copolymers, Farbenfabriken Bayer AG
LEXAN, Polycarbonate resin, film, sheet, General Electric Co., Engineering Polymers Products Dept.
LEXCOTE, Organic coating for polycarbonates, Ball Chemical Co.
LIASIL, Glass roving reinforcement, Fiber Glass Industries, Inc.
LIBATI, Plastics materials; chemical products, Shinetsu Chemical Co.
LIFE-LOK, Miniature protective locknuts, Boots Aircraft Nut Div., Townsend Co.
LIGHTNIN, Mixers & aerators, Mixing Equipment Co., A Unit of General Signal
LIGHTNING, Round knife cutting machine, Eastman Machine Co.
LIMITORQUE, Valve operators, Philadelphia Gear Corp.
LIMITROL, Instruments for indicating & controlling limits of variables, Barber-Colman Co., Industrial Instruments Div.
LIN-E-AIRE, Valve actuators, Taylor Instrument Process Control Div., Sybron Corp.
LINDOL, Phosphate plasticizers, Stauffer Chemical Co., Specialty Chemical Div.
LINK-BELT, Material handling products, FMC Corp., Material Handling Equipment Div.
LIQUI-KOLOR, Liquid colorants for plastics, Inmont Corp.
LIQUID ENVELOPE, Vinyl coatings, Jamestown Finishes Div., Essex Chemical Corp.
LIQUIDEMON, Solvent/compound, Clayton Mfg. Co.
LIQUINITE, Plastic powders for coating applications, LNP Corp.
LITHENE, Liquid Polybutadiene, Lithium Corp. of America
LITHOSOL, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
LIWAPAS, Decorative melamine laminates, Dynamit Nobel, A.G.
LO-FLO, Prepreg, Fortin Laminating Corp.
LO-VEL, Silica flatting agents, PPG Industries, Inc., Chemical Div.
LOCKWELD, Industrial casters, Fairbanks Co.
LOGOSTAT, Anti-static & cleaning agent, Bee Chemical Co.
LOMIST, Printing ink, Sun Chemical Corp., General Printing Ink Div.
LOSOL, Printing ink, Sun Chemical Corp., General Printing Ink Div.
LOTYL, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
LOXIOL, Internal/external lubricants, Henkel International GmbH
LUACTIN, Anti-skinning agent, Badische Anilin- & Soda-Fabrik AG
LUBREX, Mold lubricants, Harwick Chemical Corp.
LUBROL, Lubricants & antistats, ICI America Inc.
LUCITE, Acrylic resins, Du Pont de Nemours, E. I., & Co.
LUCOBIT, Polyethylene-bitumen mixture, Badische Anilin- & Soda-Fabrik AG
LUDOPAL, Unsaturated polyester coating resin, Badische Anilin- & Soda-Fabrik AG
LUMASITE, Acrylic sheet, American Acrylic Corp.
LUMITOL, Isocyanate hardener, Badische Anilin- & Soda-Fabrik AG
LUPERCO (SERIES), Organic peroxide catalysts, Lucidol Div., Pennwalt Corp.
LUPEROX (SERIES), Organic peroxide catalysts, Lucidol Div., Pennwalt Corp.
LUPERSOL (SERIES), Organic peroxide catalysts, Lucidol Div., Pennwalt Corp.
LUPHEN, Phenolic coating resin, Badische Anilin- & Soda-Fabrik AG
LUPOLEN, Ethylene polymers & copolymers, Badische Anilin- & Soda-Fabrik AG
LUPRENAL, Acrylate coating resin, Badische Anilin- & Soda-Fabrik AG
LURAN-S, Terpolymer ASA, BASF Wyandotte Corp.
LUSTRAN, SAN & ABS molding & extrusion resins, Monsanto Co.
LUSTRE-DIE, Machined-cavity mold steel, Bethlehem Steel Corp.
LUSTREX, Polystyrene molding & extrusion resins, Monsanto Co.
LUTANOL, Polyvinyl ether, BASF Wyandotte Corp.
LUTOFAN, Vinyl chloride copolymers, Badische Anilin- & Soda-Fabrik AG
LUTONAL, Polyvinyl ethers, Badische Anilin- & Soda-Fabrik AG
LUVIPREN, Polyurethane intermediates, Badische Anilin- & Soda-Fabrik AG
LUWIPAL, Melamine-formaldehyde resin, Badische Anilin- & Soda-Fabrik AG
LUXOL, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
LUXOR/ALUFIN, Metallized hot press foil, Kurz-Hastings, Inc.
LY LAB, Laboratory coating unit, Lyons Machine Works

M-PYROL, Solvent, pigment dispersant, GAF Corp.
MACAMOLL, Saturated polyester resins, Cassella Farbwerke Mainkur AG
MACHINE COMMANDER, Control system for injection presses, Barber-Colman Co., Industrial Instruments Div.
MACO (SERIES), Control system for injection presses, Barber-Colman Co., Industrial Instruments Div.
MACOPOL, Synthetic polymer solutions, Commercial Solvents Corp.
MACROWAVE, High frequency oven, Radio Frequency Co.
MACRYNAL, Acrylic resins, Cassella Farbwerke Mainkur AG
MACUPLEX, Processes for plating on plastics, MacDermid, Inc.
MAG-PIPE, Flow transmitters, Taylor Instrument Process Control Div., Sybron Corp.
MAGCARB, Magnesium carbonate, Merck Chemical Div., Merck & Co.
MAGIC WAND, Static neutralizers, Sticht, Herman H., Co.
MAGLITE, Light magnesium oxide, Merck Chemical Div., Merck & Co.
MAGNA-LOK, Sealing Method, Weldotron Corp.
MAGNA-SET, Thermoregulator, Princo Instruments Inc.
MAGNE GAGE, Measures coating thickness. American Instrument Co., Div. Travenol Laboratories, Inc.
MAGNO-CERAM, 3-Component castable epoxy/ceramic, Magnolia Plastics, Inc.
MAIL STIX, Polyester pressure-sensitive labels, Topflight Corp.
MAKROLON, Extruded polycarbonate sheet, May & Baker, Ltd.
MAKROLON, Polycarbonate, Farbenfabriken Bayer AG
MANATROL, Industrial valves, Parker-Hannifin Corp.
MANUMOLD, Plastics injection molding press, Florin, Ltd.
MAPICO, Iron oxides, Cities Service Co., Columbian Div.
MAPRENAL, Melamine resins, Cassella Farbwerke Mainkur AG
MARAFIL, Nylon monofilaments, Imperial Chemical Industries Ltd., Plastics Div.
MARANYL, Nylon 6 and 6/6 compounds, Imperial Chemical Industries Ltd., Plastics Div.
MARBLE-MIX, Calcium carbonate, Sylacauga calcium Products Co.
MARCOTHIX, Thixotropic resins, Grace, W. R., & Co., Marco Chemical Div.
MARGARIT, Injection moulding machines, Construcciones Margarit S.L.
MARINCATE, Magnesium trisilicate, Merck Chemical Div., Merck & Co.
MARINCO, Magnesium hydroxide, Merck Chemical Div., Merck & Co.
MARION, Horizontal mixing equipment, bucket elevators, pulverizers, Rapids Machinery Co.
MARK, Heat stabilizers for polymers, Argus Chemical Corp., Sub. Witco Chemical Corp.
MARK, Stabilizers for PVC, Lankro Chemicals Ltd.
MARKET-READY, Packaging material & equipment, Cryovac Div., W. R. Grace & Co.
MARKSMAN, Temperature recorders, Measurement & Control Systems Div., West Instrument, Gulton Industries, Inc.
MARLEX, Polyethylenes, polypropylenes, other polyolefin plastics, Phillips Petroleum Co., Chemical Dept., Plastics Div.
MARLOX, Insulated thermocouples, Marlin Mfg. Corp.
MARVELBO, Hydraulic filter, Marvel Engineering Co.
MARVELINE, Hydraulic filter, Marvel Engineering Co.
MARVELMAG, Magnetic filter shield, Marvel Engineering Co.
MARVINDICATOR, Filter indicator, Marvel Engineering Co.
MARVINOL, Vinyl resins & compounds, Uniroyal, Inc.
MASKCOAT, Electroplating stopoff coating, Western Coating Co.
MASKOTE TPC, Water base mask wash, Service Tectonics, Inc.
MASTERCOLOR, Plastic color concentrates, Ampacet Corp.
MAURYLENE, Polypropylene film, Rhodia, Inc.
MAXIBOND, Film laminating machine, Morane Plastics Co.
MEARLIN, Powdered pearl pigment, Mearl Corp.
MEARLITE, Synthetic pearl pigment, Mearl Corp.
MEARLMAID, Natural pearl essence, Mearl Corp.
MEASURAY, Thickness gages, Bendix Corp., Automation & Measurement Div.
MECLORAN, Solvent for plastics, Dynamit Nobel, A.G.
MELAN, Melamine & urea resins, Hitachi Chemical Co.
MELAX, Mold conditioners & scalers, Axel Plastics Research Laboratories, Inc.
MELDIN, Polyimide & reinforced polyimide, Dixon Corp.
MELINEX, Polyester film, Imperial Chemical Industries Ltd., Plastics Div.
MELINEX, Polyester film, ICI America Inc.
MELLITE, Stabilizers, Albright & Wilson Ltd., Industrial Chemicals Div.
MEMCO, Embossing machine & rolls, Pamarco, Inc.
MEMORYLINE, Heat-shrinkable TFE & FEP tubing, Shamban, W. S., & Co.
MERBAC, Bactericide, Merck Chemical Div., Merck & Co.
MERCAPTATE, Polyfunctional thio esters, Cincinnati Milacron Chemicals, Inc.
MERCUTHAL, Low temperature thermometers, Princo Instruments, Inc.
MERLON, Polycarbonate, Mobay Chemical Co., Div. Baychem Corp.
MERPACYL, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
MESAMOLL, Plasticizer, Farbenfabriken Bayer AG
META-CAST, Epoxy casting & potting resins, Metachem Resins Corp., Mereco Products Div.
META-CLAD, Conformal coating resins, Metachem Resins Corp., Mereco Products Div.

Trademarks and brand names (Cont'd)

METACRYLENE, Methacrylate-butadiene-styrene-terpolymer, Plastimer, S.A.
METALAM, Film lamination, Dow Chemical Co.
METALLEX, Cast acrylic sheets, Hermes Plastics, Inc.
METALLIGRAPHIC, Gold leaf, foil, metallic substrates & inks, Tolas Corp., Div. Tompkins' Label Service
METASAP (SERIES), Internal lubricants, Nopco Chemical Div., Diamond Shamrock Chemical Co.
METASEAL, Impregnation resin, American Metaseal Co.
METASOL, Catalyst, microbiocide, Merck Chemical Div., Merck & Co.
METEOR, Thermoforming machines, Comet Industries, Inc.
METEX AQUALAC, Water-based & soluble resins, MacDermid, Inc.
METLCONE, Silicone rubber dies, sheet, rollers, Gladen Enterprises, Div. Hayes-Albion Corp.
METLFORM, Male & female tooling, Richards, J. A., Co.
METOLOSE, Methyl cellulose, Shinetsu Chemical Co.
METRE-GRIP, Epoxy adhesives, Metachem Resins Corp., Mereco Products Div.
METRE-SET, Single-component epoxy systems, Metachem Resins Corp., Mereco Products Div.
METRI-GAP, Displacement measurement instrument, Lion Precision Corp.
METSIL, Rubber stamping die, Kurz-Hastings, Inc.
METSO (SERIES), Sodium metasilicates; orthosilicate; sesquisilicate, Philadelphia Quartz Co.
METYL HIMIC ANHYDRIDE, Epoxy resin hardener, Hitachi Chemical Co.
MICAL, Polyester pressure-sensitive labels, Topflight Corp.
MICAPLY, Laminates, Mica Corp.
MICARTA, High pressure thermosetting laminates, Westinghouse Electric Corp./Industrial Plastics Div.
MICCRON, Powdered resins, Michigan Chrome & Chemical Co.
MICCROSOL, Vinyl plastisol, Michigan Chrome & Chemical Co.
MICHELENE, Antistatic agent, Michel, M., & Co.
MICRO-CLAD, Flexible laminate, Fortin Laminating Corp.
MICRO-CLEAN, Colorant in bead form, Customcolor, Inc.
MICRO-DRIER, Combination dryer/grinder, Fluid Energy Processing & Equipment Co.
MICRO-FOIL, Heat flow sensors, RdF Corp.
MICRO-JET, Jet grinding mill, Fluid Energy Processing & Equipment Co.
MICRO-MATTE, Extruded acrylic sheet with matte finish, Extrudaline, Inc.
MICRO-MICA, Micronized mica, Norwegian Talc A/S
MICRO-WHITE, Water ground calcium carbonates, Sylacauga Calcium Products Co.
MICROBOSS, Engraved embossing rolls, Pamarco, Inc.
MICRODOL, Finely ground dolomite, Norwegian Talc A/S
MICROFLEX, Reset timer/counter, Eagle Signal, a Systems Div. G & W. Industries
MICROGARD, Bacteriostat & fungicide, Sanitized Sales Co. of America, Inc.
MICROLITH, Colorant, concentrate, CIBA-GEIGY Corp., Plastics & Additives Div.
MICROMITE, Micronized calcium carbonate, Tamms Industries Co.
MICRONIZER, Colorant metering system, Plastic Molders Supply Co.
MICROSHOT, Resin dispensers, Fluidyne Instrumentation
MICROSONIC, Non-contact cleaning, Scientific Enterprises, Inc.
MICROSTAT, Static elimination systems, Scientific Enterprises, Inc.
MICROTALC, Fine talc, Pfizer Minerals, Pigments & Metals Div.
MICROTHANE, 2-Component urethane foams, Cal Polymers, Inc.
MICROTHENE, Powdered polyolefins, U. S. Industrial Chemicals Co., Div. National Distillers & Chemical Corp.
MICROTHIN, Thin-wall Teflon tubing, Shamban, W. S., & Co.
MIGHTY WATT, High-watt-density cartridge heater, Ogden Sales, Inc.
MIGRALUBE, TFE- & silicone-lubricated thermoplastics, LNP Corp.
MIKRO-AIRLOCK, Rotary discharge valve, MikorPul Div., United States Filter Corp.
MIKRO-ATOMIZER, Pulverizer-classifier, MikroPul Div., United States Filter Corp.
MIKRO-COLLECTOR, Dust collector, MikroPul Div., United States Filter Corp.
MIKRO-CRUSHER, Crusher, MikroPul Div., United States Filter Corp.
MIKRO-PULSAIRE, Dust collector, MikroPul Div., United States Filter Corp.
MIKRO-PULVERIZER, Pulverizer, MikroPul Div., United States Filter Corp.
MIKRO-SAMPLMILL, Laboratory pulverizer, MikroPul Div., United States Filter Corp.
MIKRON-SEPARATOR, Classifier, MikroPul Div., United States Filter Corp.
MIL-O-SOL, Plastisols & organosols, Milligan, J. G., & Co.
MILLITEMP, Temperature controllers, Leeds & Northrup Co.
MINEX, Anhydrous aluminum silicate filler, Indusmin Ltd.
MINEX, Anhydrous aluminum silicate filler, American Nepheline Corp.
MINIMITE, Potentiometer type pyrometer indicator, Thermo Electric
MINISERT, Miniature inserts for post-molding, Boots Aircraft Nut Div., Townsend Co.
MINIT GRIP, Epoxy adhesives, Schramm Fiberglass Products Div., High Strength Plastics Corp.
MINLON, Engineering thermoplastic resin, Du Pont de Nemours, E. I., & Co.
MIPOLAM, PVC-based sheets & films, Dynamit Nobel, A.G.
MIPOPLAST, Flexible PVC sheets, Dynamit Nobel of America Inc.
MIRA-GLOS RT, High gloss film coating, Polymer Industries, Inc.
MIRASOL, Alkyd resins; epoxy esters, Osborn, C.J., Chemicals, Inc.

Trademarks and brand names (Cont'd)

MIRBANE, Amino resin, Showa Highpolymer Co.
MIROTO, Rotogravure inks, Gotham Ink & Color Co.
MIRRO-BRITE, Metallized plastic films, Coating Products, Inc.
MIRRO-TINT, Metallized film, Coating Products, Inc.
MIRROPHANE, Metallized film & sheet, Gomar Mfg. Co.
MIRROR GLAZE, Mirror Bright Polish Co.
MIRROR POCKET, Finish for extrusion coating roll, Plasma Coatings, Inc., Div. Mirror Polishing & Plating Co.
MIRROR POCKET, Extrusion chill roll finish, Mirror Polishing & Plating Co.
MIRRORGOLD, Bronze powder, Atlantic Powdered Metals, Inc.
MISTA COAT, Plastic coatings, M R Plastics & Coatings, Inc.
MISTA FLEX, Flexiible plastisols, M R Plastincs & Coatings, Inc.
MISTA FOAM, Urethane foam systems, M R Plastics & Coatings, Inc.
MISTABOND, Adhesives, M R Plastics & Coatings, Inc.
MISTAPOX, Epoxy compounds, M R Plastics & Coatings, Inc.
MIX-KIT, Package for two-part reactive liquids, Hardman, Inc.
MISTRUMAT, Continuous mixer/extruder, Bolling, Stewart, & Co., Div. Intercole Automation, Inc.
MOBALOY, Pre-pregs, Ferro Corp., Composites Div.
MOD-EPOX, Epoxy resin modifier, Monsanto Co.
MODIGLASS, Fibrous glass, Reichhold Chemicals, Inc.
MODUCAL, Reinforced polyester embedded decals, FRP tubing, SGL Industries, Inc.
MODULATIC, Steam generators, Vapor Corp., Va-Power Div.
MODULENE, Polyethylene, Muehlstein, H., & Co.
MODULITE, Glass reinforced polyester embedments, SGL Industries, Inc.
MODULODE, Pneumatic conveying control, Fuller Co.
MOGUL, Long flow carbon black, Cabot Corp., Special Blacks Div.
MOISTREX, Moisture measurement, Neotec Corp.
MOKON, Mold temperature control systems, Mokon Div., Protective Closures Co.
MOLD WIZ, Mold releases, Axel Plastics Research Laboratories, Inc.
MOLDED HEAT, Flexible molded heating elements, Thermal Systems, Div., Sierracin Corp.
MOLDOMAT, Automatic molding machinery, Gluco, Inc.
MOLECULOY, Range of linear polyamides, Belding Chemical Industries
MOLGARD, Mold release agent, Ram Chemicals
MOLTOPREN, Polyurethane foam, Farbenfabriken Bayer AG
MOLYSULFIDE, Molybdenum disulfide powders, Climax Molybdenum Co.
MONABLOW, Extrusion blow molding system, Hayssen Mfg. Co.
MONARCH, Fluffy furnace carbon black, Cabot Corp., Special Blacks Div.
MONASTROL, Pigments, Du Pont de Nemours, E. I., & Co.
MONDUR, Isocyanates, Mobay Chemical Co., Div. Baychem Corp.
MONO-GLASS, Continuous glass monofilaments, Fram Corp.
MONOBEAM, Infrared analyzers, Beckman Instruments, Inc.
MONOCAST, Direct polymerized nylon, Polymer Corp.
MonoCAST, Nylon castings, Polypenco Ltd.
MQNOFAST, Pigment colors, Kohnstamm, H., & Co.
MONOFAST, Pigment colors, Kohnstamm Co.
MONOPLAS, Monomeric plasticizers, Scott Bader Co.
MONOPLEX, Monomeric plasticizers, Rohm & Haas Co.
MONOPOXY, One-component epoxy adhesive, Hardman, Inc.
MONOSTRAL, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
MONOTHANE, One-component urethane resin, Henley & Co.
MONOTHERM, Laminate, Rexham Corp.
MOPLEFAN, Polypropylene film, Montedison S.p.A.
MOPLEN, Isotactic polypropylene, Montedison S.p.A.
MOPLEN, Polypropylene, Novament Corp.
MOPLEN,–RO, High-density polyethylene, Montedison S.p.A.
MOWILITH, Polyvinyl acetate, Farbwerke Hoechst AG
MOWITAL, Polyvinyl butyral, Farbwerke Hoechst AG
MU-STAT, Miniaturezed thermal switch, Princo Instruments Inc.
MULTI-CAST, Release-coated casting papers, Ludlow Corp.
MULTIFILM, Coextruded plastic films, U. S. Industrial Chemicals Co., Div. National Distillers & Chemical Corp.
MULTIFORM, Thermometers, Princo Instruments Inc.
MULTIMITE, Portable calibration & temperature measuring facility, Thermo Electric
MULTIPRESS, Hydraulic press, Abex Corp., Denison Div.
MULTIROTO, Rotogravure inks, Gotham Ink & Color Co.
MULTRANOL, Polyether polyols, Mobay Chemical Co., Div. Baychem Corp.
MULTRATHANE, Urethane elastomer chemicals, Mobay Chemical Co., Div. Baychem Corp.
MULTRON, Polyesters, Mobay Chemical Co., Div. Baychem Corp.
MURANO, Synthetic pearl essence, Mearl Corp.
MUSTANG, Supported plastic sheet, General Tire & Rubber Co., Chemical/Plastics Div.

Trademarks and brand names (Cont'd)

NACROMER, Synthetic pearl essence, Mearl Corp.
NACRYL, Pigment dispersion of acrylic, Convert, Ets. G.
NACRYLIC, Acrylic latex binders, National Adhesives Div., National Starch & Chemical Co.
NAFIL, Polyisocyanate resin for rigid urethane foam, Chase Chemical Corp.
NAILSYN, Synthetic pearl pigment, Rona Pearl Div., Whittaker Corp.
NALTENE, Polyethylene sheets, Convert, Ets. G.
NALTEX, Extruded plastic netting, Nalle Plastics, Inc.
NAP-ALL, Catalyst & driers for plastics resins, Mooney Chemicals, Inc.
NAPTHANIL, Pigments, Du Pont de Nemours, E. I., & Co.
NAUGAHYDE, Vinyl coated fabrics, Uniroyal, Inc.
NAUGAPOL, Synthetic rubber, Uniroyal, Inc.
NAUGARD (SERIES), Plastic additives, Uniroyal, Inc.
NAUGAWHITE, Antioxidant & antiozone chemical, Uniroyal, Inc.
NAXELLOSE, Pigment dispersions of nitrocellulose, Convert, Ets. G.
NAXETYL, Pigment dispersion of ethyl cellulose, Convert, Ets. G.
NAXOID, Cellulose acetate sheets, Convert, Ets. G.
NAXOL, Alkyd resins, Convert, Ets. G.
NAXOLENE, High-impact polystyrene film & sheet, Convert, Ets. G.
NAXOLOR, Pigment dispersion of phenol, Convert, Ets. G.
NAXOMIDE, Pigment dispersions of polyamide, Convert, Ets. G.
NAXOMINE, Urea formaldehyde, Convert, Ets. G.
NAXOPRENE, Pigment dispersion of chlorinated rubber, Convert, Ets. G.
NAXORESE, Maleic resins, Convert, Ets. G.
NAXOVYL, Pigment dispersions of PVC, Convert, Ets. G.
NEBONY, Dark aromatic resins, Neville Chemical Co.
NEDOX-NICKEL, TFE impregnated coating, General Magnaplate Corp.
NEGOMEL, Lubricants & antistats, ICI America Inc.
NEO-FAT, Distilled or fractionated fatty acids, Armak Co., Polymer Additives Dept.
NEO-NAP, Catalyst & driers for plastic resins, Mooney Chemicals, Inc.
NEO-ZEX, Medium-density polyethylene, Mitsui Petrochemical Industries, Ltd.
NEOCRYL, Acrylic resins & resin emulsions, Polyvinyl Chemicals, Inc.
NEOFLON, FEP dispersions, Daikin Kogyo Co.
NEOREZ, Urethane solutions, Polyvinyl Chemicals, Inc.
NEOROTO, Rotogravure inks, Gotham Ink & Color Co.
NEOVAC, PVA color chips, Polyvinyl Chemicals, Inc.
NEPOXIDE, Epoxy resin coating, Atlas Minerals & Chemicals Div., ESB Inc.
NERO-SET, Printing ink, Sun Chemical Corp., General Printing Ink Div.
NESTOR, Vinyl & copolymer emulsions, Ferguson, James, & Sons, Ltd.
NESTORITE, Phenolic & urea formaldehyde molding compounds, Ferguson, James & Sons, Ltd.
NEUTRO-STAT, Antistatic sprays, Simco Co.
NEUTRO-VAC, Antistatic dust removal systems, Simco Co.
NEVAMAR, Decorative laminates, Exxon Chemical Co. U. S. A.
NEVASTAIN, Nonstaining antioxidants, Neville Chemical Co.
NEVCHEM, Aromatic hydrocarbon resins, Neville Chemical Co.
NEVEX, Modified hydrocarbon resin, Neville Chemical Co.
NEVILLAC, Modified coumarone-indene resin, Neville Chemical Co.
NEW TITAN, Ancillary extrusion equipment, Betol Machinery Ltd.
NIAX, Polyols, catalysts & isocyanates for urethane foam, Union Carbide Corp., Chemicals & Plastics
NICOFORM, Electroformed mold cavities, Electromold Corp.
NIMBUS, Polyurethane foam, General Tire & Rubber Co., Chemical/Plastics Div.
NITROCOL, Nitrocellulose base pigment dispersion, Osborn, C. J., Chemicals, Inc.
NITROPORE, Organic foaming agents, Polychem Dept., Stepan Chemical Co.
NO-FLEX, Integral plate cylinders, Pamarco, Inc.
NO-FLO, Prepreg, Fortin Laminating Corp.
NO-STIK, High temperature release surface, Plasma Coatings, Inc., Div. Mirror Polishing & Plating Co.
NO STIK, Plasma-fluorocarbon composite release finish, Mirror Polishing & Plating Co.
NOB-LOCK, PVC sheet material, Ameron Corrosion Control Div.
NOBLEWEST, Marking machines, Noble & Westbrook, Div. The Bristol Brass Corp.
NONOX, Antioxidants, ICI America Inc.
NONSTICKENSTOFFE, Mold release coating, Contour Chemical Co.
NOPAK, Anticaking agent, Huber, J. M., Corp.
NOPCOSIZE, Anti-blocking agent, Nopco Chemical Div., Diamond Shamrock Chemical Co.
NOPCOSTAT (SERIES), Antistatic agents, Nopco Chemical Div., Diamond Shamrock Chemical Co.
NOPCOWAX, Internal lubricant, Nopco Chemical Div., Diamond Shamrock Chemical Co.
NORCHEM, Low-density polyethylene resin, Northern Petrochemical Co.
NOROX, Organic peroxides, Norac Co.
NORTA-MATIC, Hydraulic presses, Dake Corp.
NORYL, Phenylene oxide-based resin, General Electric Co., Engineering Polymers Products Dept.

Trademarks and brand names (Cont'd)

NOVACITE, Altered novaculite, Malvern Minerals Co.
NOVAKUP, Silane treated novaculite, Malvern Minerals Co.
NOVIMIDE, High temperature resins, Isochem Resins Co.
NOVOFIL, Pigment preparations, Farbwerke Hoechst AG.
NOVOID, Cellulose nitrate sheets, Convert, Ets. G.
NOVOLEN, Polypropylene, Badische Anilin- & Soda-Fabrik AG
NUCLESTAT, Nuclear static eliminator, Herbert Products Inc.
NUDEEA, Antistatic cleaner, Miller, Harry, Corp.
NUOPLAZ, Plasticizers, Tenneco Chemicals, Inc., Organics & Polymers Div.
NUOSTABE, Stabilizers, Tenneco Chemicals, Inc., Organics & Polymers Div.
NUPLAGLAS, Pultruded fiberglass composites, Nupla Corp.
NUPOL, Thermosetting acrylic resin, Freeman Chemical Corp., Div. H. H. Robertson Co.
NY-KON, Molybdenum disulfide-lubricated nylon, LNP Corp.
NYBRAD, Abrasive-filled nylon filaments, Nypel, Inc.
NYGLATHANE, Glass-filled polyurethane, Nypel, Inc.
NYLAFIL, Fiberglass reinforced nylon, Fiberfil Div., Dart Industries, Inc.
NYLAFLOW, Nylon tubing, Polypenco Ltd.
NYLASINT, Microporous pressed and sintered nylon, Polypenco Ltd.
NYLASINT, Sintered nylon parts, Polymer Corp.
NYLASPIN, Dye, CIBA-GEIGY Corp., Plastics & Additives Div.
NYLATINT, Nylon dye, Polymer Corp.
NYLATRON, Filled nylons, Polymer Corp.
NYLATRON, Molybdenum disulfide – filled nylon resins & extrusions, Polypenco Ltd.
NYLAWELD, Nylon-to-nylon adhesive, Polymer Corp.
NYLO-SEAL, Nylon 11 tubing, Imperial-Eastman
NYLODE, Talc reinforced nylon, Fiberfil Div., Dart Industries, Inc.
NYLOX, Adhesives for nylon, etc., Hardman, Inc.
NYPELUBE, TFE-filled nylons, Nypel, Inc.
NYPRIME, Adhesive nylon-metal, Plastic Coatings Ltd.
NYREG, Glass-reinforced nylon molding compounds, Nypel, Inc.

OASIS, Expanded phenol-formaldehyde, Smithers-Oasis Div.
OCTOPULLER; Puller for plastic extrusions, Plastic Machinery Corp.
ODO'ZONE, Odor masking compounds & neutralizers, Purethane Div., Easton RS Corp.
OHMOID, Laminated phenolic, Wilmington Fibre Specialty Co.
OILON Pv 80, Acetal-based resin; sheets, rods, tubing, profiles, Cadillac Plastic & Chemical Co.
OLEFANE, Polypropylene film, Amoco Chemicals Corp.
OLEFIL, Filled polypropylene resin, Amoco Chemicals Corp.
OLEFLO, Polypropylene resin, Amoco Chemicals Corp.
OLEMER, Copolymer polypropylene, Amoco Chemicals Corp.
OLETAC, Amorphous polypropylene, Amoco Chemicals Corp.
OLO-LITE, Resilient expanded polystyrene, Olsonite Corp., Packaging & Insulation Div.
OMEGA, Feeders, B I F, a Unit of General Signal
ON-SERT, Fasteners for plastic bosses, Palnut Div., TRW Inc.
ON THE BALL, Protective coating, Merix Chemical Co.
OPEX, DNPT foaming agents, Polychem Dept., Stepan Chemical Co.
OPPANOL, Polyisobutylene, BASF Wyandotte Corp.
OPTIWHITE (SERIES), Anhydrous aluminum silicate, Burgess Pigment Co.
ORACET, Solvent soluble dye, CIBA-GEIGY Corp., Plastics & Additives Div.
ORASOL, Solvent soluble dye, CIBA-GEIGY Corp., Plastics & Additives Div.
ORNAMIN, Impregnated foils for thermosets, Ornapress AG
ORNATHERM' Thermoplastic decoration foils, Ornapress AG
OXOLIN, Organic protective coatings, Ball Chemical Co.
OXOPRENE, Polypropylene sheets, Convert, Ets. G.
OZIDE, Zinc Oxide, Sherwin Williams Chemicals, Div. Sherwin-Williams Co.

P-SHOOTER, Thermal extruder, Hardman, Inc.
PACEMAKER: Motors, Allis, Louis, Div., Litton Industrial Products, Inc.
PACEMAKER, Machine for processing & extrusion of plastics, NRM Corp.
PACER, Motors, Allis, Louis, Div., Litton Industrial Products, Inc.
PACKAID, Solvent vinyl strippable coatings, Seal-Peel, Inc.
PAD PAK, Vibration damping machine pads, Air-Loc Div., Clark-Cutler-McDermott Co.
PAINTSTIK, Paint in stick form, Markal Co.
PAL, Lock nuts, Palnut Div., TRW Inc.
PALANIL, Dyes for polyester fibres, BASF Wyandotte Corp.
PALATAL, Unsaturated polyesters, Badische Anilin- & Soda-Fabrik AG
PALATINOL, Plasticizer, Badische Anilin- & Soda-Fabrik AG

Trademarks and brand names (Cont'd)

PALIOFAST, Pigments, BASF Wyandotte Corp.
PALIOTOL, Plastic pigments, BASF Wyandotte Corp.
PANEL MASTER, Panel cutting saw, Kett Tool Co.
PAPI (SERIES) Polymethylene polyphenylisocyanate, Upjohn Co., Polymer Chemicals Div.
PARAC, Catalysts & additives, Pacific Resins & Chemicals, Inc.
PARAD, Synthetic resin & protein adhesives, Pacific Resins & Chemicals, Inc.
PARADENE, Dark coumarone-indene resins, Neville Chemical Co.
PARAPLAST, Hot-melt water soluble mandrel compound, Hexcel Corp., Rezolin Div.
PARAPLEX, Polyester resins & plasticizers, Rohm & Haas Co.
PARICIN, Saturated waxlike castor oil esters, NL Industries, Inc., Industrial Chemicals Div.
PARKER, Hydraulic system components, Parker-Hannifin Corp.
PARNAVAC, Vacuum formers & ancillary machines, Parnall & Sons Ltd.
PAROIL, Liquid grades chloroparaffins, Dover Chemical Corp.
PARTINGKOTE, Mold release agent, Hexcel Corp., Rezolin Div.
PAXON, High density polyethylene, Allied Chemical Corp., Plastics Div.
PELASPAN-PAC, Expandable polystyrene, Dow Chemical Co.
PELLETHANE, Thermoplastic urethane, Upjohn Co., CPR Div.
PENLOC, Anacrobic adhesive, Leader, Denis, Ltd.
PENNLON, Molecularly-oriented polyolefin, Dixon Corp.
PERCADOX, Organic peroxides & mistures, Noury Chemical Corp.
PERLEX, Pearling agent, May & Baker, Ltd.
PERMA-MOLD, Mold release agent, Brulin & Co.
PERMAGENIC, Bacteriostat & fungicide, Sanitized Sales Co. of America, Inc.
PERMAREZ, Cast epoxy, Permali, Inc.
PERMICAL, Polyester pressure-sensitive labels, Topflight Corp.
PERMOLITH, White pigment, Sherwin Williams Chemicals, Div. Sherwin-Williams Co.
PERMYL, Ultraviolet absorbers, Ferro Chemical, Div., Ferro Corp.
PEROXIDOL, Vinyl plasticizers, Reichhold Chemicals, Inc.
PERSPEX, Cast acrylic sheet, block, rod, Imperial Chemical Industries, Ltd., Plastics Div.
PETROSIN, Aromatic petroleum resin, Mitsui Petrochemical Industries, Ltd.
PETROTHENE, Low-, medium- & high-density polyethylene, U. S. Industrial Chemicals Co., Div. National Distillers & Chemical Corp.
PETROTHENE XL, Crosslinkable polyethylene compounds, U. S. Industrial Chemicals Co., Div. National Distillers & Chemical Corp.
PEVIKON, Polyvinyl chloride, KemaNord AB
PEXCO, Extruded tubings, Plastic Extrusion & Engineering Co.
PHENOWELD, Phenolic adhesives for nylon, etc., Hardman, Inc.
PHENUREN, Phenol-formaldehyde resins, Badische Anilin- & Soda-Fabrik AG
PHILJO, Polyolefin films, Phillips-Joanna Co., Div. Joanna Western Mills Co.
PHOSFLEX, Phosphate plasticizers, Stauffer Chemical Co., Specialty Chemical Div.
PHOSGARD, Organophosphorous compound, Monsanto Co.
PHOTOJET, Photoelectric sensors, GPE Controls
PHTALOPAL, Phthalate coating resin, Badische Anilin- & Soda-Fabrik AG
PHTHALKYD, Alkyd resin, Hitachi Chemical Co.
PICCO, Resins, Hercules Incorporated
PICCOCIZER, Resinous hydrocarbon plasticizers, Hercules Incorporated
PICCODIENE, Polydicyclopentadiene resins, Hercules Incorporated
PICCOLASTIC, Polystyrene resins, Hercules Incorporated
PICCOLYTE, Pinene polymers, Hercules Incorporated
PICCOPALE, Aliphatic type hydrocarbon resins, Hercules Incorporated
PICCOTEX, Vinyl toluene copolymer, Hercules Incorporated
PICCOUMARON, Coumarone-indene resins, Hercules Incorporated
PICCOVAR, Alkyl-aromatic resins, Hercules Incorporated
PICOSHOT, Resin dispensers, Fluidyne Instrumentation
PILEDRIVER, Reciprocating pumps, Lincoln St. Louis, Div. McNeil Corp.
PINPOLY, Reinforced polyurethant foam, International Foam Div., Holiday Inns, Inc.
PIPELINE DeLUMPER, Size reduction machinery, Miller, Franklin, Inc.
PLACETATE, Cellulose for cellulose esters, ITT Ravonier, Inc.
PLANAROME, Odorant, May & Baker, Ltd.
PLANT COMMANDER, Computerized control system, Barber-Colman Co., Industrial Instruments Div.
PLASINTER, Polyethylene coating powders, Plastic coatings Ltd.
PLASKON, Plastic molding compounds, Allied Chemical Corp., Plastics Div.
PLASLODE, Talc reinforced polypropylene, Fiberfil Div., Dart Industries, Inc.
PLASLUBE, Lubricated thermoplastics, Fiberfil Div., Dart Industries, Inc.
PLASMACOATING, Plating process, Varian Associates, Vacuum Div.
PLASTANOX, Antioxidant, American Cyanamid Co., Organic Chemicals Div.
PLASTAZOTE, Expanded polyethylene, Bakelite Xylonite Ltd.
PLASTI-BRASS, Metal-like laminated extrusion, Anchor Plastics Co.

Trademarks and brand names (Cont'd)

PLASTI-COPPER, Metal-like laminated extrusion, Anchor Plastics Co.
PLASTI-CORDER, Torque rheometer, Brabender, C. W., Instruments, Inc.
PLASTI-GOLD, Metal-like laminated extrusion, Anchor Plastics Co.
PLASTI-KROME, Metal-like laminated extrusion, Anchor Plastics Co.
PLASTICASTER, Rotational & slush molding machines, Blue, E. B., Co.
PLASTICELL, Rigid PVC foam, BTR Silvertown Ltd.
PLASTICOTE, Gel coats, Plasticolors, Inc.
PLASTIFIKATOR, Continuous compounding systems for rigid PVC, Werner & Pfleiderer Corp.
PLASTIFILM, PVC film & sheeting, Goss Plastic Film Corp.
PLASTIFLOW POP, Modified polyethylene wax, NL Industries, Inc., Industrial Chemicals Div.
PLASTIGEL, Liquid thickeners, Plasticolors, Inc.
PLASTILEASE, Mold release agent, Ram Chemicals
PLASTIMATIC, Automated coating systems, Rockwell, W. S., Co.
PLASTISCREW, Feed screw for plastics, NRM Corp.
PLASTISPERSE, Custom dispersion, Plasticolors, Inc.
PLASTOLEIN, Vinyl plasticizers, Emery Industries, Inc.
PLASTOMOLL, Plasticizer, Badische Anilin- & Soda-Fabrik AG
PLENCO, Thermoset resins & molding compounds, Plastics Engineering Co.
PLENUM-PULSE, Dust collector, Fuller Co.
PLEOGEN, Polyester resins & gel coats; polyurethane systems, Mol-Rez Div., Whittaker Corp.
PLEX, Acrylic sheets & molding powders, Rohm & Haas Co.
PLEXI, Acrylic sheets & molding powders, Rohm & Haas Co.
PLEXIGLAS, Acrylic sheets & molding powders, Rohm & Haas Co.
PLEXTON, Reinforced fiberglass, Lewis, G. B., Co.
PLIABRAC, Plasticizers, Albright & Wilson Ltd., Industrial Chemicals Div.
PLIOBOND, Adhesives, Goodyear Tire & Rubber Co., Chemical Div.
PLIOLITE, Styrene-butadiene resins, Goodyear Tire & Rubber Co., Chemical Div.
PLIOTHENE, Polyethylene-rubber blends, Ametek/Westchester Plastics Div.
PLIOVIC, PVC resins, Goodyear Tire & Rubber Co., Chemical Div.
PLURACOL, Polyethers, BASF Wyandotte Corp.
PLURAGARD, Urethane foam systems, BASF Wyandotte Corp.
PLURONIC, Polyethers, BASF Wyandotte Corp.
PLYMASTER, Industrial adhesive film, National Adhesives Div., National Starch & Chemical Corp.
PLYOCITE, Phenolic impregnated overlays, Reichhold Chemicals, Inc.
PLYOPHEN, Phenolic resins, Reichhold Chemicals, Inc.
PNEU-PAC, Pneumatic conveyor, Sprout, Waldron & Co.
PNEU-VAC, Pneumatic conveyor, Sprout, Waldron & Co.
POCKET-PROBE, Heat-measuring instrument, Electronic Development Laboratories, Inc.
PODBIELNIAK, Continuous centrifugal contactor, Baker Perkins, Inc.
POLARFLEX, Hot dip coating, Western Coating Co.
POLARIS, Continuous in-line thermoformer, Comet Industries, Inc.
POLEX, Oriented acrylic, Southwestern Plastics, Inc.
POLIDENE, PVDC copolymer emulsions, Scott Bader Co.
POLIGEN, Dispersions, Badische Anilin- & Soda-Fabrik AG
POLLOPAS, Urea formaldehyde compounds, Dynamit Nobel of America Inc.
POLY bd, Butadiene liquid resins, ARCO chemical Co.
POLY-CAST, Cast film adhesive, Fortin Laminating Corp.
POLY-CON, Continuous reactor & devolatilizer, Baker Perkins, Inc.
POLY-CORE, Flexible laminate, Fortin Laminating Corp.
POLY-COUPLER, Crosslinkers for thermosetting resins, Purethane Div., Easton RS Corp.
POLY-COVER, Plastic sheeting, Flex-O-Glass, Inc.
POLY-CURE, Catalysts, Mooney Chemicals, Inc.
POLY-DAP, Diallyl phthalate electrical molding compounds, U. S. Polymeric, Div. Hitco
POLY-ETH, Low-density polyethylene, Gulf Oil Chemicals Co., U. S. Operations, Plastics Div.
POLY-ETH-HI-D, High density polyethylene, Gulf Oil Chemicals Co., U. S. Operations, Plastics Div.
POLY-FLO, Polyethylene tubing, Imperial-Eastman
POLY-G, Glycols, Olin Corp.
POLY-GRADE, Degradable additive for polymers, Bio-Degradable Plastics, Inc.
POLY-KNEADER, Continuous mixing machine, Baker Perkins, Inc.
POLY-LINK, Converting resins for acrylic solutions, Celanese Resins, Div. Celanese Coatings Co.
POLY-PREG, Preimpregnated products with fabric base, U. S. Polymeric, Div. Hitco
POLY PREP, Liquid mold cleaning compound, M & H Laboratories, Inc., Polywax Div.
POLY-RIB, Rib-reinforced polyethylene, Flex-O-Glass, Inc.
POLY-SOLV, Glycol ethers, Olin Corp.
POLY-STAGE, Precipitator for pollution control, Beltran Associates, Inc.
POLY SUPRA TRAN-FAST, Polyester dispersions dyestuff, 7-K Color Corp.
POLY-T, Injection-moldable thermoset, Fiberfil Div., Dart Industries, Inc.
POLY-TERGENT, Surfacants, Olin Corp.

Trademarks and brand names (Cont'd)

POLY-THANE, Integral skin urethane resins, Pelron Corp.
POLY WAX, Liquid mold release wax, M & H Laboratories, Inc., Polywax Div.
POLY-ZOLE, Free radical initiator, Polychem Dept., Stepan Chemical Co.
POLYAIRE, Urethane foams, American Rubber & Plastics Corp.
POLYAROME, Polyethylene granules with concentrated aroma content, Creative Perfumers & Flavorists, Inc.
POLYART, Plastic paper, Bakelite Xylonite Ltd.
POLYBOARD, Decorative low pressure laminates, Wilson, Ralph, Plastics Co.
POLYCARBAFIL, Fiberglass reinforced polycarbonate, Fiberfil Div., Dart Industries, Inc.
POLYCAT, Polymer catalysts, Abbott Laboratories, Chemical Marketing Div.
POLYCIN, Ricinoleate polyols, NL Industries, Inc., Industrial Chemicals Div.
POLYCIZER, Plasticizers, Harwick Chemical Corp.
POLYCLAD, Vinyl protective coating, Carboline Co.
POLYCLAY, Hydrous aluminum silicate, Burgess Pigment Co.
POLYCOAT, Polyurethane, Showa Highpolymer Co.
POLYCURE, Crosslinked polyethylene compounds, Cooke Color & Chemical Div., Reichhold Chemicals, Inc.
POLYCURE, Crosslinkable polyethylene compounds, Reichhold Chemicals, Inc.
POLYDIA, Polystyrene sheet, Poly Chemical Co.
POLYDYNE, Adjustable speed drives, General Electric Co., Industrial Sales Div.
POLYFILM, Polyethylene film, Dow Chemical Co.
POLYFLEX, Oriented polystyrene film and sheet, Monsanto Co.
POLYFLON, TFE molding & extrusion powders, dispersions, etc., Daikin Kogyo Co.
POLYFOAM, Polyurethane foam, General Tire & Rubber Co., Chemical/Plastics Div.
POLYGARD (SERIES), Antioxidants, Uniroyal, Inc.
POLYGLAS, Polyester/glass pultruded products, Westinghouse Electric Corp./Industrial Plastics Div.
POLYGUIDE, Laminates, clad plastics, High Voltage Engineering Corp.
POLYIMIDAL, Thermoplastic polyimide, Raychem Corp.
POLYLINER, Calendered chlorinated polyethylene, Goodyear Tire & Rubber Co., Plastic Film & Sheeting Dept.
POLYLITE, Polyester resins, Reichhold Chemicals, Inc.
POLYLOOM, Fibrillated polypropylene film, Chevron Chemical Co., Fibers Div.
POLYLUBE, PTFE powder, Custom Compounding
POLYLUMY, Biaxially-oriented polypropylene film, Kohjin Co.
POLYMEG, Diprimary polymeric diol reacted with isocyanates to form polyurethanes, Quaker Oats Co., Chemicals Div.
POLYMET, Plastic-filled sintered metal, Polymer Corp.
POLYMILL, High viscosity media mill, Day, J. H., Co.
POLYMIX, Metering, mixing, dispensing equipment, Ureflex Corp.
POLYMUL (SERIES), Polyethylene emulsions, Nopco Chemical Div., Diamond Shamrock Chemical Co.
POLYOX, Water-soluble resins, Union Carbide Corp., Chemicals & Plastics
POLYPEARL, Expandable polystyrene, Poly Chemical Co.
POLYPHOS, Surfactants, Olin Corp.
POLYREX, Polystyrenes, Poly Chemical Co.
POLYROTO, Rotogravure inks, Gotham Ink & Color Co.
POLYSEAL, Polyolefin films, Joanna Western Mills Co.
POLYSET, Unsaturated polyester resin, Hitachi Chemical Co.
POLYSIZER, Polyvinyl alcohol, Showe Highpolymer Co.
POLYSOL, Synthetic resin emulsion, Showa Highpolymer Co.
POLYSYSTEMS; Foamed-in-place components, Olin Corp.
POLYTERAGLAS, Polyester-coated Dacron-glass fabric, Natvar Corp.
POLYTEST, Pilot extruder, Haake, Inc.
POLYTET TFE, Blends, Ethylene Corp.
POLYTHON, Plastic sheeting & tubing, Poly Plastic Products, Inc.
POLYWRAP, Plastic film, Flex-O-Glass, Inc.
PONTACHROME, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
PONTACYL, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
PONTAMINE, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
PONTOLITH, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
POROFOR, Blowing agents, Farbenfabriken Bayer AG
PORON, Microporous plastic materials, Rogers Corp.
PORTA BLENDERS, Conical blenders, General Machine Co. of N. J., Inc.
PORTCO, Thermoformers & foam extrusion lines, Portland Co.
PORTIONATOR, Liquid resin metering & dispensing machine, Glenmarc Mfg. Co.
POW-R-JAC, Linear actuators, Philadelphia Gear Corp.
POWER-LOCK, Abrasive discs, Merit Abrasive Products, Inc.
POWER-MASTER, Reciprocating pumps, Lincoln St. Louis Div., McNeil Corp.
POWER POD, Pnematic platen presses, Tyler Machinery Co.
POWERMASTER, Extruders, Midland-Ross Corp., Hartig Plastic Machinery Div.
POXY-GARD, Solventless epoxy compounds, Sterling, Div. Reichhold Chemicals, Inc.
PRECISOR, Valve positioners, Taylor Instrument Process Control Div., Sybron Corp.

Trademarks and brand names (Cont'd)

PREMI-GLAS, Polyester molding compounds, Premix, Inc.
PREP CENTER, Pilot plant mixer, extruder, Brabender, C. W., Instruments, Inc.
PREP-MILL, Laboratory two roll mill, Brabender, C. W., Instruments, Inc.
PRES-A-Ply, Labels, Dennison Mfg. Co.
PRES-TO-SEAL, Pressure-sensitive lables, Tolas Corp., Div. Tompkins' Label Service
PRESPERSION, Dispersions of compounding ingredients, Ware Chemical Corp.
PRESSDUCTOR, Magneto-elastic transducer, ASEA Inc.
PRESURTUBE, Plastic pressure tubing, Bunnell Plastics, Inc.
PRINTAN G, Laking agent, CIBA-GEIGY Corp., Plastics & Additives Div.
PRINTOPOL, Plastics colutions; emulsions, powders & grandulates, Dynamit Nobel, A.G.
PRO-FAX, Polypropylene, Hercules Incorporated
PRO-PLUS, Carbide-tipped saw blades, Luxite Saw & Tool Corp.
PROFIL, Fiberglass reinforced polypropylene, Fiberfil Div., Dart Industries, Inc.
PROFILM, Vinyl film, Protective Lining Corp.
PROHI, High density polyethylene, Protective Lining Corp.
PROPAFILM, Polypropylene film, ICI America Inc.
PROPAFILM, Polypropylene film, Imperial Chemical Industries Ltd., Plastics Div.
PROPALIN, Flexographic inks, Gotham Ink & Color Co.
PROPAMINE, Catalysts for urethane foams, Lankro Chemicals Ltd.
PROPATHENE, Polypropylene polymers & compound, Imperial Chemical Industries Ltd., Plastics Div.
PROPIOFAN, Polyvinyl propionate, BASF Wyandotte Corp.
PROPOCON, Preblends for urethane foams, Lankro Chemicals Ltd.
PROPORTIONEERS, Metering pump, B I F, a Unit of General Signal
PROPYLEX, Extruded polypropylene sheet, British Celanese Ltd.
PROPYLUX, Polypropylene, Westlake Plastics Co.
PROTECTOLITE, Polyethylene film, Protective Lining Corp.
PROTEXO COTE, Strippable coating, Thermo Cote, Inc.
PROTRON, Ultra-high strength polyethylene, Protective Lining Corp.
PROXEL, Microbiostat preservative, ICI America Inc.
PROXISWITCH, Proximity type sensing switch, Photobell Co.
PULVA-SIZER, Pulverizer, Pulva Corp.
PURECAL, Calcium carbonate, BASF Wyandotte Corp.
PURGITOL, Purging compound, Miller, Harry, Corp.
PUSHNUT, Fasteners, Palnut Div., TRW Inc.
PYOD, Thermocouple, Foxboro Co.
PYRELL, Flexible foam, fire-retardant, Scott Paper Co., Foam Div.
PYRO-CARB, Carbon/carbon laminates, HITCO
PYRO-SCANNER, Temperature monitor system, Alnor Instrument Co.
PYROCON, Pyrometer, Alnor Instrument Co.
PYROLAREX, Carbon/carbon moldings, HITCO
PYROMATIC, Non-indicating temperature control, Alnor Instrument Co.
PYROPREG, Pre-pregs, Ferro Corp., Composites Div.
PYROTAC, Electrical temperature alarm, Alnor Instrument Co.
PYROTEX, Felted asbestos material, RM Friction Materials Co., Div. Raybestos-Manhattan, Inc.
PYROTROLLER, Electronic temperature controller, Alnor Instrument Co.

Q-CEL, Inorganic hollow microspheres, Philadelphia Quartz Co.
Q-THANE, Urethane polymers, Quinn, K. J., & Co.
QUACORR, Modified furfuryl alcohol polymer, Quaker Oats Co., Chemicals Div.
QUAD-CONE, Double cone dry blender, Patterson-Kelley Co.
QUADROL, Polyhydroxy amine, BASF Wyandotte Corp.
QUASILAN, Prepolymers for urethane foams, Lankro Chemicals Ltd.
QUELFLAM, Isocyanurates, low surface spread flame, Baxenden Chemical Co.
QUICK-SCAN, Pneumatic & electronic instruments, Taylor Instrument Process Control Div., Sybron Corp.
QUICKSET, Organic peroxide catalyst, U. S. Peroxygen Div., Witco Chemical Corp.
QUICKSET, Printing ink, Sun Chemical Corp., General Printing Ink Div.
QUIK-MELT, Hot melt processing equipment, Advanced Machine Planning, Inc.
QUIK SOL, Water-soluble film, Polymer Films, Inc.
QUIRVIL, PVC, Rumianca SpA
QUSO, Micro-fine precipitated silica, Philadelphia Quartz Co.
QWIKMIL, Color concentrates, Claremont Polychemical Corp.

RADIANT-FLOW, Sealing system, Weldotron Corp.
RADROUND, Infra-red heater, Irex Corp., Products Div.
RAM-PART, Mold release agent, Ram Chemicals
RAMAFLEX, Flexible heaters, Rama Industrial Heater Co.
RAMAROD, Cartridge heater, Rama Industrial Heater Co.
RANDO-FEEDER, Random web forming equipment, Rando Machine Corp.

Trademarks and brand names (Cont'd)

RANDO-WEBBER, Random web forming equipment, Rando Machine Corp.
RAPISONIC, Ultrasonic homogenizing mixer, Sonic Corp., Div. of General Signal
RATIOTROL, Variable speed systems, Boston Gear Div., Rockwell International
RAYBRITE, Cellulose for reinforcement of urea & melamine molding compounds, ITT Rayonier, Inc.
RAYOCORD-X, Cellulose for cellulose esters, ITT Rayonier, Inc.
RAYOTUBE, Temperature sensors, Leeds & Northrup Co.
REACTROL, Regulator & control for heat, General Electric Co., Industrial Sales Div.
REAL-EASE, Silicone release compound, Borco Chemicals, Inc.
REDI-LITH, Printing ink, Sun Chemical Corp., General Printing Ink Div.
REED, Injection molding machines, Reed-Prentice Div., Package Machinery Co.
REFRASIL, High-temperature silica, HITCO
REGAL, Furnace carbon black, Cabot Corp., Special Blacks Div.
RELEASE GEN, Mold release agents, General Mills Chemicals, Inc.
RELIALAB, Test chambers, Tenney Engineering, Inc.
RELIATEMP, Test chambers, Tenney Engineering, Inc.
RENYL, Polyamide resins, Montedison S.p.A.
REOPLAST, Epoxy plasticizers, Ciba-Geigy Marienberg GmbH
RES-O-LAC, Organic protective coatings, Ball Chemical Co.
RESARIT, Acrylic molding powers, emulsions & tubes; ultraviolet absorber, Resart-IHM AG
RESARIX, Purging agents; antifogging agents; antistatic agents, Resart-IHM AG
RESARTGLAS, Cast acrylic sheets, rods, blocks, Resart-IHM AG
RESIMENE, Melamine resins, Monsanto Co.
RESINOL, Polyolefins, Allied Resinous Products Inc.
RESINOX, Phenolic resins, Monsanto Co.
RESOFLEX, Plasticizers, Cambridge Industries Co.
RESOPHENE, Phenolic resins, Plastimer, S.A.
RESORSABOND, Resorcinol & phenol-resorcinol, Pacific Resins & Chemicals, Inc.
RESTFOAM, Flexible urethane foam, United Foam Corp.
RESYN, Resins, National Adhesives Div., National Starch & Chemical Corp.
REYNOLON, Plastic films, Reynolds Metals Co.
REYNOSOL, Urethane, PVC, Reynolds Chemical Products Div., Hoover Ball & Bearing Co.
REZ-N-BOND, Bonding agents for plastics, Schwartz Chemical Co.
REZ-N-DYE, Dyes for plastics, Schwartz Chemical Co.
REZ-N-GLUE, Cements & adhesives, Schwartz Chemical Co.
REZ-N-KLEEN, Cleaners for plastics, Schwartz Chemical Co.
REZ-N-LAC, Lacquers for plastics, Schwartz Chemical Co.
REZ-O-SPERSE, Water-dispersed chloroparaffins, Dover Chemical Corp.
REZIMAC, Resin-modified alkyds, Commercial Solvents Corp.
RHEOCORD, Torque rheometer, Haake, Inc.
RHEOMEX, Laboratory extruder, Haake, Inc.
RHIAMER, Polypropylene & polycarbonate block & rod, May & Baker, Ltd.
RHODIALINE, Cast cellulose acetate film, Rhodia, Inc.
RHODIALINE, Case celulose acetate film, May & Baker, Ltd.
RHODIOD, Cellulose acetate sheet, May & Baker, Ltd.
RHODOGLASS, Cellulose acetate sheets, May & Baker, Ltd.
RHODOPHANE, Thin cast cellulose acetate film, Rhodia, Inc.
RHODOPHANE, Cast cellulose acetate film, May & Baker, Ltd.
RHOPLEX, Acrylic emulsions, Rohm & Haas Co.
RIAG, Extruded sheets, Resart-IHM AG
RICHFOAM, Urethane foam, Carpenter, E. R., Co.
RICHLUX, Reinforced urethane foam, Carpenter, E. R., Co.
RID, Purging compound, American Cyanamid Co., Industrial Chemicals & Plastics Div.
RIDGEWAY, Reinforced plastic panels, Reichhold Chemicals, Inc.
RIGIDSOL, Rigid plastisol, Watson-Standard Co.
RIGIFLEX, Dual extrusions, Crane Plastics, Inc.
RIGIMESH, Sintered woven wire mesh, Pall Corp.
RIGOLAC, Unsaturated polyester, Showa Highpolymer Co.
RIPOXY, Modified epoxy resin, Showa Highpolymer Co.
RO-FLO, Compressors; vacuum pumps, Allis-Chalmers
ROCEL, Cellulose acetate sliced and extruded sheet, British Celanese Ltd.
ROLAPRINTER, Flexographic imprinters, Gottscho, Adolph, Inc.
ROLL RAMP, Linear actuators, Philadelphia Gear Corp.
ROLOX, Two-part epoxy compounds, Hardman, Inc.
RORACYL, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
ROSITE, Molded parts, Rostone Corp.
ROTA-CONE, Blenders; dryers, Abbe, Paul O., Inc.
ROTAHEAT, Semi-automatic ovens, Plastic Coatings Ltd.
ROTARY UNION, Rotating joint, Perfecting Service Div., Reed Tool Co.

Trademarks and brand names (Cont'd)

ROTO-BIN-DICATOR, Bulk material level control, Bin Dicator Co.
ROTO-FLOW, Air flotation dryer, Inta-Roto Inc.
ROTO-GUARD, Rotating shaft motion indicator/controller, Bin Dicator Co.
ROTO-MARKER, Rotary ink marker, Acromark Co.
ROTODRUM POLYEXPANDER, Expander for loose fill packing materials, Artisan Industries, Inc.
ROTOFEED, Continuous mixer, Baker Perkins, Inc.
ROTOMATIC, Rotating painting machines, Finish Engineering Co.
ROTOMATIC, Roller die cutting press, American Packaging Corp.
ROTOSPRAYER, Painting machine, Finish Engineering Co.
ROTOTENS, Unwind constant tension device, Inta-Roto Inc.
ROTOTHENE, Polyethylene resins for rotational molding, Rototron Corp.
ROTOVISCO, Viscometer, Haake, Inc.
ROVCLOTH, Woven glass roving, Fiber Glass Industries, Inc.
ROVER, Injection molding machines, Buhler Brothers
ROVLOK, Fibrous glass reinforcement, Fiber Glass Industries, Inc.
ROVMAT, Chopped glass mat, Fiber Glass Industries, Inc.
ROYAL, Industrial adhesives, Uniroyal, Inc., Adhesives & Coatings Dept.
ROYALEX, Structural cellular thermoplastic sheet material, Uniroyal, Inc.
ROYALITE, Thermoplastic sheeting, Uniroyal, Inc.
ROYLAR, Polyurethane elastoplastic, Uniroyal, Inc.
RT/DUROIDS, Reinforced TFE materials, Rogers Corp.
RUCOAM, Vinyl film & sheeting, Ruco Div., Hooker Chemical Corp.
RUCOBLEND, Vinyl compounds, Ruco Div., Hooker Chemical Corp.
RUCOFLEX, Plasticizers, Polyesters, Comonomers, Ruco Div., Hooker Chemical Corp.
RUCON, Vinyl resins, Ruco Div., Hooker Chemical Corp.
RUCOTHANE, Polyurethanes, Ruco Div., Hooker Chemical Corp.
RULAN, Flame-retardant plastic, Du Pont de Nemours, E. I., & Co.
RULON, Reinforced Teflon, Dixon Corp.
RUST VETO, Rust preventives, Houghton, E. F., & Co.
RUTIOX, Rutile titanium dioxide pigments, Tioxide America Inc.
RYERTEX, Industrial laminates, Ryerson, Joseph T. & Son, Inc., Plastics Div.
RYLEX, Ultraviolet absorber, Du Pont de Nemours, E. I., & Co.
RYTON, Polyphenylene sulfide, Phillips Petroleum Co., Chemical Dept., Plastics Div.

SADUR, Cast acrylonitrile-modified acrylic sheets, Resart-IHM AG
SAF-T-BRITE, Flameproof metallized films, Coating Products, Inc.
SAF-T-FOAM, Specially treated & fire retardant polyurethane foam, International Foam Div., Holiday Inns, Inc.
SAFILTMOBILE, Hydraulic portable filter, Marvel Engineering Co.
SAFLEX, Vinyl butyral film, Monsanto Co.
SALOX, Filled TFE resin, Allegheny Plastics, Inc.
SAND-O-FLEX, Contour sanding wheel, Merit Abrasive Products, Inc.
SANDITIONER, Machine for aerating granular material, Jeffrey Mfg. Co.
SANDOPLAST, Dye/polymer concentrates, Sandoz Colors & Chemicals
SANDOZIN D-100, Pigment/dye dispersant, Sandoz Colors & Chemicals
SANDT, Die presses, embossing machines, etc., Atlas-Sandt Corp.
SANIMIX, Double ribbon mixer, Howes, S., Co.
SANISEAL, Bacteriostat & fungicide, Sanitized Sales Co. of America, Inc.
SANITIZED, Bacteriostat & fungicide, Sanitized Sales Co. of America, Inc.
SANTICIZER, Plasticizers, Monsanto Co.
SANTOLITE, Aryl sulfonamide-formaldehyde resin, Monsanto Co.
SANTOMASK, Liquid odor-masking agent, Monsanto Co.
SANTONOX, Antioxidant for polyethylene, Monsanto Co.
SANYLENE, Pigment/polymer concentrates, Sandoz Colors & Chemicals
SARAN, Polyvinylidene chloride resin, Dow Chemical Co.
SARANEX, Coextruded film, Dow Chemical Co.
SARET, Crosslinking agents, Sartomer Co., Div., Sartomer Industries, Inc.
SARKOSYL, Surfactants, CIBA-GEIGY Corp., Plastics & Additives Div.
SATINTONE, Anhydrous aluminum silicate, calcined clay or kaolin, Engelhard Minerals & Chemicals Corp., Minerals & Chemicals Div.
SATURN, Rotary thermoformer, Comet Industries, Inc.
SCLEROSCOPE, Hardness tester, Shore Instrument & Mfg. Co.
SCOTCH, Adhesives, 3M Co.
SCOTCHPAK, Heat-sealable polyester film, 3M Co.
SCOTCHPAR, Polyester film, 3M Co.
SCOTTFELT, Permanently compressed polyurethane foam, Scott Paper Co., Foam Div.
SCOTTFORE, Fibre-flocked urethane foam, Scott Paper Co., Foam Div.
SCRAPMASTER, Reclaim system, Midland-Ross Corp., Hartig Plastic Machinery Div.
SEAL-STOP, Semi-strippable coating, Seal-Peel, Inc.

Trademarks and brand names (Cont'd)

SEALINE, Hand heat sealer, Century Chicago, Inc.
SEICO, Temperature sensing & control instrumentation, Syscon International, Inc.
SELAFILM, Dip coating, 7-K Color Corp.
SELECT-A-SPEDE, Adjustable speed drives, Allis, Louis, Div., Litton Industrial Products, Inc.
SELECTROFOAM, Urethane foam systems & polyols, PPG Industries, Inc., Resin Products, C&R Div.
SELECTRON, Polymerizable synthetic resins; polyesters, PPG Industries, Inc., Resin Products, C & R Div.
SENSAIRE, Pneumatic temperature transmitters, Taylor Instrument Process Control Div., Sybron Corp.
SEQUESTRENE, Chelating agent, CIBA-GEIGY Corp., Plastics & Additives Div.
SERISTON, Synthetic organic dyes, Du Pont de Nemours, E. I. & Co.
SERVOMANOMETERS, Automated manometers, Statham Instruments, Inc.
SETILITHE, Cellulose acetate granules, Akzo Plastics bv
SEVRON, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
SHAF-TITE, Industrial rolls, Hunt, Rodney, Co.
SHARPLES, Centrifuges, Sharples-Stokes Div., Pennwalt Corp.
SHAW PROCESS, Precision cast metal molds, Avnet Shaw Div., Avnet, Inc.
SHEETLINER, Temperature control units, Sterling, Inc.
SHELBLAST, Soft abrasive materials, Agrashell, Inc.
SHOT, 2-component metering & mixing unit, Pyles Industries, Inc.
SHRINK-FIT, Heat-shrinkable plastic tubing, Dielectric Materials Co.
SHRINK-TITE, Heat-shrinkable plastic tubing, Dielectric Materials Co.
SHRINKTAINER, Packaging material, Cryovac Div., W. R. Grace & Co.
SHUTHANE, PVC & urethane blend, Reichhold Chemicals, Inc., Blane Div.
SHUVIN, Vinyl molding compounds, Reichhold Chemicals, Inc.
SHUVIN, Vinyl molding compounds, Reichhold Chemicals, Inc., Blane Div.
SHUVINITE, PVC & nitrile rubber mixture, Reichhold Chemicals, Inc., Blane Div.
SICRON, PVC homopolymers, copolymers & compounds, Montedison S.p.A.
SIDAC, Transparent cellulose film, UCB-Sidac
SIDALAM, Laminate, UCB-Sidac
SIDAMIL, Polyethylene/polyamide or polyester laminate, UCB-Sidac
SIDATHENE, Polypropylene film, UCB-Sidac
SILANOX, Hydrophobic fumed silica, Cabot Corp.
SILASTIC, Silicone rubber, Dow Corning Corp.
SILBON, Rayon paper, Kohjin Co.
SILCRON, Micronized silica, Glidden Pigments & Colors, SCM Corp.
SILOGRAM, Mold releases, lubricants, Margolis, A., & Sons Corp.
SILOPREN, Silicone rubber, Farbenfabriken Bayer AG
SILVATRIM, Metal-like extrusions, Glass Laboratories, Inc.
SILVERCONE, Silicone rubber dies, sheet, rollers, Gladen Enterprises, Div. Hayes-Albion Corp.
SILVERSHEEN, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SILVEX, Aluminum pigments, Silberline Mfg. Co.
SIMICHROME, Cleaner & polish for molds & dies, Competition Chemicals
SIMILUX, Printed &/or laminated plastics, Sillcocks-Miller Co.
SIPENE, Urethane catalyst, Alcolac Inc.
SIPENOL, Ethoxylated amines, Alcolac Inc.
SIPEX, Alkyl & alkyl ether sulfates, Alcolac Inc.
SIPOMER, Functional monomers, Alcolac Inc.
SIPON, Alkyl & alkyl ether sulfates, Alcolac Inc.
SIPONATE, Alkyl aryl sulfonates, Alcolac Inc.
SIPONIC, Nonionic surfactants, Alcolac Inc.
SIRIUS, Thermoforming machines, Comet Industries, Inc.
SKANOPAL, Urea formaldehyde molding compounds, Ferguson, James, & Sons, Ltd.
SKYBOND, Polyimide resins, Monsanto Co.
SLIDE (SERIES) Mold release agents, mold conditioners, rust preventives, Harms, Percy, Corp.
SLIP-EZE, Slip & anti-block agent, Fine Organics, Inc.
SNAK-FLEX, Film laminating adhesive system, Polymer Industries, Inc.
SNAPDRI, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SNO-BRITE, Clay, Thompson, Weinman & Co.
SNOW WHITE, Powdered filler for plastics, United States Gypsum Co.
SNOWFLAKE WHITE, Calcium carbonate, Thompson, Weinman & Co.
SOFTLITE, Ionomer foam, Gilman Brothers Co.
SOLAR HEATER, Fused quartz flat surface heater, Casso-Solar Corp., Hugo N. Cahnman Associates, Inc.
SOLIDS-PROCESSOR, Liquid-solids blender & drier combination, Patterson-Kelley Co.
SOLITHANE, Urethane prepolymers, Thiokol Corp., Chemical Div.
SOLKA-FLOE, Comminuted cellulose pulp, Brown Co.
SOLVITHERM, Chlorinated PVC compounds, Solvay & Cie S.A.
SONAC, Ultrasonic controls, Delavan Mfg. Co.
SONARGAGE, Noncontact level indication, Stevens, C. W., Inc.
SONITE, Epoxy resin compound, Smooth-On, Inc.

Trademarks and brand names (Cont'd)

SONOWELD, Vibratory welding apparatus, Sonobond Corp.
SOREFLON, Polytetrafluoroethylene resin, Ugine Kuhlman of America, Inc.
SPACEMAKER, Machine for procedding & extrusion of plastics, NRM Corp.
SPANDAL, Rigid urethane laminates, Baxenden Chemical Co.
SPANDOFOAM, Rigid urethane foam board & slab, Baxenden Chemical Co.
SPARKLE SILVEX, Sparkling aluminum pigments, Silberline Mfg. Co.
SPARMITE, Fine barytes, Pfizer Minerals, Pigments & Metals Div.
SPAULDITE, Laminated plastic, Spaulding Fibre Co.
SPECTRATHENE, Color concentrates for plastics, U. S. Industrial Chemicals Co., Div. National Distillers & Chemical Corp.
SPEED NUTS, Fasteners, Eaton Corp., Engineered Fasteners Div.
SPEEDOMAX, Recorders/controllers, Leeds & Northrup Co.
SPEEDSERTS, Inserts, Tridair Industries, Fastener Div.
SPIROBE, Extruder, Royle, John & Sons
SPIROD, Extruder, Royle, John, & Sons
SPIROTO, Rotogravure inks, Gotham Ink & Color Co.
SPIROYLE, Extruder, Royle, John & Sons
SPIRSOL, Spirit soluble dyestuff, 7-K Color Corp.
SPLIT SEC, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SPRAY GRAPH, Graphite lubricant, American Resin Corp.
SPRAY MOLDER, Spray-up equipment, Venus Products, Inc.
SQUEAKY-KLEEN, Printing ink, Sun Chemical Corp., General Printing Ink Div.
STA-FLOW, Propylene-vinyl chloride copolymer compounds, Air Products & Chemicals, Inc., Plastics Div.
STA-FORM, Urea formaldehyde prepolymer, Georgia-Pacific Corp., Chemical Div.
STABILFLO, Valve, Foxboro Co.
STABILOAD, Pneumatic power cylinder, Foxboro Co.
STABILOG, Pneumatic controller, Foxboro Co.
STABILOID, Pigment-water colloidal dispersions, Wilson Products Co.
STABILOX, Stabilizers & lubricants for PVC processing, Henkel International GmbH
STAFLEX, Vinyl plasticizers, Reichhold Chemical, Inc.
STAMYLAN, Polyethylene resins, DSM
STAMYLAN-P, Polypropylene, DSM
STAN-MAG, Inorganic magnesium products, Harwick Chemical Corp.
STAN-TONE, Pigments & pigment dispersions, Harwick Chemical Corp.
STANCLERE, Heat & light stabilizers for PVC, Akzo Chemie, Interstab Dept.
STANDLITE, Phenolic resins, Hitachi Chemical Co.
STAR, 2-Stage thermoformer, Comet Industries, Inc.
STARSET, Printing ink, Sun Chemical Corp., General Printing Ink Div.
STAT-EZE, External anti-static agent, Fine Organics, Inc.
STAT-KON, Fortified static-conductive thermoplastics, LNP Corp.
STATEXAN, Antistatic agent, Farbenfabriken Bayer AG
STATIC MIXER, In-line motionless mixer, Kenics Corp.
STAY/STEEL, Stainless steel flake pigment, Pfizer Minerals, Pigments & Metals Div.
STEAMIN' DEMON, Steam cleaners for molds, Clayton Mfg. Co.
STEELGARD, Rust preventive, Miller, Harry, Corp.
STELLA, Laminated melamine sheet, Shinetsu Chemical Co.
STEPLAP, Reinforced plastic panels, Reichhold Chemicals, Inc.
STERCOLOR, Pigment dispersions of polyester, Convert, Ets. G.
STERI-CHEM PPC, Anti-fungal/agent for vinyl sheeting, Original Bradford Soap Works, Inc.
STERL-TRONIC, Temperature control units, Sterling, Inc.
STERLCO, Heat & temperature control products & systems, Sterling, Inc.
STERLEX, Auxiliary equipment, Sterling Extruder Corp.
STERLING, Furnace & thermal carbon black, Cabot Corp., Special Blacks Div.
STERPIX, Concentrated thixotropic polyester resins, Convert, Ets. G.
STERPON, Polyester resins, Convert, Ets. G.
STIKON, Resistance thermometers, RdF Corp.
STIKVEL, Adhesive base resin, Velsicol Chemical Corp., Resin Products Div.
STIXSO, Silicate adhesive, Philadelphia Quartz Co.
STONELITE, Pulverized limestone, Ohio Lime Co.
STOP-STAT, Static eliminating spray, Portland Co.
STRAPON, Temperature sensors, RdF Corp.
STRATOCLAD, Glass reinforced phenolic, Spaulding Fibre Co.
STRIPKOTE, Low-gloss release paper, Warren, S. D., Co.
STRONGFORMS, Rigid plastics, laminates, General Tire & Rubber Co., Chemical/Plastics Div.
STRUCTOFORM, Sheet molding compounds, Fiberite Corp.
STRUCTOGLAS, Reinforced plastic panels, Reichhold Chemicals, Inc.
STRUCTOMAT, Injection molding machine, Schloemann-Siemag Aktiengesellschaft, Plastics Machinery Div.
STRYPE, Styrene-Butadiene copolymer paint resins, Specialties, Borg-Warner Chemicals, Borg-Warner Corp.

Trademarks and brand names (Cont'd)

STY-GRADE, Degradable additive for polymers, Bio-Degradable Plastics, Inc.
STYCAST, Casting resins, Emerson & Cuming, Inc.
STYL-O-MATIC, Conveyors, Island Equipment
STYLOUR, Velour-covered polystyrene sheet, Gilman Brothers Co.
STYPOL, Polyesters, Freeman Chemical Corp., Div. H. H. Robertson Co.
STYRAFIL, Fiberglass reinforced polystyrene, Fiberfil Div., Dart Industries, Inc.
STYRAFLOCK, Flock-coated polystyrene, Primex Plastics Corp.
STYRETEX, Styrenated alkyd resins, Celanese Resins, Div. Celanese Coatings Co.
STYROFAN, Styrene polymers, Badische Anilin-& Soda-Fabrik AG
STYROFLEX, Biaxially oriented polystyrene film, Natvar Corp.
STYROFOAM, Polystyrene foam, Dow Chemical Co.
STYROL, Polystyrene, Idemitsu Petrochemical Co.
STYROLUX, Polystyrene, Westlake Plastics Co.
STYRON, Polystyrene resin, Dow Chemical Co.
STYRON VERELITE, Light stabilized styrene, Dow Chemical Co.
STYRONOL, Styrene, Allied Resinous Products, Inc.
STYROPHANE, ABS film, UCB-Sidac
STYROPOR, Foamable polystyrene beads, Badische Anilin- & Soda-Fabrik AG
STYROPOR, Polystyrene expandable beads, BASF Wyandotte Corp.
STYROTAC, Bonding adhesive, Dow Chemical Co.
STYVARENE, Polystyrene, Plastimer, S.A.
SULFIL, Fiberglass reinforced polysulfone, Fiberfil Div., Dart Industries, Inc.
SULFONTHRENE, Synthetic organic dyes, Du Pont de Nemours, E. I., & Co.
SULFOPON, Emulsifier for emulsion polymerization, Henkel International GmbH
SUMIKON (SERIES), PVC, phenolic, epoxy & polyethylene compounds, Sumitomo Bakelite Co.
SUMILITE (SERIES), PVC sheets; phenolic & epoxy laminates, Sumitomo Bakelite Co.
SUNAL, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUNAMIDE, Printing Ink, Sun Chemical Corp., General Printing Ink Div.
SUNAR, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUNATE, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUNBOND, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUNBRITE, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUNCLEAN, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUNCURE, Ultraviolet curing inks, Sun Chemical Corp., General Printing Ink Div.
SUNEX, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUNGLO, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUNKET; Printing ink, Sun Chemical Corp., General Printing Ink Div.
SULITE, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUNSHEEN, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUNTOL, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUPER AEROFLEX, Linear polyethylene extrusions, Anchor Plastics Co.
SUPER-CHLOR, Dry liquid conlentrates of chloroparaffins, Dover Chemical Corp.
SUPER DYLAN, High-density polyethylene, ARCO Polymers, Inc.
SUPER FLO, 2-Component meter-dispenser, Pyles Industries, Inc.
SUPER-L, Packaging material, Cryovac Div., W. R. Grace & Co.
SUPER MODULENE, Polyethylene, Muehlstein, H., & Co.
SUPER NOZZLE; Injection mixing nozzle, Kenics Corp.
SUPERGLAS, Glass wool insulation, Eagle-Picher Industries, Inc.
SUPERJET, Lampblack, Pfizer Minerals, Pigments & Metals Div.
SuperMITE, Potentiometer type pyrometer indicator, Thermo Electric
SUPERNALTENE, Polyethylene sheets, Convert, Ets. G.
SUPERSET, Printing ink, Sun Chemical Corp., General Printing Ink Div.
SUPERSHOT, Shot type meter dispenser, Pyles Industries, Inc.
SUPERSTON, Copper-base mold alloy, Abex Corp., Engineered Products Div.
SUPRESAC, Urethanes, ICI America Inc.
SUPREX, Kaolin clay, Huber, J. M., Corp.
SUR-FLEX, Ionomer film, Flex-O-Glass, Inc.
SURLYN, Ionomer resin, Du Pont de Nemours, E. I., & Co.
SURTEMP, Surface temperature probe, Leeds & Northrup Co.
SUZORITE, Mica, Marietta Resources International, Ltd.
SWEDCAST, Continuous cast acrylic sheet & rolls, Swedlow Inc., Acrylic Sheet Div.
SWEDCAST 300, Cast acrylic sheets; reinforced & decorative plastics; glass cloth, Swedlow, Inc.
SWEETSAW, Cutting equipment, Sweets, Martin, Co.
SYLGARD, Flexible encapsulating resin, Dow Corning Corp.
SYLOID, Micronized silica, Davison Chemical Div., W. R. Grace & Co.
SYN-U-TEX, Urea formaldehyde & melamine formaldehyde resins, Celanese Resins Div., Celanese Coatings Co.
SYNASOL, Solvents, Union Carbide Corp., Chemicals & Plastics
SYNCHROTORQUE, Variable speed drives, Philadelphia Gear Corp.

Trademarks and brand names (Cont'd)

SYNCRO-SPEDE, Synchronous induction motors, Allis, Louis, Div., Litton Industrial Products, Inc.
SYNFLEX, Flexible extrusions, Moore, Samuel, & Co.
SYNPRO, Metallic stearates, Synthetic Products Co., Div. Dart Industries Inc., Chemical Group
SYNPRON, Stabilizers, Synthetic Products Co., Div. Dart Industries Inc., Chemical Group
SYNTASE, Ultraviolet light absorbers, Neville-Synthese Organics, Inc.
SYNTEX, Alkyd & polyurethane ester resins, Celanese Resins, Div. Celanese Coatings Co.
SYNTRON, Material handling products, FMC Corp., Material Handling Equipment Div.
SYSTEM 101, Extruder, Davis-Standard/Goulding/Hobbs Divs., Crompton & Knowles Corp.

T-LOCK, PVC sheet material, Ameron Corrosion Control Div.
TACK-ACE, Synthetic polyterpene resin, Mitsui Petrochemical Industries, Ltd.
TACKMASTER, Industrial adhesive film, National Adhesives Div., National Starch & Chemical Corp.
TAFMER, Resin reforming elastomer, Mitsui Petrochemical Industries, Ltd.
TALCRON, Talc, Pfizer Minerals, Pigments & Metals Div.
TAMMSILITE, Micronized amorphous silica, Tammsco, Inc.
TAMOL, Dispersing agents, Rohm & Haas Co.
TAP-LOK, Self-tapping, threaded insert, Groov-Pin Corp.
TARPO, Textile-reinforced polyethylene film, UCB-Sidac
TAYLORCLAD, Copper-clad laminated plastics, Synthane-Taylor Corp., an Alco Standard company
TAYLORITE, Vulcanized fibre, Synthane-Taylor Corp., an Alco Standard company
TAYLORON, Reinforced plastics, Synthane-Taylor Corp., an Alco Standard company
TEBESTAT, Inner antistatic agents, Bohme, Dr., Th., KG
TECAM, Laboratory test instruments, Techne, Inc.
TECHNYL, Nylon 6, 6/6, 6/10, etc., Societe des Usines Chimques, Rhone-Poulene
TECNOFLON, Polytetrafluoroethylene elastomers, Montedison S.p.A.
TECQUINOL, Antioxidants, Eastman Chemical Products, Inc., Sub. Eastman Kodak Co.
TEDIMON, Toluene-diisocyanate, Montedison S.p.A.
TEFLON, FEP & TFE fluorocarbon resins, Du Pont de Nemours, E. I., & Co.
TEGIT, Phenolic-asbestos molding compound, Garfield Mfg. Co.
TELL-TALE, Hydraulic filters, Parker-Hannifin Corp.
TEMASEPT, Bacteriostat for plastics, Fine Organics, Inc.
TEMP-O-FLEX, Electric heating units, Beltran Associates, Inc.
TEMP-O-LINE, Electric heating units, Beltran Associates, Inc.
TEMP-O-QUICK, Electric heating units, Beltran Associates, Inc.
TEMP-O-SHELL, Electric heating units, Beltran Associates, Inc.
TEMP-O-SLAB, Electric heating units, Beltran Associates, Inc.
TEMP-O-TUBE, Electric heating units, Beltran Associates, Inc.
TEMPETTE, Temperature controller, Techne, Inc.
TEMPUNIT, Laboratory test instruments, Techne, Inc.
TEN-CEM, Catalyst & driers for plastics resins, Mooney Chemicals, Inc.
TENAMENE, Antioxidants, Eastman Chemical Products Inc., Sub. Eastman Kodak Co.
TENITE, Molding & extrusion compounds, Eastman Chemical Products, Inc., Sub. Eastman Kodak Co.
TENN FOAM, Polyurethane foam, Morristown Foam Corp.
TENOX, Antioxidants, Eastman Chemical Products, Inc., Sub. Eastman Kodak Co.
TENSOL, Acrylic - and vinyl-based cements, Imperial Chemical Industries Ltd., Plastics Div.
TERAGLAS, Oleoresinous-coated Dacron-glass fabric, Natvar Corp.
TERE-GARD, Solventless polyester compounds, Sterling, Div. Reichhold Chemicals, Inc.
TERLENKA, Polyester, Akzo Plastics bv
TERLURAN, ABS polymers, Badische Anilin- & Soda-Fabrik AG
TERPHANE, Polyester film, Rhodia, Inc.
TERUCELLO, Carboxy methyl cellulose, Showa Highpolymer Co.
TEST-A-MOLD, Injection mold testing system, Northern Instruments, Inc.
TETRA-ETCH, Adhesion Promoter, Gore, W. L., Associates, Inc.
TETRONIC, Polyethers, BASF Wyandotte Corp.
TEXICOTE, PVA emulsions, Scott Bader Co.
TEXICRYL, Acrylic polymer emulsions, Scott Bader Co.
TEXIGEL, Polyacrylate thickeners, Scott Bader Co.
TEXIN, Urethane elastomer molding compound, Mobay Chemical Co., Div.Baychem Corp.
TEXTOLITE, Industrial laminates, General Electric Co., Laminated & Insulated materials, Business Dept.
TEXTURECONE, Textured silicone rubber dies, sheet, rollers, Gladen Enterprises Div., Hayes-Albion Corp.
THANATE, Polymeric isocyanates, Jefferson Chemical Co.
THANCAT, Urethane catalysts, Jefferson Chemical Co.
THANOL, Urethane polyols, Jefferson Chemical Co.
THE BIG LOOK, Measuring & indicating instruments, General Electric Co., Industrial Sales Div.
THERIMAGE, Heat transfer decorating method, Dennison Mfg. Co.
THERM-O-FLOW, Bulk hot melt dispenser, Pyles Industries, Inc.
THERMABAND, Electrically heated bands, Thermel, Inc.

Trademarks and brand names (Cont'd)

THERMACARTRIDGE, Cartridge heaters & insertion cartridges, Thermel, Inc.
THERMAHEATER, Irregularly shaped heater, Thermel, Inc.
THERMAL ELECTRIC, Process heating equipment, Composite Materials & Mfg. Div., Entoleter, Inc.
THERMAL-FLO, Heat-transfer roll, Hunt, Rodney, Co.
THERMALL, High frequency generators, LaRose, W. T., & Associates, Inc.
THERMALUX, Polysulfone, Westlake Plastics Co.
THERMAPLATEN, Electrically heated platens, Thermel, Inc.
THERMARKER, Hot stamping machine, Thermark
THERMASET, Fasteners for thermoplastics, Fastener Systems Corp.
THERMASOL, Vinyl plastisols & organosols, Lakeside Plastics Inc.
THERMASTRIP, Tubular heater for cylindrical surfaces, Thermel, Inc.
THERMATUBE, Tubular type heater, Thermel, Inc.
THERMAX, Carbon blacks, Commercial Solvents Corp.
THERMEX, High frequencyheating equipment, Votator Div., Chemetron Corp.
THERMO-CABLE, Multiple thermocouple cable, Thermo Electric
THERMO-GRAV, Thermogravimetric analyzer, American Instrument Co., Div. Travenol Laboratories, Inc.
THERMO-JECT, Thermoset injection molding machines, Van Dorn Plastic Machinery Co., Div. Van Dorn Co.
THERMOCOMP, Reinforced thermoplastics, Ferguson, James, & Sons, Ltd.
THERMOCOMPS, Thermoplastics fortified with pre-dispersed glass fibers, LNP Corp.
THERMOCON, Pyrometer, Alnor Instrument Co.
THERMODOT, Infrared thermometer, Infrared Industries, Inc., Electronics
THERMOFAST, Printing ink, Sun Chemical Corp., General Printing Ink Div.
THERMOFINE, Grinding machines, Wedco, Inc.
THERMOFLITE, Extruder, Nelmor Co., Plastic Machinery Div., Sub. Entwistle Co.
THERMOGENIZER, Post-extrusion mixer, Kenics Corp.
THERMOGRIP, Adhesives & applicators, Bostik Div., USM Corp.
THERMOGUIDE, Dial thermometers, Taylor Instrument Process Control Div., Sybron Corp.
THERMOHM, Temperature detector, Leeds & Northrup Co.
THERMOLD, Plastic mold steels, Universal-Cyclops Specialty Steel Div., Cyclops Corp.
THERMOLIN, Flame retardants, Olin Corp.
THERMOMELT, Temperature indicators, Markal Co.
THERMOPROFILE, Infra-red temperature profile scanner & monitor, AGA Corp.
THERMOSEL, Hot melt viscosity controller, Brookfield Engineering Laboratories, Inc.
THERMOSWITCH, Thermostat-controller, Fenwal, Inc.
THERMOTRON, Thermal liquid & electronic controls, Brabender, C. W., Instruments, Inc.
THERMOVISION, Infra-red heat imaging system, AGA Corp.
THOROBLENDER, Double-cone blender, Patterson Industries Inc.
THREDS, Pressed-in screw thread inserts, Southco, Inc.
THUNDERBOLT, Cartridge heater, ITT Vulcan Electric
THURANE, Rigic polyurethane foam, Dow Chemical Co.
TI-PURE, Titanium dioxide pigments, Du Pont de Nemours, E. I., & Co.
TILALKYL, Titanium alkoxides, Tioxide America Inc.
TILARYL, Titanium arloxides, Tioxide America Inc.
TILBUTYL, Titanium butoxides, Tioxide America Inc.
TILCOM, Metal organic compounds, Tioxide America Inc.
TILMETHYL, Titanium methoxide, Tioxide America Inc.
TILON, Acrylic molding compound, Ticonium Div., CMP Industries, Inc.
TILPROPYL, Titanium propoxides, Tioxide America Inc.
TINOPAL, Fluorescent whitening agents, CIBA-GEIGY Corp., Plastics & Additives Div.
TINUVIN, Ultraviolet absorbers, CIBA-GEIGY Corp., Plastics & Additives Div.
TIP SEAL, Flow gun, Pyles Industries, Inc.
TISSUGLAS, Glass paper, Pallflex Products Corp.
TITANOX, Titanium dioxides, Titanium Pigment Div., N. L. Industries, Inc.
TOLHURST, Centrifuoals, Ametek/Process Equipment
TONOX, Epoxy curative,,Unirnyal, Inc.
TOOLCAST, Casting resins, American Resin Corp.
TOP-FLIGHT, Hydraulic driven extruders, Extruders, Inc.
TOPANOL, Antioxidants, ICI America, Inc.
TOPIC, Structural foam molding machine, Buhler Brothers
TORBAL, Precision weighing equipment, Torsion Balance Co.
TOSHIBA PREMIX, Alkyd molding compounds, Tokyo Shibaura Electric Co.
TOUCH-N-WEIGH, Weight loading mechanism, Ohaus Scale Corp.
TRACK-MATIC, Self-tracking wire mesh belt, Sandvik Conveyor, Inc.
TRANS-OXIDE, Transparent iron oxides, Hilton-Davis Chemical Co.
TRANSAIRE, Pneumatic temperature, pressure & load transmitters, Taylor Instrument Process Control Div., Sybron Corp.
TRANSCOPE, Pneumatic recorders, Taylor Instrument Process Control Div., Sybron Corp.
TRANSET, Indicator & control stations, Taylor Instrument Process Control Div., Sybron Corp.

Trademarks and brand names (Cont'd)

TRANSFERMIX, Continuous intensive mixer, Sterling Extruder Corp.
TRANSFLO, Conveyor, Kornylak Corp.
TRANSKOTE, High-gloss release paper, Warren, S. D., Co.
TRANSTUBE, Vinyl tubing, PLEXCO
TRAYLOR, Mills & crushers, Fuller Co.
TREM, Viscosity depressant, Nopco Chemical Div., Diamond Shamrock Chemical Co.
TRI-SCREW, Screw preheating attachments, Stokes Div., Pennwalt Corp.
TRI-SIL 404, Amorphous silica, Henley & Co.
TRIAFOL, Cellulose acetate films, Farbenfabriken Bayer AG
TRIFORM, Semi-rigid film & sheet, Goodyear Tire & Rubber Co., Plastic Film & Sheeting Dept.
TRIGONAL, UV initiator, Noury Chemical Corp.
TRIGONOX, Organic peroxide liquids, Noury Chemical Corp.
TRIGONOX, Polymerization catalysts, Akzo Chemie Nederland bv
TRIMET, Trimethylolethane, Commercial Solvents Corp.
TRIMFAST, Adhesive films, National Adhesives Div., National Starch & Chemical Corp.
TRIPLEMATIC, Proportioning pumps, Hardman, Inc.
TRIS AMINO, Tris(hydroxymethyl)aminomethane, Commercial Solvents Corp.
TRIS NITRO, Tris(hydroxymethyl)nitromethane, Commercial Solvents Corp.
TRITON, Surface-active agents, Rohm & Haas Co.
TROCAL, Rigid PVC profiles, Dynamit Nobel of America Inc.
TROCAL S, Flexible PVC sheets, Dynamit Nobel of America Inc.
TROCELLEN, Crosslinked polyethylene foam, Dynamit Nobel, A.G.
TROFIL, High density polyethylene monofilament, Dynamit Nobel, A.G.
TROFIL P, Polypropylene monofilament, Dynamit Nobel, A.G.
TROGAMID T, Polyamide molding compound, Dynamit Nobel of America, Inc.
TROJAN, Resin-forming compositions, Commercial Solvents Corp.
TROLEN, Low-density polyethylene film & sheets, Dynamit Nobel, A.G.
TROLITAN, Phenol-formaldehyde molding compounds, Dynamit Nobel, A.G.
TROLITAN (SERIES), Phenol formaldehyde compounds; boron molding compounds, Dynamit Nobel of America Inc.
TROLITAX, Industrial laminates, Dynamit Nobel of America, Inc.
TRONOX, Titanium dioxide pigments, Kerr-McGee Chemical Corp.
TROSIFOL, Polyvinyl butyral film, Dynamit Nobel of America Inc.
TROSIPLAST, PVC molding & extrusion compound, Dynamit Nobel of America, Inc.
TROSIPLAST, Polyvinyl chloride compounds, Dynamit Nobel, A.G.
TROVIDUR, Corrosion-resistant rigid PVC, Dynamit Nobel, A.G.
TROVIPOR, Flexible PVC foam, Dynamit Nobel, A.G.
TRU-CAST, Pressure cast metal molds, Manco Products Inc.
TRU-CENTER, Steel stamp type, Acromark Co.
TRU-COLOR, Color measuring instrument, Neotec Corp.
TRU-PAK, Thermocouple assemblies & parts, Instrumatics, Inc.
TRU-SHAPE, Polyester structural shapes, Fibercast Co., Div. Youngstown Sheet & Tube Co.
TRULON, Polyvinyl chloride resin, Olin Corp.
TRYCITE, Polystyrene film, Dow Chemical Co.
TRYMER, Isocyanurate foams & systems, Upjohn Co., CPR Div.
TUBE-CORE, Energy-absorbing honeycomb, Hexcel
TUBICETA, Cellulose acetate flakes, Akzo Plastics bv
TUFCOTE, Thin sheet cast urethane foam, Specialty Converters, Inc.
TUFFCORE, Reinforcing fabric, Stauffer Chemical Co., Plastics Div.
TUFRAM-ALUMINUM, TFE impregnated coating, General Magnaplate Corp.
TURBOLEX, Vinyl tubing, Brand-Rex Co.
TURBOTHERM, Vinyl tubing, Brand-Rex Co.
TURBOTUBE, Agitator for horizontal tanks, Chemineer, Inc.
TURBOZONE, Vinyl tubing, Brand-Rex Co.
TURBULENT, Intensive mixer-processor, Day, J. H., Co.
TWIN-SHELL, Dry & liquid solids blender, Patterson-Kelley Co.
TWIN TINT, Two-color extrusions, Anchor Plastics Co.
TWIN WELD, Epoxy adhesives, Schramm Fiberglass Products Div., High Strength Plastics Corp.
TY-PLY, Adhesives, Hughson Chemicals, Lord Corp.
TY-SIFTER, Sifting Machine, Tyler, W. S., Inc.
TYBON, Thermosetting liquid resins, Pacific Resins & Chemicals, Inc.
TYCHEM, Water soluble polymers, Tylac, Standard Brands Chemical Industries, Inc.
TYGON, Modified plasticized PVC tubing & sheet, Norton Co., Plastics & Synthetics Div.
TYLAC, Synthetic elastomers, Tylac, Standard Brands Chemical Industries, Inc.
TYLOSE, Methyl-carbonoxymethyl-hydroxyethyl-cellulose, Farbwerke Hoechst AG
TYNEX, Nylon filaments, Du Pont de Nemours, E. I., & Co.
TYRIL, Styrene-acrylonitrile resin, Dow Chemical Co.

Trademarks and brand names (Cont'd)

U-THANE, Rigid insulation board stock urethane, Upjohn Co., CPR Div.
UCAR, Coatings & solvents, Union Carbide Corp., Chemicals & Plastics
UCON, Lubricants; solvents, Union Carbide Corp., Chemicals & Plastics
UDEL, Plastic film; polysulfone resins, Union Carbide Corp., Chemicals & Plastics
UFORMITE, Urea & melamine resins, Rohm & Haas Co.
UGIKRAL, ABS terpolymer, Plastimer, S.A.
ULTIPOR, Filter medium, Pall Corp.
ULTRA-ETHYLUX, Linear polyethylene, Westlake Plastics Co.
ULTRA-GLAS, Oriented acrylic sheet, Fortin Plastics, Inc.
ULTRADUR, Polytetramethylene terephthalate, Badische Anilin- & Soda-Fabrik AG
ULTRAFILM, Vapor barrier film, Stauffer Chemical Co., Plastics Div.
ULTRAFLEX, Flexible lip film & sheet dies, Extrusion Dies Inc.
ULTRAFORM, Acetal resins, Badische Anilin- & Soda-Fabrik AG
ULTRALAM, Vapor barrier lamination, Stauffer Chemical Co., Plastics Div.
ULTRAMID, Polyamide grades, Badische Anilin- & Soda-Fabrik AG
ULTRAMID, Polyamide grades, Badische Anilin- & Soda-Fabrik AG
ULTRAMID, Nylon 6, 6/6 & 6/10, BASF Wyandotte Corp.
ULTRAMOLL, Polymer plasticizers, Farbenfabriken Bayer AG
ULTRAPAS, Melamine formaldehyde compounds, Dynamit Nobel of America Inc.
ULTRAPAS, Decorative melamine laminates, Dynamit Nobel, A.G.
ULTRATHENE, Ethylene-vinyl acetate resins & copolymers, U. S. Industrial Chemicals Co., Div. National Distillers & Chemical Corp.
ULTREX, Ultra high molecular weight polyethylene extrusions, Spiratex Co.
ULTROPAQUE, Printing ink, Sun Chemical Corp., General Printing Ink Div.
UNA DYN, Desiccant & hot air dryers; vacuum loaders & conveyors, Universal Dynamics Corp.
UNI-FLO, Prepreg, Fortin Laminating Corp.
UNI-REZ, Reactive polyamides, Union Camp Corp.
UNICHEM, Vinyl compounds, Colorite Plastics Co., Div. Dart Industries, Inc.
UNICHLOR, Chlorinated paraffins, Neville Chemical Co.
UNICOLOR, Color concentrate, Ametak/Westchester Plastics Div.
UNICOMB, Paper honeycomb cast fusion, Dimensional Plastics Corp.
UNICOMB, Combination woven roving mat, Ferro Corp., Fiber Glass Div.
UNIDOR, Batch mixer, Baker Perkins, Inc.
UNIDUR, Urethane structural systems, BASF Wyandotte Corp.
UNIFAB, Woven glass fabric, Ferro Corp., Fiber Glass Div.
UNIFEEDER, Force-feed hoppers, agitators, Industrial Plastics Ltd.
UNIFLEX, Polymeric plasticizer, Union Camp Corp.
UNIFLEX, Plasticizers, Union Camp Corp., Chemical Div.
UNIFORMAT, Chopped strand reinforcement mat, Ferro Corp., Fiber Glass Div.
UNIGLASS, Industrial glass fabric, Thalco, Uniglass Industries, Div. United Merchants & Mfrs., Inc.
UNIMAR, Stainless plastic mold steel, Universal-Cyclops Specialty Steel Div., Cyclops Corp.
UNIMATE, Industrial robot, Unimation, Inc., Sub. Condec Corp.
UNIMOLL, Phthalate plasticizers, Farbenfabriken Bayer AG
UNIROVE, Woven roving, Ferro Corp., Fiber Glass Div.
UNISPERSE, Aqueous paste, CIBA-GEIGY Corp., Plastics & Additives Div.
UNISTRAND, Fiber glass roving, Ferro Corp., Fiber Glass Div.
UNITANE, Titanium dioxide pigments, American Cyanamid Co., Pigments Div.
UNITAPE, Woven glass tape, Ferro Corp., Fiber Glass Div.
UNITUBE, Infrared heater, Casso-Solar Corp., Hugo N. Cahnman Associates, Inc.
UNOFLEX, One-component film laminant, Polymer Industries, Inc.
URABOND, Urethane elastomeric coating, Poly Resins
URAFIL, Fiberglass reinforced polyurethane, Fiberfil Div., Dart Industries, Inc.
URALANE, Polyurethanes, Furane Plastics, Inc.
URALITE, Urethane compounds, Hexcel Corp., Rezolin Div.
URAPOL, Urethane elastomeric coating, Poly Resins
UREFLEX, Urethane impregnants, solvent free, Purethane Div., Easton RS Corp.
UREFOME, Urethane, polyester & polyether foam systems, Purethane Div., Easton RS Corp.
UREPAN, Polyurethane elastomer, Farbenfabriken Bayer AG
UREPOT, Urethane encapsulants & potting compounds, Purethane Div., Easton RS Corp.
UROFLEX, Cold-cure urethane foam systems, BASF Wyandotte Corp.
UROPAC, Urethane foam systems, BASF Wyandotte Corp.
UROPAL, Urea-formaldehyde-butyl resins, Plastimer, S.A.
UROTUF, Polyurethane resins, Reichhold Chemicals, Inc.
URTAL, Acrylonitrile-butadiene-styrene terpolymers, Montedison S.p.A.
USM SUPRATHANE, Jacketed urethane foam, United States Mineral Products Co.
USP-245, Organic peroxide catalyst, U. S. Peroxygen Div., Witco Chemical Corp.
UVETHON, Ultraviolet barrier film, May & Baker, Ltd.

Trademarks and brand names (Cont'd)

UVEX, Cellulose acetate butyrate sheet, Eastman Chemical Products, Inc., Sub. Eastman Kodak Co.
UVI-NOX, Antioxidants, GAF Corp.
UVINUL, Ultraviolet light absorbers, GAF Corp.
UVITEX, Fluorescent whitening agent, CIBA-GEIGY Corp., Plastics & Additives Div.

V-PYROL, Pigment dispersant, GAF Corp.
VACPAC, Vacuum systems, Hull Corp.
VALERON, Oriented high-density polyethylene film laminate, Van Leer Plastics (U.S.A.) Inc.
VALOX, Engineering thermoplastic polyester, General Electric Co., Engineering Polymers Products Dept.
VALVACTOR, Valve positioner, Foxboro Co.
VAN DE GRAAFF, Particle accelerators, High Voltage Engineering Corp.
VANGUARD, Machine for processing & extrusion of plastics, NRM Corp.
VANSTAY, Stabilizers for PVC, Vanderbilt, R. T., Co.
VANTAC, Pressure-sensitive adhesives, British Oxygen Chemicals Ltd.
VAPOR-CARRIER, Coating system, Zicon Corp.
VAPOR-FLO, Humidity system, Tenney Engineering, Inc.
VARAQUA, Water emulsion polymers & resins, McClosky Varnish Co.
VARCOPOL, Copolymer vehicles, McClosky Varnish Co.
VARCUM, Phenolic resins, Reichhold Chemicals, Inc.
VAREX, Polyester resins, McClosky Varnish Co.
VAREZ, Synthetic resins; esterified resin; modified resin esters; maleic resins, McClosky Varnish Co.
VARI-BOW, Adjustable bow expander, Mount Hope Machinery Co.
VARI-FRAME, Adjustable clamping frame, Plasti-Vac, Inc.
VARIMETER, Concentrate metering system, Plastic Molders Supply Co.
VARITRODE, Electrical corona discharge film treating equipment, Precision Machine & Development Co.
VARKYD, Alkyd & modified alkyd resins, McClosky Varnish Co.
VARKYDANE, Urethane vehicles, McClosky Varnish Co.
VARLAN, PVC resins, DSM
VAZO, Vinyl polymerization catalyst, Du Pont de Nemours, E. I., & Co.
VECTRA, Reinforcing filaments, Chevron Chemical Co., Fibers Div.
VEDOC, Powder coatings, Frit Div., Ferro Corp., Powder Coating Dept.
VEDRIL, Polymethyl methacrylate granules; extruded & cast sheet, Montedison S.p.A.
VEDRILCOL, Methacrylate-based adhesive, Montedison S.p.A.
VELENE, Styrene-foam laminate, Scott Paper Co., Foam Div.
VELON, Film & sheeting, Firestone Plastics Co., Div. Firestone Tire & Rubber Co.
VELVATEX, Printing ink, Sun Chemical Corp., General Printing Ink Div.
VEREFLEX, Plasticizer, Veresit Sacifi
VEREPOR, Foaming agent, Veresit Sacifi
VERILON, PVC film, Continental Plastic Co., Div. CPI, Inc.
VERSA CUTTER, Cut-off machine, Foster & Allen, Inc., Sub. Plastics Machinery Co.
VERSA-FEED, Take-off equipment, Foster & Allen, Inc., Sub. Plastics Machinery Co.
VERSA-TESTER, Tension-compression testing machine, Soiltest, Inc.
VERSATOR, Deaerating & dispersing equipment, Cornell Machine Co.
VERSI-PLY, Coextruded films, Pierson Industries, Inc.
VERTAMOLD, Injection & Compression molding machines, USI-Clearing, Div. U. S. Industries, Inc.
VERTRUDER, Plastic scrap system, Gloucester Engineering Co.
VESPEL, Diamond grinding wheels; plastic parts, Du Pont de Nemours, E. I., & Co.
VESTABLIT EPOXI, Plasticizer, Veresit Sacifi
VESTABLIT SN, Catalyst, Veresit Sacifi
VESTAMID, Nylon 12 resins & compounds, Chemische Werke Huls, AG
VESTOLEN (SERIES), Polyethylene, polypropylene, Chemische Werke Huls, AG
VESTOLIT, PVC resins & compounds, Chemische Werke Huls, AG
VESTOPAL, Polyester resins & compounds, Chemische Werke Huls, AG
VESTYPOR, Expandable polystyrene, Chemische Werke Huls AG
VESTYRON, Polystyrene resins & compounds, Chemische Werke Huls, AG
VI-TARD, Resinous dispersion fire retardant, National Adhesives Div., National Starch & Chemical Corp.
VIBRA-BLENDER, Continuous, high-speed blender, Vibra Screw Inc.
VIBRA-METRIC, Weigh belt feeder, Vibra Screw Inc.
VIBRA-SEAL, Plastic welding equipment, Ultra Sonic Seal Div.
VIBRATHANE, Polyurethane elastomer, Uniroyal, Inc.
VIBRATUB, Vibratory tumbling machine, Vibraslide Inc.
VIBRIN-MAT, Polyester-glass molding compound, Grace, W. R., & Co., Marco Chemical Div.
VIBRO-ENERGY, Vibratory screens, grinding mills, finishing mills, SWECO, Inc.
VIBRO-FLO, Epoxy, polypropylene & polyester coating powders, Armstrong Products Co.
VIBRO-FLUIDIZER, Fluidized bed coating equipment, Armstrong Products Co.
VICLAN, Polyvinylidene chloride latices & resins, Imperial Chemical Industries Ltd., Plastics Div.
VICRON, Fine calcium carbonate, Pfizer Minerals, Pigments & Metals Div.
VICTAWET, Surfacants, dispersants, emulsifiers, Stauffer Chemical Co., Specialty Chemical Div.

Trademarks and brand names (Cont'd)

VIKEM, Vinyl spray, Bel-Art Products
VINACRON, Plastisols & organosols, Loes Enterprises
VINALINER, Calendered PVC sheet, Goodyear Tire & Rubber Co., Plastic Film & Sheeting Dept.
VINAVIL, Polyvinyl acetate resins, Montedison S.p.A.
VINAVILOL, Polyvinyl alcohols, Montedison S.p.A.
VINNAPAS, Polyvinyl acetate, Wacker-Chemie GmbH
VINNOL, Polyvinyl chloride/vinyl chloride/acetate copolymers, Wacker-Chemie GmbH
VINOFLEX, PVC resins, BASF Wyandotte Corp.
VINOFLEX, Vinyl chloride-vinylisobutyl ether copolymer, BASF Wyandotte Corp.
VINURAN, Styrene-modified PVC, Badische Anilin- & Soda-Fabrik AG
VINY L STIX, Polyester pressure-sensitive labels, Topflight Corp.
VINYFIX, Self-adhesive vinyl film, UCB-Sidac
VINYLCLAIR, Transparent PVC films, May & Baker, Ltd.
VINYLEX, Flexographic inks, Gotham Ink & Color Co.
VINYZENE, Antimicrobial additive for thermoplastics, Ventron Corp.
VIOLITE, Luminescent pigments, Jamieson Laboratories
VIPAC, Opaque PVC films, May & Baker, Ltd.
VIPLA, PVC homopolymers, Montedison S.p.A.
VIPLAST, Pelletized PVC, Montedison S.p.A.
VIPLAVIL, Vinyl chloride-vinyl acetate copolymer, Montedison S.p.A.
VIRCOL (SERIES), Flame retardant for urethane, Mobil Chemical Co., Industrial Chemical Div.
VISCO-CORDER, Viscometer, Brabender, C. W., Instruments, Inc.
VISCOFIL, Water dispersed organic pigments, Sandoz Colors & Chemicals
VISCOLINE, Inline viscosity control systems, Brookfield Engineering Laboratories, Inc.
VISCOSEL, Viscosity control systems, Brookfield Engineering Laboratories, Inc.
VISCOTESTER, Viscometer, Haake, Inc.
VISSOLVER, High speed-low viscosity mixer, Baker Perkins, Inc.
VISTAFIX, Self-adhesive polyethylene film, UCB-Sidac
VISTAFLAM, Self-extinguishing polyethylene film, UCB-Sidac
VISTAL, Polyethylene film, UCB-Sidac
VITEL, Polyester resin, Goodyear Tire & Rubber Co., Chemical Div.
VITREDIL, Methacrylic sheets, Montedison S.p.A.
VITRO-FLEX, Chopped strand mat, Johns-Manville
VITRO-STRAND, Chopped strands, Johns-Manville
VITRON, Roving, Johns-Manville
VITUF, Polyester resin, Goodyear Tire & Rubber Co., Chemical Div.
VIVICOLOR, Fluorescent color polyethylene molding compounds, Frilvam, S.p.A.
VOIDOX, Antioxidant, stabilizer, Guardian Chemical Corp.
VOLARA, Closed-cell, low density polyethylene foam, Voltek, Inc.
VOLASTA, Closed-cell, medium density polyethylene foam, Voltek, Inc.
VORANOL, Polyurethane resins, Dow Chemical Co.
VORITE, Isocyanate terminated urethane prepolymers, NL Industries, Inc., Industrial Chemicals Div.
VULCAN, Furance carbon black, Cabot Corp., Special Blacks Div.
VULCO, Extruded PVC sheets & shapes, Vulcan Metal Products Inc.
VULKOLLAN, Polyurethane elastomer, Farbenfabriken Bayer AG
VYBOND, PVC coating powder, Plastic Coatings, Ltd.
VYCOAT, Air drying polyvinyl coating, Plastic Coatings, Ltd.
VYDAX, Release agent, Du Pont de Nemours, E. I., & Co.
VYDYNE, Nylon resins, Monsanto Co.
VYFLEX, PVC coating powders, Plastic Coatings Ltd.
VYGEN, PVC resin, General Tire & Rubber Co., Chemical/Plastics Div.
VYLASTIC, PVC plastisols for coating, Plastic Coatings Ltd.
VYN-EZE, Slip & anti-block agent, Fine Organics, Inc.
VYNACLOR, Vinyl chloride emulsion coatings & binders, National Adhesives Div., National Starch & Chemical Corp.
VYNAN, Unoriented PVC films, May & Baker, Ltd.
VYNAN VINYCLAIR, Unplasticized PVC film, Rhodia, Inc.
VYNATHENE, Vinyl-acetate ethylene copolymers, U. S. Industrial Chemicals Co., Div. National Distillers & Chemical Corp.
VYPEEL, Strippable coating, Plastic Coatings Ltd.
VYPRIME, Adhesive PVC/metal, Plastic Coatings Ltd.

WATERITE, Decorative laminate, Bakelite Xylonite Ltd.
WATCHMOLD, Injection mold cycle monitor, Ingersoll-Rand/IMPCO & Negri Bossi Divs.
WATER-SKIPPER, Hydrophobic resins & coatings, Purethane Div., Easton RS Corp.
WAXTONE, Colorant dispersion, 7-K Color Corp.
WAYTROL, Belt conveyor scales; constant weight feeders, Jeffrey Mfg. Co.
WEATHER-OMETER, Accelerated weathering tester, Atlas Electric Devices Co.

Trademarks and brand names (Cont'd)

WEB MASTER, Controlled expansion guide, Mount Hope Machinery Co.
WEDGMOUNT, Adjustable vibration damping machine mount, Air-Loc Div., Clark-Cutler-McDermott Co.
WEIGHTOMETER, Conveyor belt-scale & weigh-feeder, Merrick Scale Mfg. Co.
WELDFAST, Epoxy & polyester adhesives, Fibercast Co., Div. Youngstown Sheet & Tube Co.
WELDOX, Adhesives compositions, Hardman, Inc.
WELL-A-MELD, Glass sphere & glass fiber-reinforced resins, Wellman, Inc., Plastics Div.
WELL-BLEND, Blended nylon 6 & 6/6 resins, Wellman, Inc., Plastics Div.
WELL-FIBE, Glass-fiber-reinforced nylon resins, Wellman, Inc., Plastics Div.
WELL-SPHERE, Glass-sphere-reinforced nylon resins, Wellman, Inc., Plastics Div.
WELLAMID (SERIES), Nylon 6 & 6/6 molding resins, Wellman, Inc., Plastics Div.
WELVIC, PVC compounds & masterbatches, Imperial Chemical Industries Ltd., Plastics Div.
WESTCOAT, Strippable coatings, Western Coating Co.
WHIRLCLAD, Plastic coatings; coating service; coated parts, Polymer Corp.
WHISPER SPRAY, Foam fabricating adhesive, Imperial Adhesives & Chemicals, Inc.
WICAFIX, Fixing agents, Wica Chemicals, Div. Story Chemical Corp.
WICASET, Polyvinyl acetate emulsions, Wica Chemicals, Div. Story Chemical Corp.
WICATEX, Softeners, Wica Chemicals, Div. Story Chemical Corp.
WICATHICA, Thickeners, Wica Chemicals, Div. Story Chemical Corp.
WIFAG, Offset printing machines, American Production Machine Co.
WIFAG, Dry offset printing machines, Polytype Ltd.
WILFLEX, Vinyl plastisols, Flexible Products Co.
WILLIAMS, Inorganic pigments & extenders, Pfizer Minerals, Pigments & Metals Div.
WILTROL, Retarders, Polychem Dept., Stepan Chemical Co.
WINGSTAY, Antioxidants, Goodyear Tire & Rubber Co., Chemical Div.
WINNOFIL, Calcium carbonate, ICI America Inc.
WITACLOR, Chlorinated paraffine plasticizers, Dynamit Nobel, A.G.
WITAFROL, Additives, Dynamit Nobel, A.G.
WITAMOL, Plasticizers, Dynamit Nobel, A.G.
WIXOL, Wetting agents, Wica Chemicals, Div. Story Chemical Corp.
WRAPAPRINTA, Roll leaf imprinters, Gottscho, Adolph, Inc.
WRINKLE-GUARD, Anti-wrinkle slat expander, Progressive Machine Co.
WYTOX, Antioxidants; stabilizers, Polychem Dept., Stepan Chemical Co.

X-AIR, Viscosity reducer, Isochem Resins Co.
X-LINK, Crosslinking latex coatings & binders, National Adhesives Div., National Starch & Chemical Corp.
XILOCOLLA, Urea-formaldehyde resins, Montedison S.p.A.
XT Polymer, Acrylic multipolymer, American Cyanamid Co., Industrial Chemicals & Plastics Div.

YORK, Extruded phenolic profiles, Budd Co./Polychem Div.

ZELEC, Lubricant & release agent, Du Pont de Nemours, E. I., & Co.
ZELUX, Polycarbonate shapes, Westlake Plastics Co.
ZENDEL, Polyethylene films, Union Carbide Corp., Chemicals & Plastics
ZEOFREE, Anticaking agent, Huber, J. M., Corp.
ZEOLEX, Silica pigment, Huber, J. M., Corp.
ZEOSYL, Silica pigment, Huber, J. M., Corp.
ZEOTHIX, Silica pigment, Huber, J. M., Corp.
ZEROK, Protective coatings, Atlas Minerals & Chemicals Div., ESB Inc.
ZEROMATIC, pH measuring instruments, Beckman Instruments, Inc.
ZIG-ZAG, Continuous blender, Patterson-Kelley Co.
ZINSTABE, Heat & UV stabilizer systems, New Jersey Zinc Co.
ZIPFLO, Belt conveyor, Kornylak Corp.
ZITEX, Fibrous, porous TFE, Chemplast, Inc.
ZOPAQUE, Titanium dioxide, Glidden Pigments & Colors, SCM Corp.
ZYLEX, Thermoformed material, Preservation Packaging, Inc.
ZYROTO, Rotogravure inks, Gotham Ink & Color Co.
ZYTEL, Nylon resins, Du Pont de Nemours, E. I., & Co.

A steel ball rebound tester has been found useful for the determination of thermophysical character-

APPENDIX B
A PLASTICS GLOSSARY*

A

A-stage – An early stage in the reaction of a thermosetting resin in which the material is still linear in structure, soluble in certain liquids and fusible. (See alsto B- and C-stage.)

Ablative plastics – A material which absorbs heat (while part of it is being consumed by heat) through a thermal decomposition process known as pyrolysis, which takes place in the near surface layer exposed to heat.

Absorption – (1) The penetration into the mass of one substance by another.
(2) The process whereby energy is dissipated within a specimen placed in a field of radiation energy. Since processes other than absorption occur, e.g., scattering, only a fraction of the energy removed from a beam is retained in the specimen.

Accelerator – A substance that hastens a reaction. For example, sulfur-containing compounds that speed up the vulcanization of rubber. Also known as promoter. Often used to denote a substance that hastens the action of an initiator or catalyst.

Accumulator – A term used mainly with reference to blow molding equipment that designates an auxiliary ram extruder which is used to provide extremely fast parison delivery. The accumulator cylinder is filled with plasticated melt coming from the extruder between parison deliveries or "shots" and is stored or "accumulated" until the plunger is required to deliver the next parison.

Acetal resins – Polymers containing the acetal linkage $\left(\gt C \lt {OR \atop OR}\right)$. One example would be polyoxymethylene.

Acid acceptor – A compound that acts as a stabilizer by chemically combining with acid, which may be initially present in minute quantities in a plastic or which may be formed by the decomposition of the resin.

Acrylic ester – An ester of acrylic acid, or of a structural derivative of acrylic acid, e.g., methyl methacrylate

$$(CH_2 = C(CH_3) - C(=O) - OCH_3).$$

Acrylic resin – A synthetic resin prepared from acrylic acid or from a derivative of acrylic acid.

Acrylonitrile – A monomer with the structure $CH_2 = CHCN$). Its copolymer with butadiene is nitrile rubber, and several copolymers with styrene exist that are tougher than polystyrene. Its homopolymer is also used as a synthetic fiber.

Acrylonitrile-butadiene-styrene (abbreviated ABS) – Blends or copolymers of polystyrene or styrene-acrylonitrile copolymer with butadiene-acrylonitrile rubber.

Adiabatic – An adjective used to describe a process or transformation in which no heat is added or allowed to escape from the system under consideration. It is used, somewhat incorrectly, to describe a mode of extrusion in which no external heat is added to the extruder, although heat may be removed by cooling to keep the output temperature of the melt passing through the extruder constant. The heat input in such a process is developed by the screw as its mechanical energy is converted to thermal energy.

Addition polymer – A polymer formed by a chain reaction, e.g., polyethylene and polystyrene.

Addition polymerization – Polymerization of monomers by a chain mechanism involving active centers on the growing chain. Frequently done with unsaturated monomers and usually called vinyl polymerization when unsaturated monomer contains $CH_2 = C <$ group.

Aging – The change of a material with time under defined environmental conditions, leading to improvement or deterioration of properties.

Air-assist forming – A method of thermoforming (q.v.) in which air flow or air pressure is employed to partially preform the sheet immediately before final vacuum pulldown onto the mold.

Air gap – In extrusion coating, the distance from die opening to nip formed by the pressure roll and the chill roll.

Air ring – A circular manifold used to distribute an even flow of the cooling medium, air, onto a hollow tubular form passing through the center of the ring. In blown tubing, air cools tubing uniformly for uniform film thickness.

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A Plastics Glossary (Cont'd)

Air-slip forming – A variation of snap-back forming in which the male mold is enclosed in a box in such a way that when the mold moves forward toward the hot plastic, air is trapped between the mold and the plastic sheet. As the mold advances, the plastic is kept away from it by the air cushion formed as described above until the full travel of the mold is reached, at which point a vacuum is applied, destroying the air cushion and forming the part against the plug.

Alkyd resin – Polyesters made from dicarboxylic acids and diols, primarily used as coatings, modified with vegetable oil, fatty acids, etc.

Alloy – Composite material made up by blending polymers or copolymers with other polymers or elastomers under selected conditions, e.g., styrene-acrylonitrile copolymer resins blended with butadiene-acrylonitrile rubbers. See Polyblends.

Allyl resin – Synthetic resin formed by polymerization of chemical compounds containing $CH_2 = CH - CH_2 -$. The principal commercial allyl resin is a casting material that yields allyl carbonate polymer.

Allyl diglycol carbonate (ADC) – A peroxide (free radical) cured, crystal clear thermoset with exceptional scratch resistance; used for goggles, scratch resistant glazing, etc.

Alternating copolymer – Copolymer in which the molecules of each monomer alternate in the polymer chain. See also Block and Random copolymers.

Amino – Indicates the presence of an $-NH_2$ group.

Amorphous phase – Devoid of crystalinity–no definite order. At processing temperatures a plastic is normally in an amorphous state.

Angle press – A hydraulic molding press equipped with horizontal and vertical rams and specially designed for the production of complex moldings containing deep undercuts.

Aniline-formaldehyde resins – Members of the amino-plastics family made by the condensation of formaldehyde and aniline in an acid solution. The resins are thermoplastic and are used to a limited extent in the production of molded and laminated insulating materials. Products made from these resins have high dielectric strength and good chemical resistance.

Anionic polymerization – Polymerization which is propagated by carbon atom intermediates which contain an unshared pair of electrons and are negatively charged (carbanions).

Annealing – A process of holding a material at an elevated temperature below its melting point, the objective being to permit stress relaxation without distortion of shape. It is often used on molded articles, to relieve stresses set up by flow into the mold.

Antioxidant – Substances which prevent or slow down oxidation of a polymeric material exposed to air.

Antistatic agents – Agents which minimize static electricity in plastics. Such agents are of two basic types: (1) metallic devices which come into contact with the plastics conducting the static to earth. Such devices give complete neutralization at the time, but because they do not modify the surface of the material it can become prone to further static during subsequent handling; (2) chemical additives which, when mixed with the compound during processing, give a reasonable degree of protection to the finished products.

Arc resistance – Time required for a given applied electrical voltage to render the surface of a material conductive because of carbonization by the arc discharge.

Atactic – Lack of structural regularity. Random placement of side chain substituents with respect to a vinyl polymer backbone.

Autoacceleration – The increase in rate of polymerization and molecular weight of some vinyl monomers polymerized in bulk or concentrated solution. Due to increase in viscosity of the reaction medium as the reaction proceeds. This impedes termination but does not appreciably affect propagation. Often called the Trommsdorff effect.

Autoclave – (1) Closed vessel for conducting chemical reactions under high pressure and temperature; (2) in low-pressure laminating, a round or cylindrical container in which heat and pressure can be applied to resin-impregnated paper or fabric positioned in layers over a mold.

Autoclave molding – Modification of the pressure bag method for molding reinforced plastics. After lay-up, entire assembly is placed in steam autoclave at 50 to 100 p.s.i. Additional pressure achieves higher reinforcement loadings and improved removal of air.

Automatic mold – A mold for injection or compression molding that repeatedly goes through the entire cycle, including ejection, without human assistance.

Autooxidation – The self-sustained oxidation of a polyolefin after initial exposure to some oxidizing agent such as molecular oxygen.

A Plastics Glossary (Cont'd)

Average molecular weight – Most synthetic polymers are a mixture of individual chains of many different sizes, hence a molecular weight assigned to such a mixture is of necessity an average molecular weight. See Number-, Weight-, z and Viscosity-, average molecular weights.

B

B-stage – An intermediate stage in the reaction of a thermosetting resin in which the material softens when heated and swells in contact with certain liquids but does not entirely fuse or dissolve. Resins in thermosetting molding compounds are usually in this stage. See also A-stage and C-stage.

Back pressure – The viscosity resistance of a material to continued flow when a mold is closing. In extrusion it is the resistance to the forward flow of molten material.

Back-pressure-relief port – An opening from an extrusion die for the escape of any excess material.

Back taper – Reverse draft used in mold to prevent molded article from drawing freely. (See Undercut.).

Backing plate – In injection molding, a plate used as a support for the cavity blocks, guide pins, bushings, etc.

Baffle – A device used to restrict or divert the passage of fluid through a pipe line or channel. In hydraulic systems the device, which often consists of a disc with a small central perforation, restricts the flow of hydraulic fluid in a high pressure line. A common location for the disc is in a joint in the line. When applied to molds, the term is indicative of a plug or similar device which is located in a steam or water channel in the mold and designed to divert and restrict flow to desired path.

Bag molding – A method of applying pressure during bonding or molding, in which a flexible cover, usually in connection with a rigid die or mold, exerts pressure on the material being molded through the application of air pressure or drawing of a vacuum.

Bakelite – At one time a trade name of the Bakelite Corp., and now a Union Carbide trade name to denote a thermoset synthesized by the condensation of phenol with formaldehyde. See Phenolic resin.

Balanced runner – A system designed to place all cavities the same distance from the sprue.

Banbury – A mixer for compounding materials composed of a pair of contra-rotating rotors which masticate the materials to form a homogeneous blend. This is an internal type mixer which produces excellent mixing.

Beta-cellulose – See Cellulose.

Beta gage (or beta-ray gage) – A gage consisting of two facing elements, a β-ray-emitting source and a β-ray detector. When a sheet material is passed between the elements, some of the β-rays are absorbed, the per cent absorbed being a measure of the density or thickness of the sheet.

Blanking – The cutting of flat sheet stock to shape by striking it sharply with a punch while it is supported on a mating die. Punch presses are used. Also called die cutting.

Bleed – To give up color when in contact with water or a solvent; undesired movement of certain materials in a plastic (e.g., plasticizers in vinyl) to the surface of the finished article or adjacent material. Also called migration.

Blister – A raised area on the surface of a molded plastic caused by the pressure of gases inside it on its incompletely hardened surface.

Block copolymer – Copolymer (-AAAA-BBBB-) in which the backbone consists of regions or blocks of one monomer (-AAAA-) along with regions or blocks of another monomer (-BBBB-).

Blocking – An undesired adhesion between touching layers of a material, such as occurs under moderate pressure during storage or use.

Blow molding – A method of fabrication in which a parison (hollow tube) is forced into the shape of the mold cavity by internal air pressure.

Blow pressure – The air pressure used to form a hollow part by blow molding.

Blow rate – The speed at which air enters the parison during the blow molding cycle.

Blowing agents – See Foaming agents.

Blow-up ratio – In blow molding, the ratio of the mold cavity diameter to the parison diameter. In blown tubing (film), the ratio of the final tube diameter (before gusseting, if any) to the original die diameter.

Blown tubing – A thermoplastic film which is produced by extruding a tube, applying a slight internal pressure to the tube to expand it while still molten and subsequent cooling to set the tube. The tube is then flattened through guides and wound up flat on rolls. The size of blown tubing is determined by the flat width in inches as wound rather than by the diameter as would be the case with rigid types of tubing.

A Plastics Glossary (Cont'd)

Blueing – A mold blemish in the form of a blue oxide film which occurs on the polished surface of a mold as a result of the use of abnormally high mold temperatures.

Booster – A booster or intensifier uses a large quantity of low pressure fluid in order to produce a small quantity of high pressure fluid.

Boss – Protuberance on a plastic part designed to add strength, to facilitate alignment during assembly, to provide for fastenings, etc.

Bottom blow – A specific type of blow molding machine which forms hollow articles by injecting the blowing air into the parison from bottom of mold.

Bottom plate – Part of the mold which contains the heel radius and push-up.

Branched – In molecular structure of polymers, refers to side chains attached to the main chain. Side chains are generally short. If long, then have graft copolymer.

Breakdown voltage – The voltage required, under specific conditions, to cause the failure of an insulating material. See Dielectric strength.

Breaker plate – A perforated plate located at the rear end of an extruder head. It often supports the screens that prevent foreign particles from entering the die.

Breathing – The opening and closing of a mold to allow gases to escape early in the molding cycle. Also called degassing. When referring to plastic sheeting "breathing" indicates permeability to air, bubbles, voids or trapped globules of gas within a plastic part.

Bubbler mold cooling (injection molding) – A method of cooling an injection mold in which a stream of cooling liquid flows continuously into a cooling cavity equipped with a coolant outlet that is normally positioned at the end opposite the inlet. Uniform cooling can be achieved in this manner.

Bulk density – The mass per unit volume of a molding powder as determined in a reasonably large volume.

Bulk factor – Ratio of the volume of loose molding powder to the volume of the same weight of resin after molding.

Burning rate – A term describing the tendency of plastics articles to burn at given temperatures. Certain plastics, such as those based on shellac, burn readily at comparatively low temperatures. Others will melt or disintegrate without actually burning or will burn only if exposed to direct flame and are referred to as self-extinguishing.

Bushing (extrusion) – The outer ring of any type of a circular tubing or pipe die that forms the outer surface of the tube or pipe.

Butadiene – A diene monomer with the structure ($CH_2 = CH - CH = CH_2$). May be copolymerized with styrene and with acrylonitrile. Its homopolymer is used as a synthetic rubber.

Butt fusion – A method of joining pipe, sheet or other similar forms of a thermoplastic resin wherein the ends of the two pieces to be joined are heated to the molten state and then rapidly pressed together to form a homogeneous bond.

C

C-stage – The final stage in the reactions of a thermosetting resin in which the material is insoluble and infusible. Thermosetting resins in a fully cured plastic are in this stage. See A-Stage and B-Stage.

Calender (v.) – To prepare sheets of material by pressure between two or more counter-rotating rolls. (n.) – The machine performing this operation.

Caprolactam – A cyclic amide containing six carbon atoms. Ring may be cleaved and polymerized to polycaprolactam (nylon-6).

Carbon Black – A black pigment produced by the incomplete burning of natural gas or oil. It is widely used as a filler or pigment, particularly in the rubber industry. Because it possesses ultraviolet protective properties, it is used in PE systems such as cold water piping and black agricultural sheet.

Casein – A protein material precipitated from skimmed milk by the action of dilute acid. Acid casein is a raw material used mainly in the manufacture of buttons and buckles.

Cast – (1) To form a "plastic" object by pouring a fluid monomer-polymer solution into an open mold where it finishes polymerizing; (2) forming plastic film and sheet by pouring the liquid resin onto a moving belt or by precipitation in a chemical bath.

Casting (n.) – The finished product of a casting operation: should not be used for molding, q.v.

A Plastics Glossary (Cont'd)

Casting area – The moldable area of a thermoplastic in square inches for a given thickness and under a given thickness and under a given set of injection molding conditions. Casting area is a measure of flow under actual molding conditions where flow is unrestricted by cavity boundaries.

Catalyst – A substance which speeds up the polymerization or cure of a compound when added in minor quantity as compared to the amounts of primary reactants, providing it does not become a component part of the chain; otherwise it is referred to as an initiator, See Hardener, Inhibitor, Promoter.

Cationic polymerization – Polymerization initiated by a Lewis Acid (electron acceptor) and which propagates through a positively charged carbon atom lacking a pair of electrons (carbonium ion).

Cavity – Depression in a mold made by casting, machining, hobbing or a combination of these methods; depending on number of such depressions, molds are designated either as single-cavity or multicavity.

Cellular plastics – See Foamed plastics.

Cellular striation – A layer of cells within a cellular plastic that differs greatly from the characteristic cell structure of the material.

Celluloid – A thermoplastic material made from plasticized cellulose nitrate, q.v., with camphor. Alcohol is normally employed as a volatile solvent in order to assist plasticization and is subsequently removed.

Cellulose – A naturally occurring polysaccharide made up solely of glucose units and found in most plants; the main constituent of dried woods, jute, flax, hemp, ramie, etc. Cotton is almost pure cellulose; however, in many other important natural cellulosic materials the cellulose is associated with sizable quantities of impurities including lignin (a natural resin) and various hexosans, pentosans and polyuronides collectively called hemicelluloses. The portion of a given amount of "cellulose" which does not dissolve following 45-min. action of 17.5% aqueous solution of NaOH at 20^{o} C. is alpha cellulose. The undissolved amount is called the alpha cellulose content. That portion which does dissolve is divided into two types, betacellulose, which reprecipitates upon neutralization of the filtrate with acid, and gamma-cellulose, which does not.

Cellulose acetate – An acetic acid ester of cellulose. It is obtained by the action, under rigidly controlled conditions, of acetic acid and acetic anhydride on purified cellulose usually obtained from cotton linters. All three available hydroxyl groups in each glucose unit of the cellulose can be acetylated, but in the preparation of cellulose acetate it is usual to acetylate fully and then to lower the acetyl value (expressed as acetic acid) to 52 to 56% by partial hydrolysis. When compounded with suitable plasticizers it gives a tough thermoplastic material.

Cellulose acetate butyrate – An ester of cellulose made by the action of a mixture of acetic and butyric acids and their anhydrides on a purified cellulose. It is used in the manufacture of plastics that are similar in general properties to cellulose acetate but are tougher and have better moisture resistance and dimensional stability.

Cellulose ester – A derivative of cellulose in which the free hydroxyl groups attached to the cellulose chain have been replaced wholly or in part by acidic groups, e.g., nitrate or carboxylate groups. Esterification is effected by the use of a mixture of an acid with its anhydride in the presence of a catalyst, such as sulfuric acid. Mixed esters of cellulose, e.g., cellulose acetate butyrate, are prepared by the use of mixed acids and mixed anhydrides. Esters and mixed esters, a wide range of which are known, differ in their compatibility with plasticizers, in molding properties and in physical characteristics. These esters and mixed esters are used in making thermoplastic molding compositions.

Cellulose nitrate (nitrocellulose) – A nitric acid ester of cellulose manufactured by the action of a mixture of sulfuric acid and nitric acid on cellulose, such as purified cotton linters. The type of cellulose nitrate used for celluloid manufacture usually contains from 10.8 to 11.1% of nitrogen. The latter figure is the nitrogen content of the dinitrate.

Cellulose propionate – An ester of cellulose made by the action of propionic acid and its anhydride on purified cellulose. It is used as the basis of a thermoplastic molding material.

Cellulose triacetate – A cellulosic material made by reacting purified cellulose with acetic anhydride in the presence of a catalyst. All three hydroxyl groups in each glucose unit of the cellulose are esterified. It is used in the form of films and fibers. Films and sheets are cast from clear solutions onto "drums" with highly polished surfaces. The film, which is of excellent clarity, has high tensile strength, good heat resistance and dimensional stability.

Center gated mold – An injection mold wherein the cavity is filled with resin through an orifice interconnecting the nozzle and the center of the cavity area. Normally, this orifice is located at the bottom of the cavity when forming items such as containers, tumblers, bowls, etc.

A Plastics Glossary (Cont'd)

Centipoise – A unit of viscosity conveniently and approximately defined as the viscosity of water at room temperature. The following table of approximate viscosities at room temperature may be useful for rough comparisons:

Liquid	Viscosity in centipoises
Water	1
Kerosene	10
Motor oil SAE 10	100
Caster oil; glycerin	1,000
Corn syrup	10,000
Molasses	100,000

Centrifugal casting – A method of forming thermoplastic resins in which the granular resin is placed in a rotatable container, heated to a molten condition by the transfer of heat through the walls of the container and rotated so that the centrifugal force induced will force the molten resin to conform to the configuration of the interior surface of the container. Used to fabricate large diameter pipes and similar cylindrical items.

Chain length – See Degree of polymerization.

Charge – The measurement or weight of material used to load a mold at one time or during one cycle.

Chase – An enclosure of any shape used to: (a) shrink-fit parts of a mold cavity in place; (b) prevent spreading or distortion in hobbing; (c) enclose an assembly of two or more parts of a split cavity block.

Chemically foamed plastic – A cellular plastic whose structure is produced by gases generated from the chemical interaction of its constituents, e.g., polyurethanes.

Chill roll – A cored roll, usually temperature controlled with circulating water that cools the web before winding. For chill roll (cast) film, the surface of the roll is highly polished. In extrusion coating either a polished or a matte surface may be used depending on the surface desired on the finished coating.

Chill roll extrusion (or cast film extrusion) – The extruded film is cooled while being drawn around two or more highly polished chill rolls cored for water cooling for exact temperature control.

Chlorinated polyether – A chlorine substituted polymer containing the ether linkage (–C–O–C–). Pentaerythritol, cyclized to an octane by dehydration and then polymerized by opening the ring structure is one example of a polyether.

Choked neck – Narrowed or constricted opening in the neck of a container.

CIL (flow test) – A method of determining the rheology or flow properties of thermoplastic resins developed by Canadian Industries Limited. In this test, the amount of the molten resin which is forced through a specified size orifice per unit time when a specified, variable force is applied gives a relative indication of the flow properties of various resins.

Clamping plate – A plate fitted to a mold and used to fasten the mold to a machine.

Clamping pressure – In injection molding and in transfer molding, the pressure which is applied to the mold to keep it closed in opposition to the fluid pressure of the compressed molding material.

Closed-cell foam – A cellular plastic in which there is a predominance of non-interconnecting cells.

Clearance – A controlled distance by which one part of an object is kept separated from another part.

Coating – See specific type of coating such as Curtain, Extrusion, Kiss-roll coatings.

Coat hanger die – One basic type of extrusion slot die shaped internally like a coat hanger to gain better distribution across the full width of a sheet extrusion.

Coating weight – The weight of coating per unit area. In the United States usually "per ream," i.e., 500 sheets 24 x 36 in. (3000 sq. ft.), but sometimes 1000 sq. feet.

Coefficient of expansion – See Thermal expansion.

Cold flow – See Creep.

Cold molding – A procedure in which a composition is shaped at room temperature and cured by subsequent baking.

Cold slug – The first material to enter an injection mold; so called because in passing through sprue orifice it is cooled below the effective molding temperature.

Cold slug well – Space provided directly opposite the sprue opening in an injection mold to trap the cold slug.

A Plastics Glossary (Cont'd)

Cold stretch – Pulling operation with little or no heat, usually on extruded filaments, to improve tensile properties.

Collapse – Contraction of the walls of a container, e.g., upon cooling, leading to a permanent indentation.

Compression mold – A mold which is open when the material is introduced and which shapes the material by heat and by the pressure of closing.

Compression molding – A technique of thermoset molding in which the molding compound (generally preheated) is placed in the open mold cavity, mold is closed, and heat and pressure (in the form of a downward moving ram) are applied until the material has cured.

Compression ratio – In an extruder screw the ratio of volume available in the first flight at the hopper to the last flight at the end of the screw.

Compressive strength – Pressure load at failure of a shaped specimen divided by a cross-sectional area of the specimen, usually the original sectional area.

Condensation – A chemical reaction in which two or more molecules combine with the separation of water or some other simple substance. If difunctional or higher functionality molecules react, the condensation process is called polycondensation. See also Polymerization.

Condensation polymer – A polymer formed by polycondensation, e.g., the alkyd, phenol-formaldehyde and urea-formaldehyde resins.

Conditioning – The subjection of a material to a stipulated treatment so that it will respond in a uniform way to subsequent testing or processing. The term is frequently used to refer to the treatment given to specimens before testing.

Consistency – The resistance of a material to flow or permanent deformation when shearing stresses are applied to it. The term is generally used with materials whose deformations are not proportional to applied stresses. Viscosity is generally considered to be a similar internal friction that results in flow in proportion to the stress applied. (See Viscosity; Viscosity coefficient.)

Contact pressure resins – Liquid resins which thicken or resinify on heating and, when used for bonding laminates, require little or no pressure.

Continuous tube process – A blow-molding process using a continuous extrusion of tubing to feed into the blow molds as they clamp in sequence.

Convergent die – A die in which the internal channels leading to the orifice are converging (only applicable to dies for hollow bodies).

Cooling channels – Channels or passageways located within the body of a mold through which a cooling medium is circulated to control temperature.

Cooling fixture – Block of metal or wood holding the shape of a molded piece which is used to maintain the proper shape or dimensional accuracy of molding after it is removed from the mold until it is cool enough to retain its shape without further appreciable distortion. Also known as Shrink fixture.

Coordination polymers – Organic addition polymerizations which are neither free radical nor simply ionic in nature. Prepared by catalysts which are combinations of organometallics such as triethyl-aluminum and transition metal compounds such as $TiCl_4$.

Copolymer – A polymeric system which contains two or more monomeric units. See also Alternating, Random, Block and Graft copolymers.

Core and separator – The center section of an extrusion die.

Core – (1) The central member in a sandwich construction (can be honeycomb material, foamed plastic or solid sheet) to which the faces of the sandwich are attached; the central member of a plywood assembly; (2) A channel in a mold for circulation of heat-transfer media. (3) Part of a complex mold that molds undercut parts. Cores are usually withdrawn to one side before the main sections of the mold open. Also called core pin.

Core drill – A device for making cooling channels in a mold.

Corona resistance – A current passing through a conductor induces a surrounding electrostatic field. When voids exist in the insulation near the conductor, the high voltage electrostatic field may ionize and rapidly accelerate some of the air molecules in the void. These ions can then collide with the other molecules, ionizing them and thereby "eating" a hole in the insulation. Resistance to this process is called corona resistance.

Crazing – Fine cracks which may extend in a network on or under the surface or through a layer of a plastic material. Usually occurs in the presence of an organic liquid or vapor, with or without the application of mechanical stress.

A Plastics Glossary (Cont'd)

Creep – The dimensional change with time of a material under load, following the initial instantaneous elastic deformation. Creep at room temperature called cold flow.

Crosshead (extrusion)– A device generally employed in wire coating which is attached to the discharge end of the extruder cylinder designed to facilitate extruding material at an angle. Normally this is a 90 deg. angle to the longitudinal axis of the screw.

Crosslinking – The formation of primary valence bonds between polymer molecules. When extensive, as in thermosetting resins, crosslinking makes one infusible, insoluble, supermolecule of all the chains.

Crystallinity – A state of molecular structure in some resins which denotes stereo-regularity and compactness of the molecular chains forming the polymer. Normally can be attributed to the formation of solid crystals having a definite geometric form.

Cull – Material remaining in a transfer chamber after mold has been filled. Unless there is a slight excess in the charge, the operator cannot be sure cavity is filled. Charge is generally regulated to control thickness of cull.

Cure – The changing of the physical properties of a material by chemical reactions such as polycondensation, addition polymerization or vulcanization; usually accomplished by the action of heat and catalysts alone or in combination, with or without pressure.

Curing temperature – Temperature at which a cast, molded or extruded product, resin-impregnated reinforcement, adhesive, etc., is subjected to curing.

Curing time (molding time) – In the molding of thermosetting plastics the interval of time between the instant of cessation of relative movement between the moving parts of a mold and the instant that pressure is released.

Curling – A condition in which the parison curls upwards and outwards sticking to the outer face of the die ring. Balance of temperatures between die and mandrel will normally relieve this problem.

Curtain coating – A method of coating which may be employed with low viscosity resins of solutions, suspensions, or emulsions or resins in which the substrate to be coated is passed through and perpendicular to a freely falling liquid "curtain" (or "waterfall"). The flow rate of the falling liquid and the linear speed of the substrate passing through the curtain are coordinated in accordance with the thickness of coating desired.

Curvature – A condition in which the parison is not straight, but somewhat bending and shifting to one side, leading to a deviation from the vertical direction of extrusion. Centering of ring and mandrel can often relieve this.

Cut-off – The line where the two halves of a compression mold come together; also called Flash groove or Pinch-off.

Cycle – The complete, repeating sequence of operations in a process or part of a process. In molding the cycle time is the period or elapsed time between a certain point in one cycle and the same point in the next.

D

Dash-pot – A device used in hydraulic systems for damping down vibration. It consists of a piston attached to the part to be damped and fitted into a vessel containing fluid or air. It absorbs shocks by reducing the rate of change in the momentum of moving parts of machinery.

Daylight opening – Clearance between two press platens in the open position.

Debossed – An indent or cut in design or lettering of a surface.

Deckle rod – A small rod or similar device inserted at each end of the extrusion coating die which is used to adjust the length of the die opening.

Decorative sheet – A laminated plastic sheet used for decorative purposes in which the color and or surface pattern is an integral part of the sheet.

Deflashing – Covers the range of finishing techniques used to remove the flash (excess material) on a plastic molding.

Degassing – See Breathing.

Degree of polymerization (DP) – The number of structural units or mers in the polymer molecule in a particular sample. The value is obtained from the molecular weight of the polymer divided by that of the mer. If "average" molecular weight is used, then the value is the "average" DP. In most polymers the DP must reach several thousand if worthwhile physical properties are to be had.

A Plastics Glossary (Cont'd)

Delamination – The separation of the layers in a laminate caused by the failure of the adhesive or resin binder.

Delinquescent – Capable of attracting moisture from the air.

Denier – The weight (in grams) of 9000 meters of a fiber in the form of continuous filament.

Density – Weight per unit volume of a substance expressed in grams per cubic centimeter, pounds per cubic foot, etc.

Destaticization – Treating plastics materials to minimize their accumulation of static electricity and, consequently, the amount of dust picked up by the plastics because of such charges.

Diaphragm gate – Gate used in molding annular or tubular articles.

Die adaptor – That part of an extrusion die which holds the die block.

Die blades – Deformable member(s) attached to a die body which determine the slot opening and which are adjusted to produce uniform thickness across the film or sheet produced.

Die block – That port of an extrusion die which holds the forming bushing and core.

Die body – That part of an extrusion die used to separate and form material.

Die Cutting – (1) Blanking q.v.; (2) Cutting shapes from sheet stock by striking it sharply with a shaped knife edge known as a "steel-rule die." Clinking and dinking are other names for die cutting.

Die gap – The distance between the metal faces forming the die opening.

Die lines – Vertical marks on the parison caused by damage of die parts or contamination.

Die swell ratio – The ratio of the outer parison diameter (or parison thickness) to the outer diameter of the die (or die gap). Die swell ratio is influenced by polymer type, head construction, land length, extrusion speed, temperature.

Dielectric – Insulating material. In radio-frequency preheating, dielectric may refer specifically to the material which is being heated.

Dielectric constant – Normally the relative dielectric constant; for practical purposes, the ratio of the capacitance of an assembly of two electrodes separated solely by a dielectric material to its capacitance when the electrodes are separated solely by air (ASTM D150).

Dielectric heating (electronic heating) – The plastic to be heated forms the dielectric of a condenser to which is applied a high-frequency (20 to 80 mc.) voltage. Process is used for sealing vinyl films and preheating thermoset molding compounds.

Dielectric strength – The electric voltage gradient at which an insulating material is broken down or "arced through" in volts per mil of thickness.

Difunctional – See Functionality.

Dilatant – A dilatant fluid, or inverted pseudoplastic, is one whose apparent viscosity increases instantaneously with increasing rate of shear; i.e., the act of stirring creates instantly an increase in resistance to stirring.

Dimer – A substance comprised of two molecules of a monomer. The degree of polymerization is two.

Dip Coating – Applying a plastic coating by dipping the article to be coated into a tank of melted resin or plastisol, then chilling the adhering melt.

Dispersant – In an organosol a liquid component which has a solvating or peptizing action on the resin so as to aid in dispersing and suspending it.

Dispersion – Finely divided particles of a material in suspension in another substance.

Dissipation factor – See Power factor.

Divergent die – A die in which the internal channels leading to the orifice are diverging (applicable only to dies for hollow bodies).

Doctor roll, doctor bar, doctor place – A device for regulating the amount of liquid material on the rollers of a spreader.

Double-shot molding – A means of turning out two-color parts in thermoplastics materials by successive molding operations.

Dowel – Pin used to maintain alignment between two or more parts of a mold.

Draft – The degree of taper of a side wall or the angle of clearance designed to facilitate removal of parts from a mold.

Drape assist frame – In sheet thermoforming, a frame (made up of anything from thin wires to thick bars) shaped to the peripheries of the depressed areas of the mold and suspended above the sheet to be formed. During forming, the assist frame drops down, drawing the sheet tightly into the mold and thereby preventing webbing between high areas of the mold and permitting closer spacing in multiple molds.

A Plastics Glossary (Cont'd)

Drape forming – Method of forming thermoplastic sheet in which the sheet is clamped into a movable frame, heated and draped over high points of a male mold. Vacuum is then pulled to complete the forming operation.

Draw-down ratio – The ratio of the thickness of the die opening to the final thickness of the product.

Drawing – The process of stretching a thermoplastic to reduce its cross-sectional area, placing the polymer chains in a more orderly arrangement with respect to each other.

Dry coloring – Method commonly used by fabricators for coloring plastics by tumble blending uncolored particles of the plastic material with selected dyes and pigments.

Dry spot – Area of incomplete surface film on laminated plastics; in laminated glass, an area over which the interlayer and the glass are not bonded.

Dry strength – The strength of an adhesive joint determined immediately after drying under specified conditions or after a period of conditioning in the standard laboratory atmosphere.

Ductility – The extent to which a solid material can be drawn into a thinner cross-section.

Duplicate cavity plate – Removable plate that retains cavities, used where two-plate operation is necessary for loading inserts.

Durometer hardness – Hardness of a material as it is measured by the Shore durometer.

Dwell – A pause in the application of pressure to a mold made just before the mold is completely closed in order to allow for the escape of gas from the molding material.

Dyes – Synthetic or natural organic chemicals that are soluble in most common solvents. Characterized by good transparency, high tinctorial strength and low specific gravity.

E

Ejector pin (on sleeve) – A pin or thin plate that is driven into a mold cavity from the rear as the mold opens, forcing out the finished piece. Also Knock-out pin.

Ejector pin-retainer plate – Retainer into which ejector pins are assembled.

Ejector plate – A plate which backs up the ejector pins and holds the ejector assembly together.

Ejector return pins – Projections that push the ejector assembly back as the mold closes; also called surface pins and return pins.

Ejector rod – Bar that actuates the ejector assembly when mold is opened.

Elastic deformation – The part of the deformation of an object under load that is recoverable on removal of load.

Elastic rotor – A form of screwless extrusion where melt is achieved mechanically between rotating members.

Elasticity – That property of a material by virtue of which it tends to recover its original size and shape after deformation. If the strain is proportional to the applied stress, the material is said to exhibit Hookean or ideal elasticity.

Elastomer – A material which at room temperature stretches under low stress to at least twice its length and snaps back to the original length upon release of stress.

Electronic treating – A method of oxidizing a film of polyethylene to render it printable by passing the film between the electrodes and subjecting it to a high-voltage corona discharge.

Electroformed mold – A mold made by electroplating metal on the reverse pattern on the cavity. Molten steel may be then sprayed on the back of the mold to increase its strength.

Elongation – The fractional increase in length of a material stressed in tension.

Embossing – Techniques used to create depressions of a specific pattern in plastic film and sheeting.

Emulsion – A suspension of extremely fine droplets of one liquid in another.

Emulsion polymerization – A two-phase polymerization in which an organic monomer is emulsified in aqueous solution by a soap. The initiators are water soluble and are capable of diffusing into the emulsified monomer droplets.

Encapsulating – Encasing of an article (usually an electronic component of the like) in a closed envelope of plastic by immersing the object in a casting resin and allowing the resin to polymerize, or if hot, to cool.

Engineering plastics (colloq.) – Plastics that lend themselves to engineering design, e.g., gears, structural members and similar items.

A Plastics Glossary (Cont'd)

Engraved-roll (or gravure) coating – The amount of coating applied to the web is metered by the depth of the over-all engraved pattern in a print roll. This process is frequently modified by interposing a resilient offset roll between the engraved roll and the web.

Entrance angle – Maximum angle at which the molten material enters the land area of the die, measured from the center line of the mandrel.

Envenomation – The process by which the surface of a plastic close to or in contact with another surface is deteriorated. Softening, discoloration, mottling, crazing or other effects may occur.

Environmental stress cracking (ESC) – The susceptibility of a thermoplastic to crack or craze under influence of chemical treatment and/or mechanical stress.

Epoxy resins – Based on ethylene oxide, its derivatives or homologs, epoxy resins form straight-chain thermoplastics and thermosetting resins, e.g., by the condensation of bisphenol and epichlorohydrin to yield a thermoplastic which is converted to a thermoset by active hydrogen-containing compounds, e.g., polyamines, dianhydrides.

Ester – The reaction product of an alcohol and an acid.

Ethylene-vinyl acetate – Copolymer of ethylene and vinyl acetate having many of the properties of polyethylene, but of considerably increased flexibility for its density – elongation and impact resistance are also increased.

Exotherm – (1) The temperature/time curve of a chemical reaction giving off heat, particularly the polymerization of casting resins. (2) The amount of heat given off. The term has not been standardized regarding sample size, ambient temperature, degree of mixing, etc.

Expanded plastics – See Foamed Plastics.

Extender – A substance added to a plastic composition to reduce the amount of the primary resin required per unit area.

Extraction – The transfer of a material from a substance to a liquid in contact with the substance.

Extrudate – The product or material delivered by an extruder, such as film, pipe, the coating on wire, etc.

Extrusion – The compacting of a plastic material and the forcing of it through an orifice in a more or less continuous fashion.

Extrusion coating – The coating of a resin on a substrate by extruding a thin film of molten resin and pressing it onto or into the substrate without adhesive.

F

Fabricate – To work a material into a finished form by machining, forming or other operation, or to make flexible film or sheeting into end products by sewing, cutting, sealing, etc.

Fadeometer – An apparatus for determining the resistance of resins and other materials to fading. This apparatus accelerates the fading by subjecting the article to high-intensity ultraviolet rays of approximately the same wave length as those found in sunlight.

False neck – A neck construction which is additional to the neck finish of a container and which is only intended to facilitate the blow molding operation. Afterwards the false neck part is removed from the container.

Family mold (injection) – A multicavity mold wherein each of the cavities forms one of the component parts of the assembled finished object.

Fatty acid – An organic acid containing the carboxylic functional group $(-\underset{\underset{O}{\|}}{C}-OH)$ obtained by the hydrolysis (saponification) of natural fats and oils, e.g., stearic and palmitic acids. They are monobasic, may or may not have some double bonds, contain 12 or more C atoms.

Fault – An electrical short circuit or leakage path to ground or from phase to phase inadvertently created.

Female – In molding practice, the indented half of a mold designed to receive the male half.

Fiber – This term usually refers to relatively short lengths of very small cross-sections of various materials. Fibers can be made by chopping filaments (converting). Staple fibers may be ½ to a few in. in length and usually from one to five denier.

Filament – A variety of fiber characterized by extreme length, which permits its use in yarn with little or no twist and usually without the spinning operations required for fibers.

Filament winding – Roving or single strands of glass, metal or other reinforcement are wound in a predetermined pattern onto a suitable mandrel. The pattern is so designed as to give maximum strength in the directions required. The strands can either be run from a creel through a resin bath before winding, or preimpregnated materials can be used. When the right number of layers has been applied, the wound mandrel is cured at room temperature or in an oven.

Fill-and-wipe – Parts are molded with depressed designs; after application of paint, surplus is wiped off, leaving paint remaining only in depressed areas.

Filler – A cheap, inert substance added to a plastic to make it less costly. Fillers may also improve physical properties, particularly hardness, stiffness and impact strength. The particles are usually small, in contrast to those of reinforcement (q.v.); but there is some overlap between the functions of the two types of material.

Filler specks – Visible specks of a filler, such as wood flour or asbestos, which stand out in color contrast against the background.

Fillet – A rounded filling of the internal angle between two molding surfaces.

Film – An optional term for sheeting having a nominal thickness not greater than 0.010 inch.

Fin – The web of material remaining in holes or openings in a molded part which must be removed in finishing.

Fines – Very small particles (usually under 200 mesh) accompanying larger grains, usually of molding powder.

Finish – The plastic forming the opening of a container shaped to accomodate a specific closure. Also the ultimate surface structure of an article.

Finish insert – A removable part of a blow mold to form a specific neck finish of a plastic bottle. Sometimes called neck insert.

Fish eye – A fault in transparent or translucent plastics materials, such as film or sheet, appearing as a small globular mass, and caused by incomplete blending of the mass with surrounding material.

Flake – Used to denote the dry, unplasticized base of cellulosic plastics.

Flame retardant resin – A resin which is compounded with certain chemicals to reduce or eliminate its tendency to burn. For polyethylene and similar resins, chemicals such as antimony trioxide and chlorinated paraffins are useful.

Flame spraying – Method of applying a plastic coating in which finely powdered fragments of the plastic, together with suitable fluxes, are projected through a cone of flame onto a surface.

Flame treating – A method of rendering inert thermoplastic objects receptive to inks, lacquers, paints, adhesives, etc., in which the object is bathed in an open flame to promote oxidation of the surface of the article.

Flammability – Measure of the extent to which a material will support combustion.

Flash – Extra plastic attached to a molding along the parting line which must be removed before the part can be considered finished.

Flash gate – A long, shallow rectangular gate.

Flash groove – A groove ground in a force so excess material can escape.

Flash line – A raised line appearing on the surface of a molding and formed at the junction of mold faces.

Flash mold – A mold designed to permit excess molding material to escape during closing.

Flash point – The lowest temperature at which a combustible liquid will give off a flammable vapor that will burn momentarily.

Flash ridge – That part of a flash mold along which the excess material escapes until the mold is closed.

Flexible molds – Molds made of rubber or elastomers used for casting plastics. They can be stretched to remove cured pieces with undercuts.

Flexibilizer – An additive that makes a resin or rubber more flexible. Also called a plasticizer.

Flexural strength – The strength of a material in bending, expressed as the tensile stress of the outermost fibers of a bent test sample at the instant of failure. With plastics, this value is usually higher than the straight tensile strength.

Floating chase – Mold member, free to move vertically, which fits over a lower plug or cavity, and into which an upper plug telescopes.

Floating platen – A platen located between the main head and the press table in a multi-daylight press and capable of being moved independently of them.

Flock – Short fibers of cotton, etc., used as fillers, q.v., for molding materials.

Flow – A qualitative description of the fluidity of a plastic during molding.

Flow line (weld line) – A mark on a molded piece made by the meeting of two flow fronts during molding.

A Plastics Glossary (Cont'd)

Flow marks – Wavy surface appearance of an object molded from thermoplastic resins caused by improper flow of the resin into the mold.

Fluidized bed coating – A method of applying a coating of a thermoplastic resin to an article in which the heated article is immersed in a dense-phase fluidized bed of powdered resin and thereafter heated in an oven to provide a smooth, pinhole-free coating.

Fluorescent pigments – Pigments which absorb radiation of a given frequency and then emit radiation of a different frequency. Leads to a glowing effect.

Fluorinated ethylenepropylene (FEP) – A member of the fluorocarbons, q.v., family of plastics, it is a copolymer of tetrafluoroethylene and hexafluoropropylene, processing most of the properties of polytetrafluoroethylene (PTFE), q.v., and also having a melt viscosity low enough to permit conventional thermoplastic processing. Available in pellet form for molding and extrusion, and as dispersions for spray or dip-coating processes.

Fluoroplastics (formerly called Fluorocarbons) – The family of plastics including polytetrafluoroethylene (PTFE); polychlorotrifluoroethylene (PCTFE); polyvinylidene fluoride and fluorinated ethylene propylene (FEP). q.v. They are characterized by properties including good thermal and chemical resistance and nonadhesiveness, and possess a low dissipation factor and low dielectric constant. Depending upon which of the fluorocarbons is used, they are available as molding materials, extrusion materials, dispersions, film or tape.

Flux – (1) An additive to a plastics composition during processing to improve its flow. For example, coumarone-indene resins are used as a flux during the milling of vinyl polymers. (2) Indicating a state of fluidity.

Foamed plastics – Resins in sponge form. The sponge may be flexible or rigid, the cells closed or interconnected, the density anything from that of the solid parent resin down to, in some cases, 2 lb./cu. foot. Compressive strength of rigid foams is fair, making them useful as core materials for sandwich structures. Both types are good heat barriers.

Foaming agents – Chemicals added to plastics and rubber that generate inert gases on heating, causing the resin to assume a cellular structure.

Foam-in-place – Refers to the deposition of foams which requires that the foaming machine he brought to the work which is "in place" as opposed to the procedure of bringing the work to the foaming machine.

Foil decorating – Molding paper, textile or plastic foil printed with compatible inks directly into a plastic part so that the foil is visible below the surface of the part as integral decoration.

Force plate – The plate that carries the plunger or force plug of a mold and guide pins or bushings. Since it is usually drilled for steam or water lines, it is also called the steam plate.

Force plug – The portion of a mold that enters the cavity block and exerts pressure on the molding compound, designated as top force or bottom force by position in the assembly: also called plunger or piston.

Forming – A process in which the shape of plastic pieces such as sheets, rods or tubes is changed to a desired configuration. The use of the term forming in plastics technology does not include such operations as molding, casting or extrusion, in which shapes or articles are made from molding materials or liquids.

Friction calendering – A process whereby an elastomeric compound is forced into the interstices of woven or cord fabrics while passing through the calender rolls.

Friction welding – A method of welding thermoplastics materials whereby the heat necessary to soften the components is provided by friction.

Frost line – In the extrusion of polyethylene layflat film, a ring-shaped zone located at the point where the film reaches its final diameter. This zone is characterized by a "frosty" appearance to the film caused by the film temperature falling below the softening range of the resin.

Frothing – Technique for applying urethane foam in which blowing agents or tiny air bubbles are introduced under pressure into the liquid mixture of foam ingredients.

Functionality – The ability of a compound to form covalent bonds. Compounds may be monofunctional, difunctional, trifunctional, polyfunctional, i.e., one, two, three, many functional groups participating in a reaction, respectively.

Furan resins – Dark-colored, thermosetting resins that are primarily liquids ranging from low-viscosity polymers to thick, heavy syrups. Based on furfural or furfuryl alcohol.

Furfural resin – Dark-colored synthetic resin of the thermosetting variety obtained by condensing furfural with phenol or its homologs. Used in manufacture of molding materials, adhesives and impregnating varnishes. Properties include, among others, high resistance to acids and alkalis.

Fuse – In plastisol molding, to heat the plastisol to the temperature at which it becomes a single homogeneous phase. In this sense, cure is the same as fuse.

G

Gamma cellulose – See Cellulose.

Gate – In injection and transfer molding, the orifice through which the melt enters the cavity. Sometimes the gate has the same cross-section as the runner leading to it; often, it is quite severely restricted.

Gel – That port of a three-dimensional step-reaction (crosslinked) polymer which is insoluble in all non-degrading solvents. The sol portion remains soluble and may be extracted from the gel.

Gel coat – A thin outer layer of resin, sometimes with pigment, applied to reinforced plastic molding as a cosmetic.

Gel point – The stage at which a liquid begins to exhibit elastic properties and increased viscosity. This stage may be conveniently observed from the inflection point on a viscosity-time plot. (See Gel.)

Gelation – Formation of infinitely large polymer networks in a reaction mixture.

Glass-bonded mica – A moldable thermoplastic having a glass binder and mica filler. (Also called ceramoplastic.)

Glass transition – The change in an amorphous polymer or in amorphous regions of a partially crystalline polymer from (or to) a viscous or rubbery condition to (or from) a hard and relatively brittle one. This transition generally occurs over a relatively narrow temperature region and is similar to the solidification of a liquid to a glassy state; it is not a phase transition. Not only do hardness and brittleness undergo rapid changes in this temperature region, but other properties such as thermal expansibility and specific heat also change rapidly. This phenomenon has been called second-order transition, glass transition, rubber transition and rubbery transition.

Glass transition temperature (Tg) – The temperature region in which the glass transition occurs. (See Glass transition.) The measured value of the glass transition temperature depends to some extent on the method of test.

Glitter (or filter or spangles) – A group of special decorative materials consisting of flakes large enough so that each separate flake produces a plainly visible sparkle or reflection. They are incorporated directly into the plastic during compounding.

Glucose – A carbohydrate having the molecular formula $C_6H_{12}O_6$; the main constituent of starch and cellulose.

Graft copolymer – A chain of one type of polymer to which side chains of a different or same type are attached or grafted, e.g., simultaneous polymerization of butadiene and styrene monomers.

Granular structure – Nonuniform appearance of finished plastic material due to retention of, or incomplete fusion of, particles of composition, either within the mass or on the surface.

Grid – Channel-shaped mold-supporting members.

Grinding-type resin – A vinyl resin which requires grinding to effect dispersion in plastisols or organosols.

Grit blasted – A surface treatment of a mold in which steel grit or sand materials are blown to the walls of the cavity to produce a roughened surface. Air escape from mold is improved and special appearance of molded article is often obtained by this method.

Guide pins – Devices that maintain proper alignment of force plug and cavity as mold closes.

Gum – An amorphous substance or mixture which, at ordinary temperatures, is either a very viscous liquid or a solid which softens gradually on heating and which either swells in water or is soluble in it. Natural gums, obtained from the cell walls of plants, are carbohydrates or carbohydrate derivatives of intermediate molecular weight.

Gusset – A tuck placed in each side of a tube of blown tubing as produced to provide a convenient square or rectangular package, similar to that of the familiar brown paper bag or sack, in subsequent packaging.

Gutta-percha – The naturally occurring Trans-1,4-polyisoprene which is obtained from the leaves and bark of certain tropical trees. Sometimes used to insulate electrical wiring and for transmission belting and various adhesives.

A Plastics Glossary (Cont'd)

H

Halocarbon plastics – Plastics based on resins made by the polymerization of monomers composed only of carbon and halogen.

Hand mold – A mold taken out of the press after each shot for part removal.

Hardener – A substance or mixture of substances added to a monomeric or polymeric composition, or an adhesive to promote or control the curing reaction. Also designates a substance added to control degree of hardness of a cured system. See also Catalyst.

Hardness – The resistance of a plastics material to compression and indentation. Among the most important methods of testing this property are Brinell hardness, Rockwell hardness and Shore hardness. See each of the individual listings.

Haze – The degree of cloudiness in a plastics material.

Head – End section of blow molding machine (in a general extruder) in which melt is transformed into a hollow parison.

Headspace – The space between the fill level of a container and the sealing plane.

Heat-distortion point – The temperature at which a standard test bar (ASTM D 648) deflects 0.010 in. under a stated load of either 66 or 264 p.s.i.

Heat sealing – A method of joining plastic films by simultaneous application of heat and pressure to areas in contact. Heat may be supplied conductively or dielectrically.

Heat treat – Term used to cover the process of annealing, hardening, tempering, etc., of metals.

Heat adapter – The part of an extrusion die around which heating medium is held.

Heating chamber – In injection molding, that part of the machine in which the cold feed is reduced to a hot melt. Also heating cylinder.

H.F. preheating – See Dielectric heating.

Heat-frequency heating – The heating of materials by dielectric loss in a high-frequency electrostatic field. The material is exposed between electrodes and, by absorption of energy from the electrical field, is heated quickly and uniformly throughout.

Hemi-cellulose – See Cellulose.

High-load melt index – The rate of flow of a molten resin through a 0.0825 in. orifice when subjected to a force of 21,600 gm. at 190^{o} C. See Melt index.

High polymer – A large molecule which is usually but not always comprised of repeat units of the low-molecular-weight species. Arbitrarily designated as having a molecular weight greater than 10,000.

High-pressure laminates – Laminates molded and cured at pressures not lower than 1000 p.s.i. and more commonly in the range of 1200 to 2000 p.s.i.

Hob – A master model in hardened steel used to sink the shape of a mold into a soft steel block.

Hobbing – Forming multiple mold cavities by forcing a hob (q.v.) into soft steel (or beryllium-copper) cavity blanks.

Hold-down groove – A small groove cut into the side wall of the molding surface to assist in holding the molded article in that member while the mold opens.

Homopolymer – A polymer consisting of only one monomeric species.

Honeycomb – Manufactured product consisting of sheet metal or a resin-impregnated sheet material (paper, fibrous glass, etc.) that has been formed into hexagonal-shaped cells. Used as core material for sandwich construction.

Hopper – Conical feed reservoir into which molding powder is loaded and from which it falls into a molding machine or extruder, sometimes through a metering device.

Hopper dryer – A combination feeding and drying device for extrusion and injection molding of thermoplastics. Hot air flows upward through the hopper containing the feed pellets.

Hopper loader – A curved pipe through which molding powders are pneumatically conveyed from shipping drums to machine hoppers.

Hot gas welding – A technique of joining thermoplastic materials (usually sheet) whereby the materials are softened by a jet of hot air from a welding torch and joined together at the softened points. Generally a thin rod of the same material is used to fill and consolidate the gap.

Hot-runner mold – A mold in which the runners are insulated from the chilled cavities and are kept hot. Parting line is at gate of cavity, runners are in separate plate(s), so they are not, as in the case usually, ejected with the piece.

A Plastics Glossary (Cont'd)

Hot stamping – Engraving operation for marking plastics in which roll leaf is stamped with heated metal dies onto the face of the plastics. Ink compounds can also be used. By means of felt rolls, ink is applied to type and by means of heat and pressure, type is impressed into the material, leaving the marking compound in the indentation.

Hydraulic – A system in which energy is transferred from one place to another by means of compression and flow of a fluid (e.g., water, oil).

Hydrocarbon resin – A family of thermoplastic compounds based on liquid styrene-butadiene-copolymers, polybutadiene with various high molecular weight hydrocarbon polymers such as polyethylene and elastomers.

Hydrogenation – Chemical process whereby hydrogen is introduced into a compound.

Hydrolysis – Chemical reaction of a substance with water.

Hygroscopic – Tends to absorb moisture.

I

Immiscible – Descriptive of two or more fluids that are not mutually soluble.

Impact bar (specimen) – A test specimen of specified dimensions utilized to determine the relative resistance of a plastic to fracture as a result of shock.

Impact resistance – Relative susceptibility of plastics to fracture by shock, e.g., as indicated by the energy expended by a standard pendulum-type impact machine in breaking a standard specimen in one blow.

Impact strength – (1) The ability of a material to withstand shock loading. (2) The work done in fracturing, under shock loading, a specified test specimen in a specified manner.

Impregnation – The process of thoroughly soaking a material such as wood, paper or fabric with a synthetic resin so that the resin gets within the material.

Impulse sealing – A heat-sealing technique in which a pulse of intense thermal energy is applied to the sealing area for a very short time, followed immediately by cooling. It is usually accomplished by using an RF heated metal bar which is cored for water cooling or is of such a mass that it will cool rapidly at ambient temperatures.

In-place process – A blow-molding process that makes use of a manifold with an orifice leading to each blow mold.

Infrared – Part of the electromagnetic spectrum between the visible light range and the radio wave region. Radiant heat is in this range, and infrared heaters are used in sheet thermoforming.

Inhibitor – A substance that slows down a chemical reaction. Inhibitors are sometimes used in certain types of monomers and resins to prolong storage life.

Initiator – A substance that speeds up the polymerization of a monomer and becomes a component part of the chain.

Injection blow molding – A blow-molding process in which the parison to be blown is formed by injection molding.

Injection mold – A mold into which a material is introduced from an exterior heating cylinder.

Injection molding – A molding procedure whereby a heat-softened plastic material is forced from a cylinder into a relatively cool cavity which gives the article the desired shape.

Injection molding cycle – The complete time cycle of operation utilized in injection molding of an object including injection, die close and die open time.

Injection ram – The ram which applies pressure to the plunger in the process of injection molding or transfer molding.

Inorganic pigments – Natural or synthetic metallic oxides, sulfides and other salts, calcined during processing at 1200 to 2100°F. They are outstanding in heat- and light-stability, weather resistance and migration resistance.

Insert – An integral part of a plastics molding consisting of metal or other material that may be molded into position or may be pressed into the molding after the molding is completed.

In situ foaming – The technique of depositing a foamable plastics (prior to foaming) into the place where it is intended that foaming shall take place. An example is the placing of foamable plastics into cavity brickwork to provide insulation. After being positioned, the liquid mix foams to fill the cavity. See also Foamed plastics.

A Plastics Glossary (Cont'd)

Insert, open-hole – One having a hole drilled completely through it.

Insert, protruding – One having a part protruding from molded material.

Insert, rivet – One having a protruding part that is riveted in assembly.

Insert, through type – One which is exposed on both sides of the molded plastic article.

Insulation resistance – The electrical resistance of an insulating material to a direct voltage. It is determined by measuring the leakage of current that flows through the insulation.

Interlock – A safety device designed to insure that a piece of apparatus will not operate until certain precautions have been taken.

Internal mixers – Mixing machines consisting of cylindrical containers in which the materials are deformed by rotating blades or rotors. The containers and rotors are cored so that they can be heated or cooled to control the temperature of a batch. These mixers are extensively used in the compounding of plastics and rubber materials and have the inherent advantage of keeping dust and fume hazards to a minimum.

Intrinsic viscosity – The intrinsic viscosity, $[\eta]$, of a polymer solution is defined as the limiting value of the reduced viscosity ($\eta SP/C$) as the concentration approaches zero, i.e., $[\eta] = \text{Lim} (\eta SP/C)$ where C = concentration, e.g., dl/g; ηSP = specific viscosity (see also Specific viscosity and Relative viscosity). Intrinsic viscosity is usually estimated by determining the specific viscosity at several low concentrations and extrapolating the values of $\eta SP/C$ to zero concentration.

Introfraction – The change in fluidity and wetting properties of an impregnating material, produced by the addition of an introfier, q.v.

Inventory – In injection molding or extrusion, the amount of plastic contained in the heating cylinder or barrel.

Ion-exchange resins – Small granular or bead-like particles containing acidic or basic groups, which will exchange ions with salts in solutions. One use is in the softening and purifying of water.

Ionic polymerization – A polymerization which proceeds through ionic intermediates (carbonium ions or carbanions) rather than through neutral species.

Ionomer resins – Polymers that have ethylene as their major component, but containing both covalent and ionic bonds. The polymers exhibit very strong interchain ionic forces. The anions hang from the hydrocarbon chain and the cations are metallic–magnesium, zinc. These resins have many of the same features as polyethylene plus high transparency, tenacity, resilience and increased resistance to oils, greases and solvents. Fabrication is carried out as with polyethylene.

Irradiation, atomic – As applied to plastics, refers to bombardment with a variety of subatomic particles, generally alpha-particles, beta- or gamma-rays. Atomic irradiation has been used to initiate polymerization and copolymerization of plastics and in some cases to bring about changes in the physical properties of a plastic material.

Isocyanate resins – Resins synthesized from isocyanates (– N = C = O) and alcohols (- OH). The reactants are joined through the formation of the urethane

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          O
          ||
linkage (-N-C-O-) and hence this field of technology is generally known as urethane chemistry.
          |
          H
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Isotactic – A stereoregular structure of a vinyl polymer in which the side chains are aligned on the same side of the plane of the polymer backbone.

Izod impact test – A test designed to determine the resistance of a plastics material to a shock loading. It involves the notching of a specimen, which is then placed in the jaws of the machine and struck with a weighted pendulum. See also Impact strength.

J

Jet molding – Processing technique characterized by the fact that most of the heat is applied to the material as it passes through the nozzle or jet rather than in a heating cylinder as is done in conventional processes.

Jet spinning – For most purposes, similar to melt spinning. Hot gas jet spinning uses a directed blast or jet of hot gas to "pull" molten polymer from a die lip and extend it into fine fibers.

Jetting – Turbulent flow of resin from an undersize gate or thin section into a thicker mold section, as opposed to lamular flow of material progressing radially from a gate to the extremities of the cavity.

Joint – The location at which two adherends are held together with a layer of adhesive.

Joint, butt – A type of edge joint in which the edge faces of the two adherends are at right angles to the other faces of the adherends. (See Joint; Joint, edge; Joint, scarf.)

Joint, edge – A joint made by bonding the edge faces of two adherends with adhesives. (See Joint; Joint, butt; Joint, scarf.)

Joint, lap – A joint made by placing one adherend partly over another and bonding together the overlapped portions. (See Joint, scarf.)

Joint, scarf – A joint made by cutting away similar angular segments of two adherends and bonding the adherends with the cut areas fitted together. (See Joint, Lap.)

Joint, starved – A joint that has an insufficient amount of adhesive to produce a satisfactory bond. This condition may result from too thin a spread to fill the gap between the adherends, excessive penetration of the adhesive into the adherend, too short an assembly time or use of excessive pressure.

K

Kirksite – An alloy of aluminum and zinc used for the construction of blow molds; it imparts a high degree of heat conductivity to the mold.

Kiss-roll coating – This roll arrangement carries a metered film of coating to the web; at the line of web contact it is split with part remaining on the roll, remainder of coating adhering to web.

Knife coating – A method of coating a substrate (usually paper or fabric) in which the substrate, in the form of a continuous moving web, is coated with a material whose thickness is controlled by an adjustable knife or bar set at a suitable angle to the substrate. In the plastics industry PVC formulations are widely used in this work and curing is effected by passing the coated substrate into a special oven, usually heated by infrared lamps or convected air. There are a number of variations of this basic technique, and they vary according to the type of product required.

Knit lines – See Weld mark.

Knockout pin – A device for knocking a cured piece from a mold. Also called ejector pin.

Knot tenacity (knot strength) – The tenacity in grams per denier of a yarn where an overhand knot is put into the filament or yarn being pulled to show up sensitivity to compressive or shearing forces.

L

Lacquer – Solutions of natural or synthetic resins, in readily evaporating solvents, which are used as protective coatings for products.

Laminar flow – Laminar flow of thermoplastic resins in a mold is accompanied by solidification of the layer in contact with the mold surface that acts as an insulating tube through which material flows to fill the remainder of the cavity. This type of flow is essential to duplication of the mold surface.

Laminated, cross – Pertaining to a laminate in which some of the layers of material are oriented at right angles to the remaining layers with respect to the grain or strongest direction in tension. (See Laminated, parallel.)

Laminated, parallel – Pertaining to a laminate in which all the layers of material are oriented approximately parallel with respect to the grain or strongest direction in tension. (See Laminated, cross.)

Laminated plastics (synthetic resin-bonded laminate, laminate) – A plastic material consisting of a synthetic resin-impregnated or resin-coated filler which have been bonded together, usually by means of heat and pressure, to form a single piece.

Laminated wood – A high-pressure bonded wood product composed of layers of wood with resin as the laminating agent. Plywood is a form of laminated wood in which successive layers of veneer are ordinarily cross laminated, the core of which may be veneer or sawed lumber in one piece or in a number of pieces.

Land – (1) The horizontal bearing surface of a semipositive or flash mold by which excess material escapes. See Cut-off. (2) The bearing surface along the top of the flights of a screw in a screw extruder; (3) the surface of an extrusion die parallel to the direction of melt flow.

Landed force – Force with which shoulder seats on land in landed positive mold.

A Plastics Glossary (Cont'd)

Landed plunger – See Landed force.

Latch – Device used to hold together two members of a mold.

Lay-up – As used in reinforced plastics, the reinforcing material placed in position in the mold; also the resin-impregnated reinforcement. (v.) – The process of placing the reinforcing material in position in the mold.

Leach – To extract a soluble component from a mixture by the process of percolation.

Leader pin – See Guide pins.

Leader-pin bushing – See Guide pins; Bushing.

Light resistance – The ability of a plastic material to resist fading after exposure to sunlight or ultraviolet light. Nearly all plastics tend to darken under these conditions.

L/D ratio – A term used to define an extrusion screw which denotes the ratio of the length of the screw to the diameter of the screw.

Lignin plastics – Plastics based on resins made by the treatment of lignin with heat or by reaction with chemicals or with not more than an equal weight of synthetic resins. The material is used as binders or extenders.

Linear molecule – A long-chain molecule of two-dimensional structure which may or may not contain side chains or branches. In effect, structural units connected to one another in a linear sequence.

Linters – Short fibers that adhere to the cotton seed after ginning. Used in rayon manufacture, as fillers for plastics and as a base for the manufacture of cellulosic plastics.

Loading space – Space provided in a compression mold or in the pot used with a transfer mold to accommodate the molding material before the material is compressed.

Loading tray (charging tray) – A device in the form of a specially designed tray which is used to load the charge simultaneously into each cavity of a multi-cavity mold by the withdrawal of a sliding bottom from the tray.

Locating ring – A ring which serves to align the nozzle of an injection cylinder with the entrance of the sprue bushing and the mold to the platen of a plastics processing machine.

Loop tenacity (loop strength) – The tenacity or strength value obtained by pulling two loops, as two links in a chain, against each other to demonstrate the susceptibility that a yarn, cord or rope has for cutting or crushing itself.

Loose-detail mold – A mold having parts that come out with the piece.

Loss factor – The product of the power factor and the dielectric constant.

Low-pressure laminates – In general, laminates molded and cured in the range of pressures from 400 p.s.i. down to and including pressures obtained by the mere contact of the plies.

Lucite – A trade name of Du Pont also used generically for polymers prepared from methyl methacrylate. Also called Plexiglas, a trade name of Rohm & Haas.

Lug – An indentation or raised portion of the surface of a container, provided to control automatic (multicolor) decorating operations.

Luminescent pigments – Special pigments available to produce striking effects in the dark. Basically there are two types: one is activated by ultraviolet radiation, producing very strong luminescence and, consequently, very eye-catching effects; the other type, known as phosphorescent pigments, does not require any separate source of radiation.

Lyophilic – In dispersions, having affinity for the dispersing medium.

Lyophobic – In dispersions, not having affinity for the dispersing medium.

M

[redacted]

Macromolecules – Large ("giant") molecules which make up high polymers.

Mandrel – (1) The core around which paper, fabric or resin-impregnated fibrous glass is would to form pipes or tubes, (2) In extrusion, the central finger of a pipe or tubing die.

Manifold – A term used mainly with reference to blow molding and sometimes with injection molding equipment. It refers to the distribution or piping system which takes the single channel flow output of the extruder or injection cylinder and divides it to feed several blow molding heads or injection nozzles.

Mark-Houwink equation – Expresses, for homogeneous linear polymers, the relationship between intrinsic viscosity $[\eta]$, and molecular weight, M, as $[\eta] = kM^a$ where a and k are constants. For random coils a lies between 0.5 and 1.0 and approaches 2.0 for rigid rods.

Masterbatch – A plastics compound that includes a high concentration of an additive or additives. Masterbatches are designed for use in appropriate quantities with the basic resin or mix so that the correct end concentration is achieved. For example, color masterbatches for a variety of plastics are extensively used as they provide a clean and convenient method of obtaining accurate color shades.

Mat – A randomly distributed felt of glass fibers used in reinforced plastics lay-up molding.

Material well – Space provided in a compression or transfer mold to care for bulk factor.

Matched metal molding – Method of molding reinforced plastics between two close-fitting metal molds mounted in a hydraulic press.

Mechanically foamed plastic – A cellular plastic whose structure is produced by physically incorporated gases.

Melamine formaldehyde resin – A synthetic resin derived from the reaction of melamine (2.4.6-triamino-1.3.5. triazine) with formaldehyde.

Melt extractor – Usually refers to a type of injection machine torpedo but could refer to any type of device that is placed in a system for the purpose of separating completely molten material from partially molten pellets and material. It thus insures a completely molten discharge of material from the system.

Melt fracture – An instability in the melt flow through a die starting at the entry to the die. It leads to surface irregularities on the finished article like a regular helix or irregularly spaced ripples.

Melt index – The amount, in grams, of a thermoplastic resin that can be forced through a 0.0825-in. orifice when subjected to 2160 gm force in 10 min. at 190° C.

Melt instability – An instability in the melt flow through a die starting at the land of the die. It leads to the same surface irregularities on the finished part as melt fracture.

Melt strength – The strength of the plastic while in the molten state.

Mer – The repeating structure unit of any high polymer.

Metallizing – Applying a thin coating of metal to a nonmetallic surface. May be done by chemical deposition or by exposing the surface to vaporized metal in a vacuum chamber.

Metallic pigments – A class of pigments consisting of thin opaque aluminum flakes or copper alloy flakes incorporated into plastics to produce unusual silvery and other metal-like effects.

Metastable – An unstable condition evidenced by changes of physical properties not caused by changes in composition or in environment. Metastable refers, for example, to the temporary, more flexible condition of some plastics after molding. No physical tests should be made while the plastic is in a metastable condition, unless data regarding this condition are desired.

Metering screw – An extrusion screw which was a shallow constant depth and constant pitch section over, usually, the last three to four flights.

Methyl methacrylate – $CH_2 = \overset{\overset{\displaystyle CH_3}{|}}{C} - COOCH_3$. A colorless, volatile liquid derived from acetone cyanohydrin, methanol and dilute sulphuric acid and used in the production of acrylic resins, q.v.

Methylpentene polymer – A thermoplastic material based on 4-methylpentene-1 and having low gravity (0.83), 90% optical transmission and 390° F. thermal range plus excellent electrical properties.

Migration of plasticizer – Loss of plasticizer from an elastomeric plastic compound with subsequent absorption by an adjacent medium.

M_{ii} (number-average molecular weight) – The total weight of all molecules divided by the total number of molecules,

$$M_{ii} = \frac{\Sigma N_i M_i}{\Sigma N_i}$$

or where N_i is the moles of species i and M_i its molecular weight.

Modified – Containing ingredients such as fillers, pigments or other additives, that help to vary the physical properties of a plastic material. An example is oil-modified resin.

Modulus of elasticity – Stress/strain ratio in a plastic material that is elastically deformed.

A Plastics Glossary (Cont'd)

Mohs value – A measure of hardness based on a scale, established in 1822 by Frederick Mohs, giving a relative ranking of minerals in the order in which one will scratch another.

Moisture-vapor transmission – The rate at which water vapor permeates through a plastic film or wall at a specified temperature and relative humidity.

Mold (v.) – To shape plastic parts or finished articles by heat and pressure. (n.) – (1) The cavity or matrix into which the plastic composition is placed and from which it takes its form. (2) The assembly of all the parts that function collectively in the molding process.

Mold base – The assembly of all parts making up an injection mold other than the cavity, cores and pins.

Mold insert (removable) – Part of a mold cavity or force that forms undercut or raised portions of a molded plastic article.

Mold efficiency – In a multimold blowing system the percentage of the total turn-around time of the mold actually required for forming, cooling and ejection of the container.

Molding cycle – (1) The period of time occupied by the complete sequence of operations on a molding press requisite for the production of one set of moldings. (2) The operations necessary to produce a set of moldings without reference to the time taken.

Molding powder – Plastic material in varying stages of granulation and comprising resin, filler, pigments, plasticizers and other ingredients ready for use in the molding operation.

Molding pressure – The pressure applied to the ram of an injection machine or press to force the softened plastic to fill the mold cavities.

Molding shrinkage (mold shrinkage, shrinkage, contraction) – The difference in dimensions, expressed in in./in., between a molding and the mold cavity in which it was molded, both the mold and the molding being at normal room temperature when measured.

Mold release – See Parting agent.

Mold seam – A vertical line formed at the point of contact of the mold halves. The prominence of the line depends on the accuracy with which the mating mold halves are matched. See Parting line.

Molecular weight distribution – A measure of the frequency of occurrence of the different molecular weight chains contained in a homologous polymeric system. The ratio of the weight average molecular weight to the number average molecular weight is sometimes used as an indication of the breadth of the distribution.

Monodispersity – Refers to a polymer system which is homogeneous in molecular weight, i.e., lacks molecular weight distribution.

Monofilament (monofil) – A single filament of indefinite length. Monofilaments are generally produced by extrusion. Their outstanding uses are in the fabrication of bristles, surgical sutures, fishing leaders, tennis racquet strings, screen materials, ropes and nets. The finer monofilaments more often than not are woven and knitted on conventional textile knitting machinery.

Monomer – A relatively simple compound which can react to form a polymer. See also Polymer.

Mounting plate – Part of blow-molding unit to which the mold is attached.

Movable platen – The large back platen of an injection molding machine to which the back half of the mold is secured during operation. This platen is moved either by a hydraulic ram or a toggle mechanism.

Multifilament yarn – The multifilament yarn is composed of a multitude of fine continuous filaments, often 5 to 100 individual filaments, usually with some twist in the yarn to facilitate handling. Multifilament yarn sizes are described in denier and range from 5 to 10 denier up to a few hundred denier. The larger deniers are usually obtained by plying smaller yarns together. Individual filaments in a multifilament yarn are usually about 1 to 5 denier (which is about ½ mil to 1 mil in diameter in Marlex polyethylene.)

Multiple-head machine – A blow-molding machine in which the plastic melt prepared by the extruder is divided into many separate streams (parisons), each giving ultimately a finished item.

$\bar{M}_v$ (viscosity-average molecular weight) is obtained from viscosity measurements, and it is expressed as

$$\bar{M}_v = \left[\frac{\Sigma N_i M_i^{a+1}}{\Sigma N_i M_i} \right]^{1/a}$$

where a is the constant in the Mark-Houwink equation.

A Plastics Glossary (Cont'd)

$\bar{M}_w$ (weight-average moledular weight) – The sum of the total weights of molecules of each size multiplied by their respective weights divided by the total weights of all molecules, or:

$$\bar{M}_w = \frac{\Sigma N_i M_i^2}{\Sigma N_i M_i}$$

$\bar{M}_z$ (Z-average molecular weight) defined as

$$\bar{M}_z = \frac{\Sigma N_i M_i^2}{\Sigma N_i M_i^2}$$

(See $\bar{M}_w$, $\bar{M}_v$).

Mylar – A film produced from the polyester of ethylene glycol and terephthalic acid (dimethyl terephthalate actually used). The fiber which is made by this particular procedure is called Dacron. Both Mylar and Dacron are Du Pont company trade names.

N

Neck – The part of a container where the shoulder cross-section area decreases to form the finish.

Neck-in – In extrusion coating, the difference between the width of the extruded web as it leaves the die and the width of the coating on the surface.

Neck insert – Part of the mold assembly that forms the neck and finish. Sometimes called neck ring.

Needle blow – A specific blow-molding technique where the blowing air is injected into the hollow article through a sharpened hollow needle that pierces the parison.

Nest plate – A retainer plate with a depressed area for cavity blocks used in injection molding.

Newtonian liquid – A liquid in which the rate of flow is directly proportional to the force applied. The viscosity is independent of the rate of shear, and there is no yield value in Newtonian flow.

Nip – The "V" formed where the pressure roll contacts the chill roll.

Nonpolar – Having no concentrations of electrical charge on a molecular scale (no dipole moment), thus incapable of significant dielectric loss. Examples among resins are polystyrene and polyethylene.

Nonrigid plastic – A nonstiffness or apparent modulus of elasticity of not over 50,000 p.s.i. at 25^{o} C. when determined according to ASTM test procedure D-747.

Novolac – A phenol-formaldehyde resin that, unless a source of methylene groups (more formaldehyde) is added, is permanently thermoplastic. Prepared by acid-catalyzed condensation.

Nozzle – The hollow cored metal nose screwed into the extrusion end of (a) the heating cylinder of an injection machine or (b) a transfer chamber where this is a separate structure. A nozzle is designed to form under pressure a seal between the heating cylinder of the transfer chamber and the mold. The front end of a nozzle may be either flat or spherical in shape.

Nylon – The generic name for all synthetic fiber-forming polyamides; they can be formed into monofilaments and yarns characterized by great toughness, strength and elasticity, high melting point and good resistance to water and chemicals. The material is widely used for bristles in industrial and domestic brushes and for many textile applications; it is also used in injection molding gears, bearings, combs, etc.

O

Oil-soluble resin – Resin which at moderate temperatures will dissolve in. disperse in or react with drying oils to give a homogeneous film of modified characteristics.

Olefins – A group of unsaturated hydrocarbons of the general formula C_aH_{2n} and named after the corresponding paraffins by the addition of "ene" or "ylene" to the stem. Examples are ethylene and pentene-1.

Oleo resins – Semisolid mixtures of the resin and essential oil of the plant from which they exude and sometimes referred to as balsams. Oleoresinous materials also consist of products of drying oils and natural or synthetic resins.

A Plastics Glossary (Cont'd)

One-shot molding – In the urethane foam field, indicates a system whereby the isocyanate, polyol, catalyst and other additives are mixed together directly and a foam is produced immediately (as distinguished from prepolymer).

Open-cell foam – A cellular plastic in which there is a predominance of interconnected cells.

Orange peel – Injection moldings that have unintentionally rough surfaces.

Organic pigments – Characterized by good brightness and brilliance. They are divided into toners and lakes. Toners, in turn, are divided into insoluble organic toners and lake toners. The insoluble organic toners are usually free from salt-forming groups. Lake toners are practically pure, water-insoluble heavy metal salts of dyes without the fillers or substrates of ordinary lakes. Lakes, which are not as strong as Lake toners, are water-insoluble heavy metal salts or other dye complexes precipitated upon or admixed with a base or filler.

Organosol – A resin (e.g., PVC) dispersion, the liquid phase of which contains one or more organic solvents. See also Plastisols.

Orientation – The alignment of the crystalline structure in polymeric materials so as to produce a highly uniform structure. Can be accomplished by cold drawing or stretching in fabrication.

Orifice – The opening in the extruder die formed by the orifice bushings (ring) and mandrel.

Orifice bushing – The outer part of the die in an extruder head.

Overcoating – In extrusion coating, the practice of extruding a web beyond the edge of the substrate web.

Overflow capacity – The capacity of a container to the top of the finish or to the point of overflow.

Overflow groove – Small groove used in molds to allow material to flow freely to prevent weld lines and low density and to dispose of excess material.

Overlay sheet (surfacing mat) – A nonwoven fibrous mat (either glass, synthetic fiber, etc.) used as the top layer in a cloth or mat lay-up to provide a smoother finish or minimize the appearance of the fibrous pattern.

Oxidation – The addition of oxygen to a compound or removal of hydrogen.

P

Paneling – Distortion of a container occuring during aging or storage caused by the development of a reduced pressure inside the container.

Parallels – (1) Spacers placed between the steam plate and press platen to prevent the middle section of the mold from bending under pressure. (2) Pressure pads or spacers between the steam plates of a mold to control height when closed and to prevent crushing the parts of the mold when the land area is inadequate.

Parison – The hollow plastic tube from which a container is blow molded.

Parison swell – In blow molding, the ratio of the cross-sectional area of the parison to the cross-sectional area of the die opening.

Parting agent – A lubricant, e.g., wax, silicone oil, used to coat a mold cavity to prevent the molded piece from sticking to it and thus to facilitate its removal from the mold. Also called release agent.

Parting line – Mark on a molding or casting where the two halves of a mold meet in closing.

Partitioned mold cooling – A large diameter hole drilled into the mold (usually the core) and partitioned by a metal plate extending to near the bottom end of the channel. Water is introduced near the top of one side of the partition and removed on the other.

Parylene – Poly-para-xylene, used in ultra-thin films for capacitor dielectrics and as a pore-free coating. Films are formed by heating a monomer and condensing it on a cool surface.

Pearlescent pigments – A class of pigments consisting of particles that are essentially transparent crystals of a high refractive index. The optical effect is one of partial reflection from the two sides of each flake. When reflections from parallel plates reinforce each other, the result is a silvery luster. Effects possible range from brilliant highlighting to moderate enhancement of the normal surface gloss.

Peptides – Low-molecular-weight-polymers of a-amino acids. Arbitrarily designated as having molecular weights under 10,000. Higher molecular-weight species are called polypeptides or proteins.

Permanent set – The increase in length, expressed in a percentage of the original length, by which an elastic material fails to return to original length after being stressed for a standard period of time.

Permeability – (1) The passage or diffusion of a vapor, liquid or solid through a barrier without physically or chemically affecting it. (2) The rate of such passage.

pH – The negative log of hydrogen ion concentration. It is an expression of the degree of acidity or alkalinity of a substance. Neutrality is pH7–acid solutions being under 7 and alkaline solutions over 7. There are pH meters commercially available that enable accurate readings.

Phenolic resin – A synthetic resin produced by the condensation of phenol with formaldehyde in base. Phenolic resins from the basis of a family of thermosetting molding materials, laminated sheet and stoving varnishes. They are also used as impregnating agents and as components of paints, varnishes, lacquers and adhesives.

Phenoxy resins – A high molecular weight thermoplastic polyether resin based on bisphenol-A and epichorohydrin having bisphenol A terminal groups. Recently developed in the United States, the material is available in grades suitable for injection molding, extrusion, coatings and adhesives, q.v.

Phthalate esters – A group of plasticizers, q.v., produced by the direct action of alcohol or phthalic anhydride. They are the most widely used of all plasticizers and are generally characterized by moderate cost, good stability and good all-round properties.

Phthalocyanine pigments – Organic pigments, q.v., of extremely stable chemical configuration resulting in very good fastness properties. These properties are enhanced by the formation of the copper complex which is the phthalocyanine blue most used. The introduction of chlorine atoms into the molecule of blue gives the well-known phthalocyanine green, also usually in the form of a copper complex.

Pill – See Preform.

Pinch-off – A raised edge around the cavity in the mold that seals off the part and separates the excess material as the mold closes around the parison in the blow-molding operation.

Pinch-off blades – The part of the mold that compresses the parison to effect sealing of the parison prior to blowing and to permit easy removal and cooling of flash.

Pinch-off land – The width of a pinch-off blade that will effect the sealing of the parison.

Pinch-off tail – The bottom of the parison pinched off when the mold closes.

Pinch-tube process – A basic blow-molding process in which the extruder drops a tube between mold halves, and tube is pinched off when mold closes.

Pinhole – A very small hole in an extruded resin coating of film.

Pinpoint gate – A restricted orifice of 0.030 in. or less in diameter through which molten resin flows into a mold cavity.

Pipe train – A term used in extrusion of pipe which denotes the entire equipment assembly used to fabricate the pipe, e.g., extruder, die, cooling bath, haul-off and cutter.

Pitch – The distance from any point on the flight of a screw line to the corresponding point on an adjacent flight, measured parallel to the axis of the screw line or threading.

Plastic deformation – A change in dimensions of an object under load that is not recovered when the load is removed; opposed to elastic deformation.

Plastic – (adj.) Pliable and capable of being shaped by pressure. "Plastic" is incorrectly used as the generic word for the industry and its products.

Plastics tooling – Tools, e.g., dies, jigs, fixtures, etc., for the metal-forming trades constructed of plastics, generally laminates or casting materials.

Plasticate – To soften by heating or kneading. Synonyms are: plastify, flux and (imprecisely) plasticize (q.v.)

Plasticity – The quality of being able to be shaped by plastic flow.

Plasticize – To soften a material and make it plastic or moldable either by adding a plasticizer or using heat.

Plasticizer – Chemical agents added to plastic compositions to improve flow and processability and to reduce brittleness. This is achieved by lowering the glass transition temperature.

Plasticorder or plastigraph – A laboratory device used to predict the performance of a plastic material by measurement of temperature, viscosity and shear rate relationships.

Plastigel – A plastisol exhibiting gel-like flow properties. Achieved by adding a thixotropic agent, e.g., gentonite, to the plastisol.

Plastisols – Mixtures of resins and plasticizers that can be molded, cast or converted to continuous films by the application of heat. If the mixtures contain volatile thinners also, they are known as organisols.

Plastometer – An instrument for determining the flow properties of a thermoplastic resin by forcing the molten resin through a die or orifice of specific size at a specified temperature and pressure.

Plate dispersion plug – Two perforated plates held together with a connecting rod which are placed in the nozzle of an injection molding machine to aid in dispersing a colorant in a resin as it flows through the orifices in the plates.

A Plastics Glossary (Cont'd)

Platens – The mounting plates of a press to which the entire mold assembly is bolted.

Platform blowing – A special technique for blowing large parts. To prevent excessive sag of the heavy parison, the machine employs a table which, after rising to meet the parison at the die, descends with the parison but at a slightly lower speed than the parison extrusion.

Plug and ring – Method of sheet forming in which a plug, functioning as a male mold, is forced into a heated plastic sheet held in place by a clamping ring.

Plug forming – A thermoforming process in which a plug or male mold is used to partially preform the part before forming is completed using vacuum or pressure.

Pock marks – Irregular indentations on the surface of a blown container caused by insufficient contact of the blown parison with the mold surface due to the low blow pressure, air or gas entrapment or moisture condensations on the mold surfaces.

Poise – A unit of viscosity in which the shearing stress is expressed in dynes per square centimeter to produce a velocity gradient of one centimeter per second per centimeter.

Polishing roll (s) – A roll or series of rolls which has a highly polished chrome-plated surface and is utilized to produce a smooth surface on sheet as it is extruded.

Polyacrylate – A thermoplastic resin made by the polymerization of an acrylic compound such as methyel methacrylate

$$(CH_2 = \overset{CH_3}{\overset{|}{C}} - COOCH_3).$$

Polyamide – A polymer in which structural units are linked by amide groupings $(- \overset{O}{\overset{||}{C}} - \underset{H}{\underset{|}{N}} -)$. Many polyamides are fiber formers.

Polyblends – A mechanical (nonchemical) mixture of two or more polymers, e.g., polystyrene and rubber.

Polycarbonate resins – Polymers derived from the direct reaction between aromatic and aliphatic dihydroxy compounds with phosgene or by the ester exchange reaction with appropriate phosgene derived precursors. Structural units are linked by carbonate groups $(- O - \underset{O}{\underset{||}{C}} - O -)$.

Polycondensation – See Condensation.

Polydispersity – Refers to a polymer system which is nonhomogeneous in molecular weight, i.e., having some molecular weight distribution.

Polyester – A resin formed by the reaction between a dibasic acid and a dihydroxy alcohol, both organic, or by the polymerization of a hydroxy carboxylic acid. Modification with multifunctional acids and/or alcohols and some unsaturated reactants permit crosslinking to thermosetting resins.

Polyester-reinforced urethane – A poromeric material, which may have a urethane impregnation or a silicone coating, for shoe uppers and industrial leathers.

Polyethylene – A thermoplastic material composed solely of ethylene. It is normally a translucent, tough, waxy solid that is unaffected by water and by a large range of chemicals.

Polyimide resins – Aromatic polyimides made by reacting pyromellitic dianhydride with aromatic diamines. Characterized by high resistance to thermal stress. Applications include components for internal combustion engines.

Polyisobutylene – The polymerization product of isobutylene. It varies in consistency from a viscous liquid to a rubber-like solid with corresponding variation in molecular weight from 1000 to 400,000.

Polyliner – A perforated longitudinally ribbed sleeve that fits inside the cylinder of an injection molding machine; used as a replacement for conventional injection cylinder torpedos.

Polymer – A high-molecular-weight compound, natural or synthetic, whose structure can usually be represented by a repeated small unit, the mer: e.g., polyethylene, rubber, cellulose. Synthetic polymers are formed by addition or condensation polymerization of monomers. Some polymers are elastomers, some plastics and some are fibers.

A Plastics Glossary (Cont'd)

Polymerization – A chemical reaction in which the high-molecular-weight molecules are formed from the original substances. When two or more monomers are involved, then the process is called copolymerization or heterpolymerization.

Polymethyl methacrylate – A thermoplastic polymer synthesized from methyl methacrylate. It is a transparent solid with exceptional optical properties and good resistance to water. It is obtainable in the form of sheets, granules, solutions and emulsions. Polymethyl methacrylate is a material that is extensively used for aircraft domes, lighting fixtures, decorative articles, etc.; it is also used in optical instruments and in surgical appliances.

Polyphenylene oxide – A polyether of 2, 6-dimethyl-phenol synthesized via an oxidative coupling process by means of air or pure oxygen in the presence of a copper-amine complex catalyst. These resins have a useful temperature range from less than -275 to 375° F. with intermittent use up to 400° F. possible.

Polypropylene – A tough, lightweight, rigid plastic made by the polymerization of high-purity propylene gas in the presence of an organometallic catalyst at relatively low pressures and temperatures.

Polysaccharides – Naturally occurring polymers that consist of simple sugars (monosaccharides). Examples are starch and cellulose.

Polysiloxanes – Polymers that contain the Si–O linkage. Usually synthesized by the polycondensation of silanols.

Polystyrene – A water-white thermoplastic produced by the polymerization of styrene (vinyl benzene). The electrical insulating properties of polystyrene are outstandingly good and the material is relatively unaffected by moisture. In particular the power loss is low over the frequency range 10^3–10^8 c.p.s.

Polysulfides - Polymers containing sulfur and carbon linkages. An example of this type polymer is Thiokol rubber, which is synthesized from organic dihalides and sodium polysulfide.

Polysulfone – A polymer containing the sulfone linkage $(- \overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}} -)$. These thermoplastic materials exhibit exceptional high temperature and low creep properties, have arc resistance, are self-extinguishing and may be molded and extruded.

Polyterpene resins – Thermoplastic resins obtained by the polymerization of turpentine in the presence of catalysts. These resins are used in the manufacture of adhesives, coatings, varnishes and in food packaging. They are compatible with waxes, natural and synthetic rubbers and polyethylene.

Polytetrafluoroethylene (PTFE) resins – Members of the fluorocarbons, q.v., family of plastics made by the polymerization of tetrafluoroethylene, PTFE, is characterized by its extreme inertness to chemicals, very high thermal stability and low frictional properties. Among the applications for these materials are bearings, fuel hoses, gaskets, tapes and coatings for metal and fabric.

Polyurethane resins – A family of resins produced by reacting diisocyanates in excess with glycols to form polymers having free isocyanate groups. These groups, under the influence of heat or certain catalysts, will react with each other, or with water, glycols, etc., to form a thermoset.

Polyvinyl acetal – A member of the family of vinyl plastics, q.v., polyvinyl acetal is the general name for resins produced from a condensation of polyvinyl alcohol with an aldehyde. There are three main groups: polyvinyl acetal itself, polyvinyl butyral and polyvinyl form, q.v., Polyvinyl acetal resins are thermoplastics that can be processed by casting, extruding, molding and coating, but their main uses are in adhesives, lacquers, coatings and films.

Polyvinyl acetate – A thermoplastic material composed of polymers of vinyl acetate in the form of a colorless solid. It is obtainable in the form of granules, solutions, latices and pastes and is used extensively in adhesives, for paper and fabric coatings and in bases for inks and lacquers.

Polyvinyl alcohol – A thermoplastic material composed of polymers of the hypothetical vinyl alcohol. Usually a colorless solid, insoluble in most organic solvents and oils, but soluble in water when the content of hydroxy groups in the polymer is sufficiently high. The product is normally granular and is obtained by hydrolysis of polyvinyl esters, usually by the complete hydrolysis of polyvinyl acetate. Used mainly for adhesives and coatings.

Polyvinyl butyral – A thermoplastic material derived from a polyvinyl ester in which some or all of the acid groups have been replaced by hydroxyl groups and some or all of these hydroxyl groups have been replaced by butyral groups by reaction with butyraldehyde. It is a colorless, flexible, tough solid and is used primarily in interlayers for laminated safety glass.

A Plastics Glossary (Cont'd)

Polyvinyl carbazole – A thermoplastic resin, brown in color, obtained by reacting acetylene with carbazole. The resin has excellent electrical properties and good heat and chemical resistance. It is used as an impregnate for improving paper capacitors.

Polyvinyl chloride (PVC) – A thermoplastic polymer synthesized from vinyl chloride; a colorless solid with outstanding resistance to water, alcohols and concentrated acids and alkalies. It is obtainable in the form of granules, solutions and pastes. Compounded with plasticizers, it yields a flexible material (plastisol) superior to rubber in aging properties. Widely used for cable and wire coverings and in making protective garments.

Polyvinyl chloride acetate – A thermoplastic copolymer of vinyl chloride and vinyl acetate; a colorless solid with good resistance to water, concentrated acids and alkalies. It is obtainable in the form of granules, solutions and emulsions. Compounded with plasticizers, it yields a flexible material superior to rubber in aging properties. Widely used for cable and wire coverings and in protective garments.

Polyvinyl formal – One of the groups of polyvinyl acetal resins, q.v., made by the condensation of formaldehyde with polyvinyl alcohol. It is used mainly in combination with cresylic phenolics for wire coatings and for impregnations, but can also be molded, extruded or cast. It is resistant to greases and oils.

Polyvinylidene chloride – A thermoplastic polymer of vinylidene chloride (1,1-dichloroethylene). It is a white powder with softening temperature at 185 to 200° C. The material is also supplied as a copolymer with acrylonitrile or vinyl chloride, giving products that range from the soft flexible type to the rigid type. Polyvinylidene chloride is also known as saran.

Polyvinylidene fluoride – This member of the fluorocarbons, q.v., family of plastics is a homopolymer of vinylidene fluoride (1,1-diffluoroethylene). It is supplied as powders and pellets for molding and extrusion and in solution form for casting. The resin has good tensile and compressive strength and high impact strength. Other applications are in chemical equipment such as gaskets, impellers and other pump parts, and packaging uses such as drum linings and protective coatings.

Porous molds – Molds that are made up of bonded or fused aggregates (powdered metal, coarse pellets, etc.) in such a manner that the resulting mass contains numerous open interstices of regular or irregular size through which either air or liquids may pass through the mass of the mold.

Positive mold – A mold designed to trap all the molding material when it closes.

Postforming – The forming, bending or shaping of thermoset laminates that have been heated to make them flexible before the final thermosetting reaction has occurred. On cooling, the formed laminate retains the contours and shape of the mold over which it has been formed.

Pot plunger – A plunger used to force softened molding material into the closed cavity of a transfer mold.

Pot retainer – Plate channeled for heat and used to hold pot of transfer mold.

Potting – Similar to encapsulating (q.v.), except that steps are taken to insure complete penetration of all the voids in the object before the resin polymerizes.

Pour-out finish – A container finish with an undercut below the top, designed to facilitate pouring without dripping.

Powder molding – General term used to denote several techniques for producing objects of varying sizes and shapes by melting polyethylene powder, usually against the inside of a mold. The techniques which are employed vary as to whether the molds are stationary (e.g., as in variations on rotational molding).

Power factor – In a perfect condenser, the current leads the voltage by 90°. When a loss takes place in the insulation, the absorbed current which produces heat disrupts the 90° relationship in proportion to the current absorbed by the dielectric. The power factor is the cosine of the angle between voltage applied and the current resulting. Measurements are usually made at million-cycle frequencies.

Preform (n.) – A compressed tablet or biscuit of plastic composition used for efficiency in handling and accuracy in weighing materials. (v.) – To make plastic molding powder into either pellets or tablets.

Preheating – The heating of a compound prior to molding or casting in order to facilitate the operation or to reduce the molding cycle.

Preheat roll – In extrusion coating, a heated roll installed between the pressure roll and unwind roll whose purpose is to heat the substrate before it is coated.

Pre-impregnation – The mixing of resin and reinforcing material before molding takes place.

Premix – Materials in which the resin, reinforcement, extenders, fillers, etc., have been premixed before molding.

Preplastication – Technique of premelting injection molding powders in a separate chamber, then transferring the melt to the injection cylinder. Device used for preplastication is known as a preplasticizer. See Plasticate.

A Plastics Glossary (Cont'd)

Preplasticizer – See Preplastication.

Prepolymer (n.) – A chemical intermediate whose molecular weight is between that of the monomer or monomers and the final polymer or resin.

Prepolymer molding – In the urethane foam field, indicates a system whereby a portion of the polyol is pre-reacted with the isocyanate to form a liquid prepolymer with a viscosity range suitable for pumping or metering. This component is supplied to end users with a second premixed blend of additional polyol, catalyst, blowing agent, etc. When the two components are mixed together, foaming occurs. (See One-shot molding).

Prepreg – A term generally used in reinforced plastics to mean the reinforcing material containing or combined with the full complement of resin before molding.

Preprinting – In sheet thermoforming, the distorted printing of sheets before they are formed. During forming, the print assumes its proper proportions.

Press polish – A finish for sheet stock produced by contact under heat and pressure with a very smooth metal, which gives to the plastic a high sheen.

Pressure forming – A thermoforming process wherein pressure is used to push the sheet to be formed against the mold surface as opposed to using a vacuum to suck the sheet flat against the mold.

Pressure pads – Reinforcements of hardened steel distributed around the dead areas in the faces of a mold to help the land absorb the final pressure of closing without collapsing.

Pressure roll – In extrusion coating, the roll that, with the chill roll, applies pressure to the substrate and the molten extruded web.

Pressure-sensitive adhesive – An adhesive which develops maximum bonding power by applying only a light pressure.

Primary plasticizer – Has sufficient affinity to the polymer or resin so that it is considered compatible and therefore may be used as the sole plasticizer.

Profile die – An extrusion die for the production of continuous shapes, excepting tubes and sheets.

Programming – The extrusion of a parison which differs in thickness in the length direction in order to equalize wall thickness of the blown container. It can be done with a pneumatic or hydraulic device which activates the mandrel shaft and adjusts the mandrel position during parison extrusion (parison programmer, controller or variator). It can also be done by varying extrusion speed on accumulator-type blow molding machines.

Projected area – The total parting line area of all moldings, runners, sprues, vents or culls in a mold.

Pseudoplastic – A fluid whose apparent viscosity or consistency decreases instantaneously with increase in rate of shear; i.e., an initial relatively high resistance to stirring decreases abruptly as the rate of stirring is increased.

Promoter – A chemical, itself a feeble catalyst, that greatly increases the activity of a given catalyst.

Prototype mold – A simplified mold construction often made from a light metal casting alloy or from an epoxy resin in order to obtain information for the final mold and/or part design.

Pulp – A form of cellulose obtained from wood or other vegetable matter by prolonged cooking with chemicals.

Pulp molding – Process by which a resin-impregnated pulp material is preformed by application of a vacuum and subsequently oven cured or molded.

Purging – Cleaning one color or type of material from the cylinder of an injection molding machine or extruder by forcing it out with the new color or material to be subsequently used. Purging materials are also available.

Push-up – The bottom contour of a plastic container designed in such a manner as to allow an even bearing surface on the outside edge and to prevent the bottle from rocking when it stands.

PVC – Polyvinyl chloride.

Pyrrones – Polyimidazopyrrolones synthesized from dianhydrides and tetramines. Soluble only in sulfuric acid and resistant to temperatures up to 600° C.

Q

Quench (thermoplastics) – A process of shock cooling thermoplastic materials from the molten state.

Quench bath – The cooling medium used to quench molten thermoplastic materials to the solid state.

Quench-tank extrusion – Extrusion of a film cooled in a quench-water bath.

A Plastics Glossary (Cont'd)

R

Radio frequency (r.f.) preheating – A method of preheating used for molding materials to facilitate the molding operation or reduce the molding cycle. The frequencies most commonly used are between 10 and 100 Mc/sec.

Radio frequency welding – A method of welding thermoplastics using a radio frequency field to apply the necessary heat. Also known as high frequency welding.

Ram – See Force plug.

Ram travel – The distance the injection ram moves in filling the mold in either injection or transfer molding.

Random copolymer – Copolymer in which the molecules of each monomer are randomly arranged in the polymer backbone.

Rayon – The generic term for fibers, staple and continuous filament yarns composed of regenerated cellulose, q.v. Rayon fibers are similar in chemical structure to natural cellulose fibers (e.g., cotton) except that the synthetic fiber contains shorter polymer units. Most of the rayon is made by the viscose process.

Reactivity ratios – The ratio of the rate of reaction of a monomer with itself to the rate of reaction with its comonomer in a copolymerization reaction.

Reciprocating screw – An extruder system in which the screw when rotating is pushed backwards by the molten polymer that collects in front of the screw. When sufficient material has been collected, the screw moves forward and forces the material through the head and die at a high speed.

Recycle – Ground material from flash and trimmings which, after mixing with a certain amount of virgin material, is fed back into the blow molder.

Reduced viscosity – The ratio of the specific viscosity, η_{sp}, to the concentration, c. i.e., η_{sp}/c.

Regenerated cellulose (cellophane) – A transparent cellulose plastic material made by mixing cellulose xanthate with a dilute sodium hydroxide solution to form a viscose. Regeneration is carried out by extruding the viscose in sheet form into an acid bath to create regenerated cellulose. The material is very widely used as a packaging and overwrapping material of exceptional clarity. The film also has good electrical properties and is resistant to oils and greases. Included among recent applications is the use of the material as a release agent in reinforced plastics moldings.

Reinforced molding compound – Compound containing resin and a reinforcing filler, supplied in the form of ready-to-use materials as distinguished from premix (q.v.)

Reinforcement – A strong inert material put into a plastic to improve its strength, stiffness and impact resistance. Reinforcements are usually long fibers of glass, sisal, cotton, etc.—in woven or nonwoven form. To be effective, the reinforcing material must form a strong adhesive bond with the resin.

Relative viscosity – The relative viscosity of a polymer solution is the ratio of the absolute viscosities of the solution (of stated concentration) and of the pure solvent at the same temperature, i.e.,

$$= \frac{\eta}{\eta_o}$$

where η_r = relative viscosity, η = absolute viscosity of polymer solution, η_o = absolute viscosity of pure solvent.

Release agent – See Parting agent.

Relief angle – The angle of the cut-away portion of the pinch-off blade measured from a line parallel to the pinch-off land.

Resin – Any of a class of solid or semisolid organic products of natural or synthetic origin, generally of high molecular weight, with no definite melting point. Most resins are polymers (q.v.).

Resinoid – Any of the class of thermosetting synthetic resins, either in their initial (temporarily fusible) or in their final (infusible) state. Compare this with Thermoset.

Resin pocket – An apparent accumulation of excess resin in a small, localized section on cut edge of molded surface.

Resistivity – The ability of a material to resist passage of electrical current either through its bulk or on a surface. The unit of volume resistivity is the ohm-cm., or surface resistivity, the ohm.

Restricted gate – A very small orifice between runner and cavity in an injection or transfer mold. When the piece is ejected, this gate breaks cleanly, simplifying separation of the runner from the piece.

Restrictor ring – A ring-shaped part protruding from the torpedo surface that provides increase of pressure in the mold to improve, e.g., welding of two streams.

A Plastics Glossary (Cont'd)

Retainer plate – The plate on which demountable pieces, such as mold cavities, ejector pins, guide pins and bushings are mounted during molding; usually drilled for steam or water.
Retaining pin – Pin on which insert is placed and located prior to molding.
Return pins – Pins that return the ejector mechanism to molding position.
Reverse-roll coating – The coating is premetered between rolls and then wiped off the web. The amount of coating is controlled by the metering gap and also by the speed of rotation of the coating roll.
Rheology – The study of flow of polymeric materials on a macroscopic and microscopic level.
Rib – A reinforcing member of a fabricated or molded part.
Rigid PVC – Polyvinyl chloride or a polyvinyl chloride/acetate copolymer characterized by a relatively high degree of hardness; it may be formulated with or without a small percentage of plasticizer.
Rigid resin – One having a modulus high enough to be of practical importance; e.g., 10,000 p.s.i. or greater.
Ring gate – Annular opening for entrance of material into cavity of injection or transfer mold.
Rockwell hardness – A common method of testing a plastics material for resistance to indentation in which a diamond or steel ball, under pressure, is used to pierce the test specimen. The load used is expressed in kilograms and a 10-kilogram weight is first applied and the degree of penetration noted. The so-called major load (60 to 150 kilograms) is next applied and a second reading obtained. The hardness is then calculated as the difference between the two loads and expressed with nine different prefix letters to denote the type of penetrator used and the weight applied as the major load.
Roller coating – Used for applying paints to raised designs or letters.
Roll mill – Two rolls placed in close relationship to one another used to admix a plastic material with other substances. The rolls turn at different speeds to produce a shearing action to materials being compounded.
Rosin – A resin obtained as a residue in the distillation of crude turpentine from the sap of the pine tree (gum rosin) or from an extract of the stumps and other parts of the tree (wood rosin).
Rotating spreader – A type of injection torpedo consisting of a finned torpedo which is rotated by a shaft extending through a tubular cross-section injection ram behind it.
Rotational casting (or molding) – A method used to make hollow articles from plastisols and latices. Plastisol is charged into hollow mold capable of being rotated in one or two planes. The hot mold fuses the plastisol into a gel after the rotation has caused it to cover all surfaces. The mold is then chilled and the product stripped out.
Roving – A form of fibrous glass in which spun strands are woven into a tubular rope. The number of strands is variable, but 60 is usual. Chopped roving is commonly used in preforming.
Runner – In an injection or transfer mold, the channel, usually circular, that connects the sprue with the gate to the mold cavity.

S

Sag – The local extension (often near the die face) of the parison during extrusion by gravitational forces. This causes necking-down of the parison. Also refers to the flow of a molten sheet in a thermoforming operation.
SAN – Styrene acrylonitrile thermoplastic copolymer with good stiffness, scratch, chemical and stress-crack resistance.
Sandwich constructions – Panels composed of a lightweight core material–honeycomb, foamed plastic, etc., q.v.– to which two relatively thin, dense, high-strength faces or skins are adhered.
Sandwich heating – A method of heating a thermoplastic sheet prior to forming which consists of heating both sides of the sheet simultaneously.
Saturated compounds – Organic compounds that do not contain double or triple bonds and thus cannot add on elements or compounds.
Scrap – Any product of a molding operation that is not part of the primary product. In compression molding, this includes flash, culls, runners and is not re-usable as a molding compound. Injection molding and extrusion scrap (runners, rejects, sprues, etc.) can usually be regrounded and remolded.
Screw plasticizing injection molding – A technique in which the plastic is converted from pellets to a viscose melt by means of an extruder screw that is an integral part of the molding machine. Machines are either single stage (in which plastication and injection are done by the same cylinder) or double stage (in which the material is plasticated in one cylinder and then fed to a second for injection into a mold).

A Plastics Glossary (Cont'd)

Sealing diameter – Portion of the insert that is free of knurl and is allowed to enter into the mold to prevent the flow of material.

Secondary plasticizer (or extender plasticizer) – Has insufficient affinity for the resin to be compatible as the sole plasticizer and must be blended with a primary plasticizer. The secondary acts as a diluent with respect to the primary and the primary-secondary blend has less affinity for the resin than does the primary alone.

Segregation – A close succession of parallel, relatively narrow and sharply defined wavy lines of color on the surface of a plastic that differ in shade from surrounding areas and create the impression that the components have separated.

Self-extinguishing – A somewhat loosely used term describing the ability of a material to cease burning once the source of flame has been removed.

Semipositive mold – A mold that allows a small amount of excess material to escape when it is closed. See Flash mold and Positive mold.

Semirigid plastic – A plastic that has a stiffness or apparent modulus of elasticity of between 10,000 and 100,000 p.s.i. at 23° C., when determined in accordance with the Standard Method of Test for Stiffness in Flexure of Plastics (ASTM Designation: D747).

Set – To convert a liquid resin or adhesive into a solid state by curing (q.v.) or by evaporation of solvent or suspending medium or by gelling.

Setting temperature – The temperature to which a liquid resin, an adhesive or products or assemblies involving either must be heated in order to set them.

Setting time – The period of time during which a molded or extruded product is subjected to heat and/or pressure to set the resin or adhesive.

Shear rate – The over-all velocity over the cross-section of a channel with which molten polymer layers are gliding along each other or along the wall in laminar flow:

$$\text{shear rate} = \frac{\text{velocity}}{\text{clearance}}$$

Shear strength – (a) The ability of a material to withstand shear stress. (b) The stress at which a material fails in shear.

Shear stress – The stress development in a polymer melt when the layers in a cross-section are gliding along each other or along the wall of the channel (in laminar flow):

$$\text{shear stress} = \frac{\text{force}}{\text{area sheared}}$$

Sheet (thermoplastics) – A flat section of a thermoplastic resin with the length considerably greater than the width and 10 mils or greater in thickness.

Sheet train – The entire assembly necessary to produce sheet which includes extruder, die, polish, rolls, conveyor, draw rolls, cutter and stacker.

Sheeter lines – Parallel scratches or projection ridges distributed over a considerable area of a plastic sheet.

Shim – In the manufacture of plywood, a long narrow patch that is either glued into the panel or cemented into the lumber core itself.

Shoe – See Chase.

Shore hardness – A method of determining the hardness of a plastic material. The device used consists of a small conical hammer fitted with a diamond point and acting in a glass tube. The hammer is made to strike the material under test and the degree of rebound is noted on a graduated scale. Generally the harder the material, the greater will be the rebound.

Short or short shot – In injection molding, failure to fill the mold completely.

Shot – The yield from one complete molding cycle, including scrap.

Shot capacity – Maximum weight of material that accumulator can push out with one forward stroke of the ram.

Shrinkage – Contraction of a molded material upon cooling or of a casting upon polymerizing.

Shrink fixture – See Cooling fixture.

Shrink wrapping – A technique of packaging in which the strains in a plastics film are released by raising the temperature of the film, thus causing it to shrink over the package. These shrink characteristics are built into the film during its manufacture by stretching it under controlled temperatures to produce orientation, q.v., of the molecules. Upon cooling, the film retains its stretched condition but reverts toward its more random original dimensions when it is heated. Shrink film gives good protection to the products packaged and has excellent clarity.

Siamese blow – A colloquial term applied to the technique of blowing two or more parts of a product in a single blow and then cutting them apart.

Side bars – Loose pieces used to carry one or more molding pins and operated from outside the mold.

Side draw pins – Projections used to core a hole in a direction other than the line of closing a mold and which must be withdrawn before the part is ejected.

Sink mark – A shallow depression or dimple on the surface of an injection-molded part due to collapsing of the surface following local internal shrinkage after the gate seals. May also be an incipient short shot.

Sinking a mold – See Hobbing.

Sintering – In forming articles from fusible powders, e.g., nylon, the process of holding the pressed-powder article at a temperature just below its melting point for a period of time. Particles are fused (sintered) together, but the mass as a whole does not melt.

Sizing – The process of applying a material to a surface to fill pores and thus reduce the absorption of the subsequently applied adhesive or coating or to otherwise modify the surface. Also the surface treatment applied to glass fibers used in reinforced plastics. Material used is often called size.

Sleeve ejector – Bushing-type knockout.

Sliding plate – See Duplicate cavity plate.

Slip additive – A modifier that acts as an internal lubricant that exudes to the surface of the plastic during and immediately after processing. The additive coats the surface and provides the necessary lubricity to reduce the coefficient of friction and improve slip.

Slip forming – Sheet-forming technique in which some of the plastic sheet material is allowed to slip through the mechanically operated clamping rings during a stretch-forming operation.

Slip joint – The method of laying-up veneers in flexible-bag molding, wherein edges are beveled and allowed to overlap over part or all of scarfed area.

Slip-plane – Plane within transparent material visible in reflected light due to poor welding and shrinkage on cooling.

Slot extrusion – A method of extruding film sheet in which the motion thermoplastic compound is forced through a straight slot.

Slurry preforming – Method of preparing reinforced plastics preforms by wet processing techniques similar to those used in pulp molding (q.v.).

Slush molding – Method for casting thermoplastics in which the resin in liquid form is poured into a hot hollow mold where a viscous skin forms. The excess slush is drained off, the mold is cooled and the molding stripped out.

Snap-back forming – Sheet-forming technique in which an extended heated plastic sheet is allowed to contract over a form shaped to the desired contours.

Softening range – The range of temperature in which a plastic changes from a rigid to a soft state. Actual values will depend on the method of test. Sometimes erroneously referred to as softening point.

Solid-piled – Sometimes called dead-piled or bulked-down. Plywood fresh from clamps or hot press is piled on a solid, flat base without stickers and weighted down while reaching normal temperature and moisture content.

Solution – Homogeneous mixture of two or more components, e.g., gas dissolved in gas or liquid, or a solid dissolved in a liquid.

Solvation – The process of swelling, gelling or solution of a resin by a solvent or plasticizer.

Solvent molding – Process for forming thermoplastic articles by dipping a mold in a solution or dispersion of the resin and drawing off the solvent to leave a layer of plastic film adhering to the mold.

Spanishing – A method of depositing ink in the valleys of embossed film.

Specific gravity – The density (mass per unit volume) of any material divided by that of water at a standard temperature, usually 4^{o} C. Since water's density is nearly 1.00 g./cc., density in g./cc. and specific gravity are numerically nearly equal.

Specific heat – The amount of heat required to raise a specified mass by one unit of a specified temperature.

A Plastics Glossary (Cont'd)

Specific viscosity – The specific viscosity, η_{sp}, of a polymer is the relative viscosity, η_r, of a polymer solution of known concentration minus one. It is usually determined at low concentration of the polymer (0.5 g. per 100 ml. of solution or less), i.e., $\eta_{sp} = \eta_r - 1$.

SPI tolerances – A presentation of workable tolerance values that can be achieved in molding various materials.

Spider – (1) In a molding press, that part of an ejector mechanism which operates the ejector pins. (2) In extrusion, a term used to denote the membranes supporting a mandrel within the head/die assembly.

Spider lines – Vertical marks on the parison (container) caused by improper welding of several melt-flow fronts formed by the legs with which the torpedo is fixed in the extruder head.

Spinneret – A type of extrusion die, i.e., a metal plate with many tiny holes, through which a plastic melt is forced to make fine fibers and filaments. Filaments may be hardened by cooling in air, water, etc., or by chemical action.

Spinning – Process of making fibers by forcing plastic melt through spinneret.

Spin welding – A process of fusing two objects together by forcing them together while one of the pair is spinning, until frictional heat melts the interface. Spinning is then stopped and pressure held until they are frozen together.

Spiral flow test – A method for determining the flow properties of a thermoplastic resin in which the resin flows along the path of a spiral cavity. The length of the material that flows into the cavity and its weight gives a relative indication of resin flow properties.

Spiral mold cooling – A method of cooling injection molds or similar molds wherein the cooling medium flows through a spiral cavity in the body of the mold. In injection molds, the cooling medium is introduced at the center of the spiral near the sprue section, as more heat is localized in this section.

Split cavity – Cavity made in sections.

Split-cavity blocks – Blocks which, when assembled, contain a cavity for molding articles having undercuts.

Split-ring mold – A mold in which a split-cavity block is assembled in a chase to permit the forming of undercuts in a molded piece. These parts are ejected from the mold, then separated from the piece.

Sprayed metal mold – Mold made by spraying molten metal onto a master until a shell of predetermined thickness is achieved. Shell is then removed and backed up with plaster, cement, casting resin or other suitable material. Used primarily as a mold in sheet forming.

Spray-up – Covers a number of techniques in which a spray gun is used as the processing tool. In reinforced plastics, for example, fibrous glass and resin can be simultaneously deposited in a mold. In essence, roving is fed through a chopper and ejected into a resin stream that is directed at the mold by either of two spray systems. In foamed plastics, very fast-reacting urethane foams or epoxy foams are fed in liquid streams to the gun and sprayed on the surface. On contact the liquid material starts to foam.

Spreader – A streamlined metal block placed in the path of flow of the plastics material in the heating cylinder of extruders and injection molding machines to spread it into thin layers, thus forcing it into contact with heating areas.

Spring box mold – A type of compression mold having a spacing fork that is removed after partial compression to prevent loss of bottom-loaded inserts or fine mold details.

Sprue – Feed opening provided in the injection or transfer mold; also the slug formed at this hole. Spur is a shop term for the sprue slug.

Sprue bushing – A hardened steel insert in an injection mold which contains the tapered sprue hole and has a suitable seat for the nozzle of the injection cylinder. Sometimes called an adapter.

Sprue gate – A passageway through which molten resin flows from the nozzle to the mold cavity.

Sprue lock – In injection molding, a portion of the plastic composition that is held in the cold slug well by an undercut; used to pull the sprue out of the bushing as the mold is opened. The sprue lock itself is pushed out of the mold by an ejector pin. When the undercut occurs on the cavity block retainer plate, this pin is called the sprue ejector pin.

Sprue puller – A pin having a Z-shaped slot undercut in its end which serves to pull the sprue out of the sprue bushing.

Stabilizer – An ingredient used in the formulation of some polymers to assist in maintaining the physical and chemical properties of the compounded materials at their initial values throughout the processing and service life of the material, e.g., heat and UV stabilizers.

Staple – Refers to textile fibers of a short length, usually ½ to 3 in. for natural fibers; often larger for synthetics.

Starch – A polysaccharide with the same chemical make-up as cellulose in that it consists of glucose units. Differs from cellulose in the manner in which the glucose units are linked together.

Steam molding (expandable polystyrene) – Used to mold parts from pre-expanded beads of polystyrene using steam as a source of heat to expand the blowing agent in the material. The steam in most cases is contacted intimately with the beads directly or may be used indirectly to heat mold surfaces which are in contact with the beads.

Steam plate – Mounting plate for molds, cored for circulation of steam.

Stereospecific polymers – Implies a specific or definite order of arrangement of molecules in space. This ordered regularity of the molecules, in contrast to the random arrangement of molecules, permits close packing of the molecules and leads to high crystallinity (i.e., as in isotactic polypropylene).

Stir-in resin – A vinyl resin that does not require grinding to effect dispersion in a plastisol or an organisol.

Stitching – The progressive welding of thermoplastic materials by successive applications of two small mechanically operated electrodes, connected to the output terminals of a radio frequency generator using a mechanism similar to that of a normal sewing machine.

Stress crack – External or internal crack in a plastic caused by tensile stresses. The development of such cracks is frequently accelerated by the environment to which the plastic is exposed. The stresses that cause cracking may be present internally or externally or a combination of both. Appearance of a network of fine cracks is called crazing.

Stretch forming – A plastic sheet-forming technique in which the heated thermoplastic sheet is stretched over a mold and subsequently cooled.

Striation – Rippling of thick parisons caused by a local orientation effect in the melt by the spider legs.

Stripper plate – A plate that strips a molded piece from core pins or force plugs. The stripper plate is set into operation by the opening of the mold.

Styrene plastics – Plastics made by the polymerization of styrene or copolymerization of styrene with other unsaturated compounds.

Styrene-rubber plastics – Plastics consisting of at least 50% of a styrene plastic combined with rubbers and other compounding ingredients.

Submarine gate – A type of edge gate where the opening from the runner into the mold is located below the parting line or mold surface as opposed to conventional edge gating, where the opening is machined into the surface of the mold. With submarine gates the item is broken from the runner system on ejection of the part.

Support post or pillar – A post which is used in molds, designed to resist deflection under pressure.

Surface resistivity – The electrical resistance between opposite edges of a unit square of insulating material. It is commonly expressed in ohms.

Surface treating – Any method of treating a polymer so as to alter the surface, rendering it receptive to inks, paints, lacquers, adhesives and chemical, flame and electronic treating.

Surging – Unstable pressure build-up in an extruder leading to variable throughout and waviness of the parison.

Suspension – A mixture of fine particles of any solid within a liquid or gas. The particles are called dispersed phase; the suspending medium is called the continuous phase.

Syndiotactic – A vinyl polymer in which the side chains alternate regularly above and below the plane of the backbone.

Syneresis – The contraction of a gel. This is usually evidenced by the separation of a liquid. (See definition of Gel.)

Synergism – A term used to describe the use of two or more stabilizers in an organic material where the combination of such stabilizers improves the stability to a greater extent than could be expected from the additive effect of each stabilizer.

T

Tab gates – A small removable tab of approximately the same thickness as the mold item, usually located perpendicular to the item. The tab is used as a site for edge-gate location, usually on items with large flat areas.

Tack – Stickiness of an adhesive measurable as the force required to separate an adherent from it by viscous or plastic flow of the adhesive.

A Plastics Glossary (Cont'd)

Tack range – The period of time in which an adhesive will remain in the tacky-dry condition after application to an adherent under specified conditions of temperature and humidity.

T-die – A term used to denote a center-fed slot extrusion die for film which in combination with the die adapter resembles an inverted T.

Tenacity (gpd) – The term generally used in yarn manufacture and textile engineering to denote the tensile strength of a yarn or a filament for its given size. Numerically it is the grams of breaking force per denier unit of yarn or filament size. The yarn is usually pulled at the rate of 12 in./min. Tenacity equals breaking strength (gm.) divided by denier. Tenacity (gpd) x specific gravity x 12,800 = tensile strength (p.s.i.).

Tensile bar (specimen) – A compression or injection molded specimen of specified dimensions used to determine the tensile properties of a material.

Tensile strength – The pulling stress in p.s.i., required to break a given specimen. Area used in computing strength is usually the original, rather than the necked-down area.

Terpolymer – A polymeric system that contains three monomeric units, e.g., ABS (acrylonitrile, butadiene, styrene) terpolymer.

Thermal conductivity – Ability of a material to conduct heat; quantity of heat that passes through unit cube of a substance in unit of time when difference in temperature between the two faces is one degree.

Thermal expansion (coefficient of) – The fractional change in length (sometimes volume specified) of a material for a unit change in temperature. Values for plastics range 0.01 to 0.2 mils/in. ^{o}C.

Thermal stress cracking (TSC) – Crazing and cracking of some thermoplastic resins resulting from overexposure to elevated temperatures.

Thermoelasticity – Rubber-like elasticity exhibited by a rigid plastic and resulting from an increase of temperature.

Thermoforming – Any process of forming thermoplastic sheet that consists of heating the sheet and pulling it down onto a mold surface.

Thermoplastic (a.) – Capable of being repeatedly softened by heat and hardened by cooling (n.) – A material having a linear macromolecular structure that will repeatedly soften when heated and harden when cooled. Typical of the thermoplastics family are the styrene polymers and copolymers, acrylics, celulosics, polyethylenes, vinyls, nylons, and the various fluorocarbon materials.

Thermoset – A material that will undergo or has undergone a chemical reaction by the action of heat, catalysts, ultra-violet light, etc. leading to a relatively infusible and crosslinked state. Typical of the plastics in the thermosetting family are the epoxies, glyptals, ureaformaldehyde resins and phenolics.

Thixotropic – Said of materials that are gel-like at rest but fluid when agitated. Liquids containing suspended solids are apt to be thixotropic. Thixotropy is desirable in paints.

Thread contour – The shape or type of thread design as observed in a cross-section along the major axis, i.e., flat-headed, square, round, etc.

Thread plug – A part of a mold that shapes an internal thread and must be unscrewed from the finished piece.

Three-plate mold – A third or intermediate, movable plate used often in injection molds to permit center or offset gating of each cavity.

Tie bars – Bars that provide structural rigidity to the clamping mechanism often used to guide platen movement.

Toggle action – A mechanism that exerts pressure developed by the application of force on a knee joint. It is used as a method of closing presses and also serves to apply pressure at the same time.

Tracking – A phonomenon wherein a high-voltage source current creates a leakage or fault path across the surface of an insulating material by slowly but steadily forming a carbonized path.

Transfer molding – A method of molding thermosetting materials in which the plastic is first softened by heat and pressure in a transfer chamber, then forced at high pressure through suitable sprues, runners and gates into closed mold for final curing.

Trapped-air process – For blowing closed objects, the bottom pinch is conventional and after blowing, the parison sliding pinchers close off the top – forming a sealed-air inflated product.

Tumbling – Finishing operation for small plastics articles by which gates, flash and fins are removed and/or surfaces are polished by rotating them in a barrel together with wooden pegs, saw-dust and polishing compounds.

Turning table – A rotating table or wheel carrying various molds in a multimold single parison blow-molding operation.

Two-level mold – Placement of one cavity of a mold above another instead of alongside it to reduce clamping force (often used for large area parts).

U

Ultrasonic sealing – A film sealing method in which sealing is accomplished through the application of vibratory mechanical pressure at ultrasonic frequencies (20 to 40 kc.). Electrical energy is converted to ultrasonic vibrations through the use of either a magnetostrictive or piezoelectric transducer. The vibratory pressures at the film interface in the sealing area develop localized heat losses that melt the plastic surfaces effecting the seal.

Ultraviolet – Zone of invisible radiations beyond the violet end of the spectrum of visible radiations. Since UV radiation is of shorter wave length than visible, it is of higher energy. Energy is sufficient enough to initiate some chemical reactions and to degrade most plastics.

Undercut – (a.) Having a protuberance or indentation that impedes withdrawal from a two-piece rigid mold. Flexible materials can be ejected intact even with slight undercuts. (n.) Any such protuberance or indentation; depends also on design of mold.

Unit mold – A simple mold that comprises only a single cavity without further mold devices. Used for the production of sample containers having a shape difficult to blow.

Unsaturated compounds – Any compound having more than one bond between two adjacent atoms, usually carbon, and capable of adding other atoms at that point to reduce it to a single bond.

Urea-formaldehyde resin (urea resin) – A synthetic thermoset resin derived from the reaction of urea (carbamide) with formaldehyde or its polymers.

Urethane – See Isocyanate resins.

UV stabilizer (ultraviolet) – Any chemical compound which, admixed with a thermoplastic material, selectively absorbs UV rays.

V

Vacuum forming – Method of sheet forming in which the plastic sheet is clamped in a stationary frame, heated and drawn down by a vacuum into a mold. In a loose sense it is sometimes used to refer to all sheet-forming techniques, including drape forming (q.v.), involving the use of vacuum and stationary molds.

Vinyl resin – A synthetic resin formed by polymerization of chemical compounds containing the group CH_2 = CH -. For example polyvinyl chloride acetate, alcohol and butyral.

Viscosity – Internal friction or resistance to flow of a liquid. The constant ratio of shearing stress to rate of shear. In liquids for which this ratio is a function of stress, the term "apparent viscosity" is defined as this ratio. See also Intrinsic, Specific, Reduced and Relative viscosities of polymer solutions.

Volume resistivity (specific insulation resistance) – The electrical resistance between opposite faces of a 1-cm. cube of insulating material. It is measured under prescribed conditions using a direct current potential after a specified time of electrification. It is commonly expressed in ohm-centimeters. The recommended test is ASTM D257.

Vulcanization – The chemical reaction that induces extensive changes in the physical properties of a rubber or plastic, brought about by reacting it with sulphur and/or other suitable agents. The changes in physical properties include decreased plastic flow, reduced surface tackiness, increased elasticity, much greater tensile strength and considerable less solubility.

W

Waist – The central portion of a container that has a smaller cross-section than the adjacent areas.

Weatherometer – An instrument utilized to subject articles to accelerated weathering conditions, e.g., rich UV source and water spray.

Weld lines – A mark on a container caused by incomplete fusion of two streams of molten polymer. See also Spider lines.

Weld mark (also flow line) – A mark on a molded plastic piece made by the meeting of two flow fronts during the molding operation.

A Plastics Glossary (Cont'd)

Window – A defect in a thermoplastics film, sheet or molding caused by the incomplete "plasticization" of a piece of material during processing. It appears as a globule in an otherwise blended mass. See also Fish eye.

Wire train – The entire assembly utilized to produce a resin-coated wire, normally consisting of an extruder, a crosshead and a die, cooling means and feed and take-up spools for the wire.

Y

Young's Modulus of Elasticity – In an ideal (Hookian) elastic deformation, where the stress is proportional to the strain, Young's Modulus of Elasticity, E, in tension or compression is the ratio of stress to axial strain.

Yield value (yield strength) – The lowest stress at which a material undergoes plastic deformation. Below this stress the material is elastic; above it, viscous.

Z

Ziegler catalysts – Combinations of organometallics and transition metal compounds that lead to stereospecific polymers. Although the mechanism of polymerization with these catalysts is not completely known, the reaction seems to proceed through anionic propagation.–END

APPENDIX C. SPECIFICATIONS/MATERIALS CHART*

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
THERMOPLASTIC RESINS AND COMPOUNDS							
ABS	ASTM D1788 Fed. L-P-1183	2 I	3	5		466	Absun 89110 inj. mldg. & extr., med. imp.
	ASTM D1788 Fed. L-P-1183	3 II	3	4		466	Abson 89120 - inj. mldg. & extr. high imp.
	ASTM D1788 Fed. L-P-1183	4 V	2	3		466	Abson 89129 - inj. mldg. & extr., flame ret., high imp.
	ASTM D1788 Fed. L-P-1183	4 V	3	4		466	Abson 89130 inj. mldg., high imp.
	ASTM D1788 Fed. L-P-1183	4 V	4	4		466	Abson 89151 inj. mldg., electropl't.
	ASTM D1788 Fed. L-P-1183	5 VI	3	3		466	Abson 89140 inj. mldg., high imp.
	ASTM D1788 Fed. L-P-1183	5 VI	3	3		466	Abson 89170 inj. mldg. & extr. of sheet & profiles, low temp. imp.
	ASTM D1788 Fed. L-P-1183	6 V	3	2		466	Abson 89161 - inj. mldg., very high imp.
	ASTM D1788 Fed. L-P-1183	6 VI	4	2		466	Abson 89171 extr. of sheet & profiles, low temp. imp
	ASTM D1788	1	1,2			466,	Abson 89143 DWV fitting cmpd.
		1	4	5		288	Cevian V 110, 120 - inj. mldg.
		2	2	2			Absrom K - rot. mldg.
		2	3	5			Cevian V 610 inj. mldg.
		2	4	5			Cevian V 100 inj. mldg.
		2	5	5			Cevian V 410 inj. mldg.
		3	3	4			Cevian V 200 inj. mldg.
		5	3	3			Cevian V 300 inj. mldg.
		1	4	6		146	Novodur PH/GV - inj. mldg., glass reinf.
		2	3	3			Novodur H/GV extr., glass reinf.
		3	3	4			Novodur H extr., antistat.
		3	3	5			Novodur PX inj. mldg
		4	3	3			Novodur PH/AT inj. mldg., antistat
		4	3	4			Novodur PMT/AT inj. mldg., heat res., antistat.
		4	4	4			Novodur P2T inj. mldg., heat res.
		4	4	4			Novodur PMT inj. mldg., heat res.
		5	2	3			Novodur PM/AT inj. mldg., antistat.
		5	2	3			Novodur PM/3C plating grade
		5	3	4			Nofodur PM gen. purp.
		5	3	4			Novodur PHE extr.
		5	4	4			Novodur P2T/AT inj. mldg., heat res., antistat.
		6	1	2			Novodur PK/AT inj. mldg., high imp., antistat.
		6	2	2			Novodur PK inj. mldg., high imp.
		6	2	2			Novodur PKE extr.
		2	2	4		171	Cycolac T
		2	3	3			Cycolac AS
		2	4	4			Cycolac X 17, X 27
		3	2	2			Cycolac LL4111N
		3	4	5			Cycolac DH
		4	2	3			Cycolac EP, EPB
		4	3	4			Cycolac AM
		4	4	5			Cycolac AH
		5	2	2			Cycolac HM, LL4102N, LS
		5	2	4			Cycolac GSM
		5	3	3			Cycolac GSE, X 7
		5	4	4			Cycolac X-11
		6	4	2			Cycolac CG
	ASTM D3011				Cell 213	634	Thermocomp AF 1004 20% glass
					Cell 323		Thermocomp AF 1006 30% glass
					Cell 343		Thermocomp AF 1008 40% glass
	Fed. L-P-1183	1				1119	Kralastic MH, K2938 inj. mldg.; SRA sheet extr.
		2					Kralastic W pipe extr.; MV inj. mldg. & extr.; MH, K 2938
		3					Kralastic K 2938
		4					Kralastic K 2938
		5					Kralastic MV, W
		6					Kralastic MV, W

* See pg. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
ABS (Cont'd)	Fed. L-P-1183 (Cont'd)	1 2 3 4 5 6				171	Cycolac AH, AS, DH, X-27, X-17, X-7 Cycolac AH, DF, DH, EP, GSE, GSM, LS, T, TD, X-7 Cycolac DH (annealed @ 200°F.) Cycolac X-17 (annealed @ 200°F.) Cycolac CG, GSE, GSM, HM, LS, Cycolac, LS, GSE-Nat, GSM-Nat
ABS (Cont'd)	ISO DIS 2580				22342 22424 32424 32433 32442	715	Tufrex 710-inj. mldg., high imp. Tuflex 461-extr. Tuflex 210-inj. mldg., high stiffness Tuflex 309-plating, 410-inj. mldg. Tuflex 610-inj. mldg., high imp.
ACETAL	ASTM D2133				Copolymer	219	Celcon (see supplier for specific grade designations)
ACETAL			1 1 2		Homopolymer	335	Delrin 900, 8010-low visc. Delrin 500, 507, 550, 8020-med. visc. Delrin 100, 150-high visc.
ACETAL	ASTM D2948				36269 67229 97199 99289 40300	634	Thermocomp KF 1004 – 20% glass Thermocomp KF 1006 – 30% glass Thermocomp KF 1008 40% glass Thermocomp KFL 4036 – 30% glass, 15% TFE Fulton 404 – 20% glass, TFE lubr
ACETAL	Fed. L-P-392				Copolymer	219	Celcon (see supplier for specific grade designations)
ACETAL		1 1		1,2,3 1 1	Homopolymer	335	Delrin 900 NC10 – low visc., 500 NC10 – med. visc., inj. mldg. Delrin 507 BK601 low visc., inj. mldg. Delrin 100 NC10, 150 NC10 – high visc., extr., 507 NC10
ACETAL	Fed. WW-P-541				Plumbing fixtures	219	Celcon (see supplier for specific grade designations)
ACETAL	Fed. FF-D-396G				Soap dispensers		
ACETAL	MIL-I-28964			1	Homopolymer	335	Delrin BK 601
ACETAL	MIL-P-46137	I		20	20% glass reinf.	335	Delrin 570 NC000, 577 BK000 – homopolymer
ACETAL		I I I II II II		20 30 40 20 30 40	20% glass reinf. 30% glass reinf. 40% glass reinf. 20% glass reinf. 30% glass reinf. 40% glass reinf.	634	LNP KF 1004 – homopolymer LNP KF 1006 homopolymer LNP KF 1008 homopolymer LNP KF 1004 copolymer LNP KF 1006 copolymer LNP KF 1008 copolymer
ACETAL	MIL-F-18240				Fastener, extr.	219	Celcon (see supplier for specific grade designations)
ACETAL	MIL-F-19017 (Docks)				Fittings		
ACETAL	MIL-S-19015 (Docks)				Sinks, washroom		
ACETAL	MIL-S-19114 (Docks)				Sinks, scullery		
ACETAL	MIL-U-17336A				Urinals		
ACETAL	MIL-W-11477B (CE)				Water closet		
ACETAL	NSF 14				Potable water	219	Celcon M90, U10, Gr20, GC25, M25 – natural Celcon M90 gold, gray & ivory Celcon M90, M25, GC25 Black
ACETAL	USDA				Meat hooks	219	Celcon M90
ACETAL	DIN 16975 DIN 16976 DIN 16977 DIN 16985				Copolymer	378	Hostaform C 2520, C 9020 extr.
ACETAL	VDI/VDE 2477				Copolymer	378	Hostaform (see supplier for specific grade classif.)

* See pg. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier, trade name[a] and grade[b]: Supplier code[d]	Trade name, material grade designation and description[e]
ACRYLIC (THERMOPLASTIC)	ASTM D788		6 6 8 8			536	Diakon LB 156/1 inj. mldg., easy flow Diakon LH 173/1 inj. mldg., craze res. Diakon MG 102/1 mldg. & extr. Diakon MH 253/1 mldg. & extr., craze res.
			5 6 8			950	Plexiglas VS- inj. mldg. Plexiglas VM- inj. mldg. & extr. Plexiglas V 044, 045, -052, -400, 415, 811, -920 inj. mldg. & extr.
	ASTM D1547		6 8		Extr. sheet	950	Plexiglas VM Plexiglas V 044, 045, 052, 400, 415, 811 920
			6 8		Extr. sheet	335	Lucite 129 Lucite 140, 147
	Fed. L-P-380	I, II I, II I, II		1 2 3		950	Plexiglas VS inj. mldg. & extr. Plexiglas VM inj. mldg. & extr. Plexiglas V 044, 045, 052, 400, 415, 811 920 inj. mldg. & extr.
		I, II I, II I, II		1 2 3		335	Lucite 130 Lucite 129 Lucite 140, 147
	Fed. L-P-507	I II				950	Plexiglas VM extr. Plexiglas V811, V930 extr.
		I II				335	Lucite 129 Lucite 140, 147
CELLULOSE ACETATE	ASTM D706		H6-1 H4-1 MH-2 MH-1 MS-2			288	Acetyloid 36 inj. mldg. Acetyloid 35 inj. mldg. Acetyloid 32 inj. mldg. Acetyloid 22 inj. mldg. Acetyloid 10 inj. mldg.
			H4-1 H2-1 MH-2 MS-2 S2-1			146	Cellidor SHH mldg. & extr. Cellidor SM mldg. & extr. Cellidor SW mldg. & extr. Cellidor SWW mldg. & extr. Cellidor SWW-37 mldg. & extr.
			H6-1 H4-1 H2-1 MH-2 MH-1 MS-2 MS-1 S2-1			346	Tenite 036 H6 Tenite 007, 008, 036, 042, 043, 081, 087-H4 flow Tenite 007, 008, 036, 042, 043, 087 H2 flow Tenite 007, 008, 036, 043, 087 MH flow Tenite 007, 008, 036, 043, 062, 087 MH flow Tenite 043 MS Tenite 007, 008, 036, 087 MS flow Tenite 043 S2
	DIN 7742	434 435				146	Cellidor SM mldg. & extr. Cellidor SW mldg. & extr.
	Fed. L-P-397		H, H2 H3, H4 M, MH			346	Tenite 007, 008, 036 inj. mldg. & extr. Tenite 007, 008, 036, 043 inj. mldg. & extr. Tenite 008, 036 inj. mldg. & extr.
CAB	ASTM D707		H2 H4 MH MS S2			146	Cellidor BspH mldg. & extr. Cellidor BspHH mldg. & extr. Cellidor BspM mldg. & extr. Cellidor BspW mldg. & extr. Cellidor BspWW mldg. & extr.
			H4 H3 H2 H MH M MS S S2			346	Tenite 218, 233, 239, 265, 268, 435, 479, 518, 527 H4 flow Tenite, 218, 233, 265, 268, 435, 479, 518, 527, H3 flow Tenite 218, 233, 239, 265, 268, 435, 479, 518, 527- H2 flow Tenite 218, 239, 265, 268, 435, 479, 518, 527 H flow Tenite 218, 239, 265, 268, 435, 479, 518, 527 MH flow Tenite 218, 239, 265, 268, 435, 479, 518, 527 M flow Tenite 218, 239, 265, 268, 435, 479, 518, 527, MS flow Tenite 218, 239, 265, 268, 435, 518, 527 S flow Tenite 218, 265, 435, 518, 527 S2 flow

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a], and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
CAB (Cont'd)	DIN 7743	411 412 413				146	Cellidor BspH mldg. & extr. Cellidor BspM mldg. & extr. Cellidor BspW mldg. & extr.
	Fed. L-P-349		H,MH M,MS H2, H3 H4 S S2			346	Tenite 218, 239, 265, 268, 435, 479, 518, 525, 536 inj. mldg. & extr. Tenite 218, 239, 265, 268, 435, 479, 518, 525, 536 inj. mldg. & extr. Tenite 205, 218, 239, 265, 268, 433, 518, 525, 536 inj. mldg. & extr. Tenite 218, 265, 435, 518, 525, inj. mldg. & extr., UV res.
CAP	ASTM D1562					146	Cellidor CPHH mldg. & extr. Cellidor CPH mldg. & extr. Cellidor CPM mldg. & extr. Cellidor CPW, CPWW mldg. & extr.
			H5 H4 H3 H2 H MH			346	Tenite 306, 307, 316, 320, 325, 326, 327, 332, 335, 338, 350 H5 flow Tenite 306, 307, 316, 320, 325, 326, 327, 332, 335, 338, 350 H4 flow Tenite 307, 316, 320, 325, 327, 332, 335, 338, 350 H3 flow Tenite 307, 316, 320, 325, 326, 327, 332, 335, 338 H2 flow Tenite 325, 332, 335 H flow Tenite 325 MH
	MIL-P-46074		H,H3, H4,MH H5 H2 H2W			346	Tenite 307, 325 inj. mldg. & extr. Tenite 307, 320, 325 inj. mldg. & extr. Tenite 307 inj. mldg. & extr. Tenite 313, 323 inj. mldg. & extr., food appl.
CTFE	ASTM D1430 Fed. L-P-385A	2 2	1 1	A		37	Plaskon 2100 mldg. & extr.
FEP	ASTM D2116	I				335	Teflon 100 mldg. & extr.
	Fed. L-P-389	I II III				335	Teflon 100 mldg. & extr. Teflon 110 inj. mldg. Teflon 160 trans. mldg., extr.
NYLON	ASTM D789	I IV V	2 2 2		Type 6/6 n-Alkoxy alkyl 6/6 Alcohol sol.	150	BCI Moleculdy 66-01 BCI 808, 809, 818, 819, 829 BCI 653 copolymer
		I	2		Type 6/6	219	Celanese 1000, 1003, 1310, 1200
		II II II II			Type 6 Type 6 Type 6 Type 6	146	Durethan BK30S, BK35M, BK40SK inj. mldg. Durethan BK31F, BK35T film Durethan BK40F film, blow mldg. Durethan BK50F extr., blow mldg.
		I I I II II II II III	2 2 4 1 2 3 4 1		Type 6/6 Type 6/6 Type 6/6 Type 6 Type 6 Type 6 Type 6 Type 6/10	536	Maranyl A100, A125, A101, A127 inj. mldg. Maranyl AD146 extr. Maranyl AD148, A150 extr. Maranyl F124 inj. mldg. Maranyl F106, F114 inj. mldg. Maranyl F400 extr. Maranyl F500 extr. Maranyl B100 inj. mldg., extr.
		II	2		Type 6	788	Nylene 7102C inj. mldg.
		II II II II II IIa IIa IIb	2 2 2A 3 4 2 2	 Typ	Type 6 Type 6 Type 6 Type 6 Type 6 Type 6 Type 6 Type 6	37	Plaskon 8200, 8202 inj. mldg. Plaskon 8207, 8220 extr. Plaskon 8204, 8206 inj. mldg. Plaskon 8203 extr. Plaskon 8205 extr. Plaskon 8202C inj. mldg. Plaskon 8203C extr. Plaskon 8252, 8253 inj. mldg. & extr.
		I III III VII	2 1 2 2	 T	Type 6/6 Type 6/10 Type 6/10 Type 6/6 mod.	738	Vydyne 10X, 20X, 21X, 10V, 20V, 20M, 10H, 20H, 20N inj. mldg. Vydyne 50V, 50X, 50H inj. mldg. Vydyne 52V extr. Vyvyne 80X inj. mldg.

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SPECIFICATIONS/MATERIALS CHART* (Cont'd)

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Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Supplier, trade name[a], and grade[b]: Trade name, material grade designation and description[e]
NYLON (Cont'd)	ASTM D789 (Cont'd)	I	2		Type 6/6	335	Zytel 101, 101L, 101L1, 101L2, 103HSI-L, 121, 122L, 105 inj. mldg.
		Ib	2		Type 6/6		Zytel 408, 408HS inj. mldg.
		I	4		Type 6/6		Zytel 42 extr.
		V	2		Copolymer		Zytel 63
		VI	2		Plas. copolymer		Zytel 69
		VII	2		6-6/6 copolymer		Zytel 109
		VIII	1		Type 6/12		Zytel 151L inj. mldg.
		VIII	2		Type 6/12		Zytel 153HS-L, 157HS L, 158 inj. mldg. & extr.
	ASTM D2897	I	2		Type 6/6	27	Akulon R600 inj. mldg. & extr.
		II	1		Type 6		Akulon K2 ZG 340 inj. mldg.
		II	2		Type 6		Akulon M2 ZG 340 inj. mldg., K2(Spl), MZ extr.
		II	2A		Type 6		Akulon M10 ZG340 inj. mldg., B10, M10 extr.
		II	3		Type 6		Akulon BE X367 inj. mldg., BE-64 extr.
		II	4		Type 6		Akulon BE 65, B2 66 extr.
					Type 6/6, cell 2362	335	Minlon 10A-40 min. filled
					Type 6/6, cell 2571		Minlon 10B 40 min. filled
					Glass reinf. type 6	634	
					10%-2352		Thermocomp PF 1002
					20%-3463		Thermocomp PF 1004
					30%-4564		Thermocomp PF 1006
					40%-5665		Thermocomp PF 1008
					50%-5865		Thermocomp PF 100 10
					Glass reinf. type 6/6		
					10% 2381		Thermocomp RF 1002
					20% 3482		Thermocomp RF 1004
					30% 5684		Thermocomp RF 1006
					40% 5794		Thermocomp RF 1008
					50% 6895		Thermocomp RF 100 10
					Glass reinf. type 6/10		
					10% 1352		Thermocomp QF 1002
					20% 3462		Thermocomp QF 1004
					30% 4564		Thermocomp QF 1006
					40% 5665		Thermocomp QF 1008
					50% 5766		Thermocomp QF 100 10
					Glass reinf. type 6/12		
					25% 4564		Thermocomp IF 1005
					35% 5765		Thermocomp IF 1007
					30% glass reinf. type 11 2434		Thermocomp HF 1006
					30% glass reinf. type 12 3535		Thermocomp SF 1006
					40% min. filled type 6/6 1451		Thermocomp RM 3480
					5% M.S. lubr.		
					type 6 2111		Nykon P
					type 6/6 2211		Nykon R
					30% glass + 15% PTFE		
					type 6 3663		Thermocomp PFL 4036
					type 6/6 4683		Thermocomp RFL 4036
					type 6/10 4564		Thermocomp QFL 4036
					Cell 3694	738	Vydyne R-100, R-200 min. reinf.
	Fed. L-P-395	I	2,3,4		Type 6/6 glass reinf.	219	Celanese 1500, 1503 inj. mldg. & extr.
		II	2,3,4		Type 6/6 glass reinf.		Celanese 1600, 1603 inj. mldg. & extr.
		I	1-4		Type 6/6	634	LNP RF 1007, 1009
		I	1-4		Type 6		LNP PF 1007, 1009
		I	1-4		Type 6/10		LNP QF 1007, 100 10
		II	2-4		Type 6/10		LNP QF 1009
		I	2,3,4		Type 6/6 glass reinf.	874	Nylatron 50-9
		I	4		Type 6/6 glass reinf.		Nylatron GS-51
		II	3,4		Type 6/6 glass reinf.		Nylatron 50-13
		II	4		Type 6/6 glass reinf.		Nylatron GS-51 13
	Fed. L-P-410				Type 6/6 tubes, flats.	219	Celanese 1000, 1003, 1210, 1200 extr.
					Type 6	37	Plaskon 8200, 8202, 8203, 8205 w/suffix HS-1 or BK106, 8200HS extr.

* See pg. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a], and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
NYLON (Cont'd)	Fed. L-P-410 (Cont'd)				Type 6/6 Type 6/10 Type 6/10	738	Vydyne 10X, 20X, 21X, 10V, 20M, 10H, 20H--inj. mldg. Vydyne 50V, 50X, 50H--inj. mldg. Vydyne 52V--extr.
	FDA CFR 121.2502				Type 6/6	219	Celanese 1000-1, 1200-1, 1310-1
	FDA CFR 125 2502				Type 6	37	Plaskon 8200, 8202, 8203, 8205, 8207--extr. & inj. mldg.
	ISO R 1874				Type 6/6-0400 Type 6-190 Type 6-310 Type 6-410 Type 6-610 Type 6-710 Type 6-810 Type 6-910	27	Akulon R 600--inj. mldg. & extr. Akulon K10-ZG340--inj. mldg. Akulon K2S, K2-ZG340--inj. mldg. Akulon M2Z, M2-ZG340--inj. mldg.; K2 (spl.), M2--extr. Akulon B2-X613--inj. mldg. Akulon B2-X367--inj. mldg.,B2-64--extr. Akulon B2-65--extr. Akulon B2-66--extr.
					Type 6-210 Type 6-610 Type 6-490 Type 6-610 Type 6-810	146	Durethan BK30S--inj. mldg. Durethan BK40SK--inj. mldg. Durethan BK35M--inj. mldg. Durethan BK40F--film, blow mldg. Durethan BK50F--extr. blow mldg.
					Type 6/6-300/400 Type 6/6-500 Type 6/6-600 Type 6/6-700 Type 6/6-800 Type 6-210 Type 6-410 Type 6-710 Type 6-810	536	Maranyl A100, A125--inj. mldg. Maranyl AD144--extr. Maranyl AD146--extr. Maranyl AD148--extr. Maranyl A150--extr. Maranyl F124--inj. mldg. Maranyl F114--inj. mldg. Maranyl F400--extr. Maranyl F500--extr.
	MIL-M-19887				Type 6/6 30% glass reinf.	634	LNP FR1006
	MIL-M-20693	I			Type 6/6	150	BCI Moleculdy 66-01
		I			Type 6/6 comp. A	219	Celanese 1000, 1003, 1210, 1200--inj. mldg. & extr.
		I IV IV IVA			Type 6/6 comp. A Type 6/6 comp. A Type 6 comp. B Type 6 comp. B Type 6 comp. B	536	Maranyl A100, A125--inj. mldg. Maranyl AD144, AD146, AD148, A150--extr. Maranyl F124--inj. mldg. Maranyl F400, F500--extr. Maranyl F114--inj. mldg.
		IV IVA			Type 6 comp. B	37	Plaskon 8200, 8202, 8203, 8205 with or without HS or HS1--extr. & inj. mldg.
		I III			Type 6/6 comp. A Type 6/10 comp. A	738	Vydyne 10X, 20X, 21X, 10V, 20V, 20M, 10H, 20H--inj. mldg. Vydyne 50V, 50X, 50H--inj. mldg. Vydyne 52V--extr.
		I II III			Type 6/6 Type 6/6 Type 6/6 Type 6/12	335	Zytel 101, 101L, 101LI, 101L2--inj. mldg. Zytel 42--extr. Zytel 105--UV res. Zytel 151L, 153HS-L, 157HS-L, 158L--inj. mldg. Zytel FE2908L--extr.
	MIL-P-22096	II			Alcohol sol.	150	BCI 653--copolymer
		IVA			Type 6	37	Plaskon 8206, 8216--extr. & inj. mldg.
		II III IV			Type 6/6 Type 6/6 Type 6	335	Zytel 63--copolymer Zytel 69--plas. copolymer Zytel 211
	NSF 14				Potable water	219	Celanese 1000-2, 1200, 1310--Type 6/6
Phenylene oxide based resin	MIL-P-46131	I I II II III	1 2 1 2 1			634	LNP ZF 1004--inj. mldg. LNP ZF 1004FR--flame ret., inj. mldg. LNP ZF 1006--inj. mldg. LNP ZF 1006FR--flame ret., inj. mldg. LNP ZF 1008--inj. mldg.

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Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYALLOMER	Fed. L-P-394	IV	A			346	Tensite 5020A copolym, FDA, inj. mldg. Tensite 5021A copolym, inj. mldg.
		IV	B				Tensite 5B20A copolym, high imp., FDA, inj. mldg. Tensite 5B21A copolymer, high imp., inj. mldg. Tensite 5321A copolymer, high imp., inj. mldg. & extr.
POLYCARBONATE	AMS 3628A					444	Lexan 101, 141, 121 inj. mldg.
	ASTM D2473				Cell 2223 Cell 3223 Cell 4223	444	Lexan 101 inj. mldg. & extr. Lexan 141 inj. mldg. & extr. Lexan 121 inj. mldg. & extr.
					Cell 2113 Cell 2213 Cell 2223 Cell 3223 Cell 4223	146	Makrolon 6030–inj. mldg., flame ret., opaque Makrolon 6030 inj. mldg., flame ret., transp. Makrolon 3100 inj. mldg. & extr.; 3200 extr. Makrolon 2600, 2800 inj. mldg. Makrolon 2400 inj. mldg.
					Cell 1223 Cell 2117 Cell 2113 Cell 2213 Cell 2223 Cell 3113 Cell 3213 Cell 3223 Cell 4223	719	Merlon M-60 inj. mldg. & extr. Merlon SE2200 inj. mldg., flame ret. Merlon SE2300 extr., flame ret. Merlon SE2100 inj. mldg. & extr., flame ret. Merlon M50 inj. mldg. & extr. Merlon SE3200 inj. mldg., flame ret. Merlon SE3100 inj. mldg., flame ret. Merlon M40 inj. mldg. Merlon M39 inj. mldg.
	ASTM D2848				Cell 2211 Cell 4321 Cell 2112	444	Lexan 3412–inj. mldg., reinf. Lexan 3414 inj. mldg., reinf. Lexan 500 inj. mldg., reinf.
					Cell 2211 Cell 2211 Cell 2225 Cell 3221 Cell 4431	146	Makrolon 8020–inj. mldg., reinf. Makrolon 9310 inj. mldg., flame ret., reinf. Makrolon 8320 inj. mldg., flame ret., reinf. Makrolon 8030 inj. mldg., reinf. Makrolon 8340 inj. mldg., flame ret., reinf.
					Cell 2111 Cell 2112	719	Merlon 9310 inj. mldg., flame ret., reinf. Merlon 8310 inj. mldg., flame ret., reinf.
					Cell 2315 Cell 3425 Cell 4435 Cell 5322	634	Thermocomp DF 1004 20% glass reinf. Thermocomp DF 1006 30% glass reinf. Thermocomp DF 1008 40% glass reinf. Thermocomp DFL 4036 30% glass reinf. + 15% PTFE lub.
	DIN 7744	300				146	Makrolon 2800-3200
	Fed. L-P-393	1				444	Lexan 101, 141, 121 inj. mldg. & extr.
						146	Makrolon 2600-3200
	MIL-P-81390	I II III			40% glass 20% glass 20% glass	634	LNP DF 1008 LNP DF 1005 LNP DF 1005
		II III				146	Makrolon 8340 Makrolon 8320
POLYESTER (THERMOPLASTIC)	MIL-P-46160	I II	A A		PTMT PTMT	346	Tenite 7DR0 Tenite 6PR0, 6P20, 6P40, 6P50
	MIL-P-46161		A A A B B	1 2 3 2 3	PTMT (PBT)	346	Tenite 6F91–reinf. Tenite 6G91–reinf. Tenite 6H91–reinf. Tenite 6G9R reinf. Tenite 6H9H-reinf.
			A A A A B B	1 2 3 4 2 3	PBT	634	Thermocomp WF 1002 10% glass reinf. Thermocomp WF 1004 20% glass reinf. Thermocomp WF 1006–30% glass reinf. Thermocomp WF 1008 40% glass reinf. Thermocomp WF 1004FR 20% glass reinf., flame ret. Thermocomp WF 1006FR 30% glass reinf., flame ret.
	NSF 14				Classif. 2,4 PBT	219	Celanex 3300
	VDE 0703	1			PET	378	Hostadur K6022, A4000 inj. mldg. Hostadur K8022GV2–inj. mldg., glass reinf.

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Material	Specification					Supplier, trade name[d] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYETHYLENE	ANS 1 C 8.35				Cable jacket	778	Nor. Pet. NPE 130, 190
	ASTM D1248	I		A	Cat. 2	335	Alathon 1540, 1560, 1570 extr. ctg., 1724 rot. mldg.
		I		A	Cat. 3		Alathon 16, 1645 extr. ctg., 20, 2020 blow mldg. & sheet, 1730 rot. mldg; 4249, 4275 inj. mldg.; 2005, 2010 inj. mldg., high ESCR
		I		A	Cat. 4		Alathon 3442,3445 - indus. film, 3646, 2650 liner film
		I		A	Cat. 5		Alathon 2530 pallet shrink film
		II		A	Cat. 3		Alathon 34 - inj. mldg., 7440 - rot. mldg.; 4352 extr. ctg.
		III		A	Cat. 2		Alathon 7250 extr. ctg.
		III		A	Cat. 3		Alathon 7830, 7835, 7840 cast film, 7040, 7140 - rot. mldg.
		I	J1	A, C	Cat. 5	536	Alkathene Q6524, O779 blk. 904 cable jacket
		I	J1	C	Cat. 5		Alkathene D33/04 blk. 904 cable jacket
		I		A	Cat. 1		Alkathene WSG22, WSM78 - inj. mldg.
		I		A	Cat. 2		Alkathene WRM19, XRM21, XRM40 inj. mldg.
		I		A	Cat. 3		Alkathene WNG17, WJG47, XNM68 - inj. mldg. WNF15, XJF46 film, WNC18, XLC82- entr. ct.; XJK25, Q1388J blow mldg.
		I		A	Cat. 4		Alkathene XHF77 film, XHB48 blow mldg.
		I		A	Cat. 5		Alkathene XDB30, XDB76 blow mldg.; XDG33 film & inj. mldg.;Q6800/50-copol., film
		I		B	Cat. 4		Alkathene O458 wht 1135, 0689 wht 1183 film
		I		C	Cat. 3		Alkathene D11/02 blk. 904 pipe
		I		C	Cat. 4		Alkathene D38/02 blk. 904 pipe
		II	E4	A	Cat. 5		Alkathene XDK74, Q6450/1 wire ins.
		II		A	Cat. 4		Alkathene YHG31 - inj. mldg.
		II		A	Cat. 5		Alkathene YDB36 - blow mldg.
		III		A,B		72	Amoco 603A2, 603C2, 607A2 blow mldg. & extr.
		IV		A,B			Amoco 650B4, 670B4, 670C4, 680B4 inj. mldg.
		I		A	Cat. 5	146	Bayton 25D760 wire ins.
		I			Cat. 1	233	Chemplex 1030, 3026, 3028 - inj. mldg.
		I			Cat. 2		Chemplex 1013 extr. ctg.; 1026 inj. mldg.
		I			Cat. 3		Chemplex 1014, 1016, 1017 extr. ctg., 1005, 1050, 1054 film, 1029 inj. mldg.
		I			Cat. 5		Chemplex 3019 film
		II			Cat. 2		Chemplex 1018 extr. ctg., 1027 inj. mldg.
		II			Cat. 3		Chemplex 3002, 3003, 3007, 3020, 3022, 3041, 3104 film 1019 extr. ctg., 1028 inj. mldg.
		III			Cat. 2		Chemplex 5180, 5250 - inj. mldg.
		III			Cat. 3		Chemplex 5060 inj. mldg.; 5080, 5360 rot. mldg
		III			Cat. 5		Chemplex 5003, 5602, 5604 blow mldg
		IV			Cat. 1		Chemplex 6300 - inj. mldg.
		IV			Cat. 2		Chemplex 6150 inj. mldg.
		IV			Cat. 3		Chemplex 6060 - inj. mldg.
		IV			Cat. 4		Chemplex 6006, 6008, 6009 blow mldg., 6108-film
		IV			Cat. 5		Chemplex 6001, 6003 - extr., 5701 blow mldg.
		I	E4	A	Cat. 5	624	Dylan 1000W - wire & cable
		I	E5, J1	C	Cat. 5		Dylan 1909W - wire & cable
		I	J3	C	Cat. 5		Dylan 3900W wire & cable
		I		A	Cat. 3		Dylan B300 blow mldg.; 2007F food wrap; 2012F - shrink film; 2020F, 2040F - liner film; 3020F, 3812F clear film
		I		A	Cat. 4		Dylan B200 - blow mldg.
		I		A	Cat. 5		Dylan B100, B375, B800 blow mldg., 0144F, 0244F shrink film; 1000F, 2800F heavy film, 2000F - heavy food wrap
		II	P23	A	Cat. 5		Super Dylan 4002 extr.
		II	P23	C	Cat. 5		Super Dylan 4002N pipe
		II		A	Cat. 3		Super Dylan 4042 extr.
		III	E8	A	Cat. 5		Super Dylan 5003W ins.
		III	E9, J5	B	Cat. 5		Super Dylan 5001W - weathr. res.
		III	J5	C	Cat. 5		Super Dylan 5900W - jacket
		III	P33	C	Cat. 5		Super Dylan 7000N pipe
		III		A	Cat. 1		Super Dylan 7280 - inj. mldg.
		III		A	Cat. 2		Super Dylan 7180, 7200 inj. mldg., FW72-film
		III		A	Cat. 3		Super Dylan 5440 rot. mldg.; 6530, 6550, 6560 - inj. mldg., 6060FH, FB66 film
		III		A	Cat. 4		Super Dylan 6515 inj. mldg.
		III		A	Cat. 5		Super Dylan 5503 extr.; 7003 2 - blow mldg., 7004C - pipe ctg., FB55 - film
		III		B	Cat. 5		Super Dylan 7004CS 80801 pipe ctg
		IV		A	Cat. 2		Super Dylan 7120 - inj. mldg., FW78 - film
		IV		A	Cat. 3		Super Dylan 7080 - inj. mldg.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART*

Plastics and resins qualified under ASTM, ISO, Military Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYETHYLENE (Cont'd)	ASTM D 1248 (Cont'd)	I	4			219	Fortiflex D18-30-05, D18-120
		I	3				Fortiflex D18-170-05, D24-120
		I			Cat. 1	481	Gulf PE1009, 1408.5, 1409, 1410–inj. mldg.
					Cat. 2		Gulf PE1018–extr. coating
							Gulf PE1008, KN220–inj. mldg.
					Cat. 3		Gulf PE4516, PE1017–extr. coating
							Gulf PE1115, PE5858,PE6550–film extr.
							Gulf PE1007, PE1400–inj. mldg.
							Gulf PE5104–blow molding
							Gulf PE3003, PE3103–roto mldg.
					Cat. 4		Gulf PE5753, PE4522–film extr.
					Cat. 5		Gulf PE5613, PE5616–film extr.
		II			Cat. 1		Gulf KN226, KN228–inj. mldg.
					Cat. 3		Gulf PE2652, PE2653, PE5955, PE1605, PE5554, PE5555–film extr.
					Cat. 5		Gulf HiD9404–blow mldg.
		III			Cat. 1		Gulf HiD9020–inj. mldg.
					Cat. 2		Gulf HiD9014, HiD9022–inj. mldg.
					Cat. 3		Gulf HiD9006, HiD9018–inj. mldg.
					Cat. 5		Gulf HiD9406, HiD9410, HiD9412–blow mldg.
		IV			Cat. 1		Gulf HiD9016–inj. mldg.
					Cat. 3		Gulf HiD9010–inj. mldg.
							Gulf HiD9420–blow mldg.
							Gulf LR3807, 3907–roto mldg.
					Cat. 4		Gulf HiD9414–blow mldg.
							Gulf HiD9614, HiD9616, HiD9618–blow film extr.
					Cat. 5		Gulf HiD9401, HiD9400–blow mldg.
							Gulf HiD9602, HiD9600–film sheet extr.
		III	P34	C		55	Hostalen GM5010–pipe
		III		A			Hostalen GUR–ultra high M.W.
		III		A	Cat. 2	843	Marlex BMB5095–copolymer, inj. mldg.
		III		A	Cat. 3		Marlex BHB5012, BMB5040, BMB5065–copolymer, inj. mldg.
		III		A	Cat. 4		Marlex EHM6006, EHB6009–copolymer, blow mldg., extr.
		III		A	Cat. 5		Marlex EHM6001, EHM6003–copolymer, blow mldg., extr.
		III		A	Cat. 5		Marlex BMN5565, EMB6035, EMB6050, EMN6065–copolymer, inj. mldg.
		III		A	Cat. 5		Marlex BHM5002, BXM43065, BHB5003–copolymer, blow mldg. & extr.
		III		A	Cat. 5		Marlex HHM5202, HHM5502, copolymer, blow mldg. & extr.
		III		C	Cat. 5		Marlex TR415, TR416–copolymer, extr.
		II		C	Cat. 4		Marlex TR236–copol., extr.
		III		C	Cat. 5		Marlex TR418–copol., extr.
		III	E8	A	Cat. 5	738	Monsanto MPE240–copolymer, insul. grade
		III	P14	A	Cat. 5		Monsanto MPE200–copolymer, blow mldg.
		III	P23	A	Cat. 3		Monsanto MPE715–copolymer, Inj. mldg.
		III	P33	A	Cat. 2		Monsanto MPE775–copolymer, inj. mldg.
		III	P33	A	Cat. 3		Monsanto MPE720, MPE750, MPE770–homopolymer inj. mldg.
		III	P33	A	Cat. 4		Monsanto MPE321–copolymer, blow mldg.
		III	P33	A	Cat. 5		Monsanto MPE315, 316, 210, 211, 212–copolymer, blow mldg.
		I	E4, J3	C	Cat. 5	778	Nor. Pet. NPE 130–homop., NPE 190–copol.–cable jacket
		I		A	Cat. 2		Nor. Pet. NPE 860–inj. mldg.
		I		A	Cat. 3		Nor. Pet. NPE 831–inj. mldg., 810–blow mldg.; 330–garmt. film; 270–foam extr.; 350, 952–film extr.
		I		A	Cat. 4		Nor. Pet. NPE 930–film extr.
		I		A	Cat. 5		Nor. Pet. NPE 980–shrink film
		II	P23			37	Paxon 7008, 7009, 7010–pipe cmpd.
		III			Cat. 2		Paxon SS55-180, SS55-250, SS60-300 inj. mldg.
		III			Cat. 3		Paxon SS55-100–inj. mldg.
		III			Cat. 4		Paxon AA60-007, AD60-007–blow mldg.; AF60-007–film
		III			Cat. 5		Paxon AA40-003–blow mldg., wire & cable; AF40-003–film, AA45-001, AB50-003, AA55-003–blow mldg., AC50-003, AB55-003–antistat., blow mldg., AA60-003–sheet extr., blow mldg.
		III	P34				A-C pipe cpd.–ultra-high M.W.
		I			Cat. 1,2,3	928	Rexene PE126–high stiffness

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix gives numerical specification index.

Material	Specifications					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYETHYLENE (Cont'd)	ASTM D1248 (Cont'd)	I		A	Cat. 3	962	Rumiten 250, 250BQ, 250CQ- flown film; 251BQ, 251CQ–blown film, clear; 270–inj. mldg.
		IV		A	Cat. 3		Rumiten HD615, 670–inj. mldg.; 630, 650–inj. mldg. & extr., paper film
		I		A,B	Cat. 1	346	Tenite 18DO–inj. mldg.
		I		A,B	Cat. 2		Tenite 18BO, 811, 1913–inj. mldg.
		I		A,B	Cat. 3		Tenite 800, 1830, 1870 -inj. mldg.; 183H 184M, 184L, 1925–film extr.; 808, 1550, 1924–extr. ctg.
		I		A, B	Cat. 4		Tenite 1811–film extr.
		II	P23	C	Cat. 4		Tenite 2911E-60099BK–pipe
		II		B	Cat. 4		Tenite 2910E-60805BK–extr.
	ASTM D2103					335	Alathon–see supplier for specific grade designations
					10000	146	Baylon 231, 430–lam., extr.
					23100		Baylon V10M564–EVA copol., film
					23120		Baylon V22H864–EVA copol., film
					23130		Baylon V18E564, V18H564, V22E564 - EVA copol., film
					23320		Baylon V22HT64–EVA copol., film
					23330		Baylon V18E464, V18H464, V22E464–EVA copol., film blow mldg.
	CS 197	I			Pipe	219	Fortiflex D24-120-20
		II			Pipe		Fortiflex C34-170
		III			Pipe		Fortiflex BFX31146, B45-30R-02
		II	3	C	Pipe	624	Super Dylan 4002N -PPI2306
		III	3	C	Pipe		Super Dylan 7000N PPI3306
	CS 227	I	2	1	Film	335	Alathan 2646, 2650–film
		II	1	1			Alathon 3445–film
		II	3	1			Alathon 3120–film
		II		1		778	Nor. Pet. NPE 350, 930, 952–film
		I		L		928	Rexene PE102
	DIN 7740 Bl. 1	550			51PB pipe	378	Hostalen HGM 5010–extr.
	DIN 8074				Pipe	378	Hostalen GM 5010–extr., high dens.
	DIN 8075				Pipe	378	Hostalen GM 5010–extr., high dens.
	FAA E-2072					778	Nor. Pet. NPE 130, 190–cable jacket
	Fed. L-P315				Pipe, PR, SDR PR	624	Dylan 7000N(PE3306), 4002N(PE2306), 4014N(PE2305)
	Fed. L-P 378	I	C			335	Alathon 2646, 2650–film
		II	C				Alathon 3120, 3445–film
		I			Sheet & strip thin ga.	624	Dylan 1020F, 2030F, 3020F
		II		2		778	Nor. Pet. NPE 350, 930, 952–film
		II			Sheet & strip thin ga.		Dylan 1000F, 2000F, 2007F, 2800F, 3812F
		I, II				928	Rexene PE125 high clarity
	Fed. L-P 390	I	1	L	Cat. 2	335	Alathon 1560, 1570 extr. ctg.; 1724 rot. mldg.
		I	1	L	Cat. 3		Alathon 1540–extr. ctg.; 3442, 3445–indus. film; 2646, 2650 liner film; 4249, 4275–inj. mldg.; 1730 rot. mldg.
		I	1	L	Cat. 4		Alathon 3120 liq. pkg. film
		I	1	L	Cat. 5		Alathon 2530 pellet wrap film
		I	1	M	Cat. 3		Alathon 4352 extr. ctg.
		I	2	H	Cat. 2		Alathon 7250 extr. ctg.
		I	2	H	Cat. 3		Alathon 7140 rot. mldg.
		I	2	L	Cat. 3		Alathon 20, 2005, 2010, 2020–inj. & blow mldg.; 16, 1645 extr. ctg.
		I	2	M	Cat. 3		Alathon 34 inj. mldg.
		I	5	H	Cat. 3		Alathon 7830, 7835, 7840 cast film; 7040–rot mldg.
		I	1-5	H		72	Amoco 607A2 blow mldg. & extr.
		I	2	H			Amoco 650B4, 670C4, 680B4–inj. mldg.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYETHYLENE (Cont'd)	Fed L-P-390 (Cont'd)	I	1	H		233	Chemplex 5060, 5080, 5360, 5602
		I	1,2,3,4	H			Chemplex 5003, 5180, 5250, 5604, 5701, 6001 6003, 6006, 6008, 6009, 6060, 6108, 6150, 6300
		I	1	L			Chemplex 1014, 1016, 1017, 1029, 1050, 1054, 1056, 3019
		I	1	M			Chemplex 3002, 3003, 3007, 3020, 3022, 3041, 3104
		I	2	L			Chemplex 1029, 1054, 1056, 3019
		I	2	M			Chemplex 3002, 3041, 3104
		I	3	L			Chemplex 3019
		I	3	M			Chemplex 3041
		I	5,6	H			Chemplex 5601, 5604, 6001, 6003, 6006, 6008, 6009, 6108, 6105, 6300
		I	1	L		624	Dylan 1000F, 2007F, 2012F, 2020F, 2800F, 3020F, 3812F
		I	2	L			Dylan 1000F, 2007F, 2012F, 2800F, 3020F, 3812F
		I	2	M			Super Dylan 4002(5), 4002-S60028(5)ylo, 4042(3)
		I	2	M			Super Dylan 4002(5), 4002-S60028(5)ylo, 4042(3)
		I	1	H			Super Dylan 5502(5),5003(5),7004C(5) 7004C-S80801(5),FB-55(5)
		I	2	H			Super Dylan 5502(5), 5503(5), 5440(5), 6060-FH(4),6515(3),6530(3),6530-S20239(3), 6550(3),6560(3),6560-S20202(3),7003(5), 7004C(4),7004C-S80801(5), 7120(2), 7180(2), 7200(2), 7280(1), FB-55(5), FW-72(2), FW-78(2), 7080(3)
		I	4	H			Super Dylan 7003(5), 7120(2), 7180(2), 7200(2), 7280(2), FW-72(2), FW-78(2), 7080(3)
		II	1	L			Dylan 1000W, 2000W
		II	2	L			Dylan 1000W, 2000W
		II	3	L			Dylan 1000W, 2000W
		II	4	L			Dylan 1000W
		II	1,2	H			Super Dylan 5000W(5), 5003W(5)
		III	1	L			Dylan 1901W blk.
		III	2,3	L			Dylan, 1909W blk.
		III	4	L			Dylan 2900W blk.
		III	1,2,3	M			Super Dylan 4002N-S20202(5)
		III	1	H			Super Dylan 5900W(3), 5901W(5), 7004C(5)
		I	1,2	H		843	Marlex BXM 43065, BHM5002, BHB5003, BHV5005–copol. blow mldg. & extr.
		I	1,2	H			Marlex TR415, TR418, TR236–copolymer, extr.
		I	1,2	H			Marlex BHB5012,BMB5040,BMB5065–copolymer, inj. mldg.
		I	1-4	H			Marlex HHM5202, HHM5502–copolymer, blow mldg. & extr.
		I	1-4	H			Marlex BMB5095–copolymer, Inj. mldg.
		I	1-5	H			Marlex EHM6001, EHM6003,EHM6006, EHB6009–copolymer, blow mldg. & extr.
		I	1-5	H			Marlex BMN5565, EMB6035,EMB6050,EMN6065–copolymer, inj. mldg.
		I	2	H		738	Monsanto MPE715, MPE725, MPE755, MPE775–copolymer, inj. mldg.
		I	2	H			Monsanto MPE720, MPE750, MPE770–homopolymer, inj. mldg.
		I	4	H			Monsanto MPE775–copolymer, Inj. mldg.
		I	4	H			Monsanto MPE720, MPE750, MPE770–homopolymer, inj. mldg.
		I	6	H			Monsanto MPE720–homopolymer, Inj. mldg.
		II	3	H			Monsanto MPE240–copolymer, insulation
		I	2	H			Monsanto MPE200, 315, 316, 210, 211, 212–copolymer, blow mldg.
		I	4	H			Monsanto MPE321–copolymer, blow mldg.
		I	2	L		778	Nor. Pet. NPE350, 952–film
		I	3	L			Nor. Pet. NPE930–film
		III	8	L			Nor. Pet. NPE130, 190–cable jacket
		I		L		928	Rexene PE109–gen. purp.
		I		L			Rexene PE135–high impact
		I		L			Rexene PE254–overwrap
		I		L			Rexene PE108–drawdown
		I		L			Rexene PE115–high flow

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART*

Plastics and resins qualified under ASTM, ISO, Military Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYETHYLENE (Cont'd)	Fed. L-P-390 (Cont'd)	I	1	L	Cat. 3	346	Tenite 800A, 808A, 1550A, 1830A–inj. mldg.
		I	1	L	Cat. 3		Tenite 800E, 808E, 1550E, 1830E -extr.
		I	1	L	Cat. 3		Tenite 1830HF, 184LF, 184LF, 184MF–film extr.
		I	1	L	Cat. 3		Tenite 808P, 1550P -extr. coating
		I	1	L	Cat. 4		Tenite 1811F–film extr.
		I	2	L	Cat. 3		Tenite 800A, 808A, 1830A–inj.mldg.
		I	2	L	Cat. 3		Tenite 800E, 808E, 1830E–extr.
		I	2	L	Cat. 3		Tenite 183HF, 184LF, 184MF -film extr.
		I	2	L	Cat. 4		Tenite 1811F, E8-556F film extr.
	Fed. L-P-512	I				928	Rexene PE127 warp res.
	FDA CFR-121-2501					928	Rexene PE202 copolymer, high clarity Rexene PE203 copolymer, high imp. Rexene PE204 copolymer, high imp. & clarity Rexene PE209–copolymer Rexene PE143–gen. purp. Rexene PE179–low temp. imp. Rexene PE207–gen. purp., high gloss
	IPCEA S 61-402					778	Nor. Pet. NPE 130, 190 cable jacket
	MIL-C-17	A IIIa			Coax	778	Nor. Pet. NPE 270–foam ins. Nor. Pet. NPE 130, 190–jacket
	MIL-C-9660				Coax	778	Nor. Pet. NPR 270–foam ins.
	MIL-C-19547					778	Nor. Pet. NPE 130, 190 cable jacket
	MIL-S-21894				Shoecounters (Navy)	624	Dylan 3020
	MIL-P-23536				Sheets, virgin & borated	624	Dylan V2030
	MIL-C-27072			C	Style 2–sheath	778	Nor. Pet. NPE 130, 190–cable jacket
	MIL-S-41821				Shoecounters (Army)	624	Dylan 3020
	MIL-C-43103				Body canteen, water Cup & strap, canteen	624	Super Dylan 5502, 5503, 7003 Dylan 1000, 2030, 3020
	NSF 14				Potable water	219	Fortiflex B45-30R, B45-30R-02, F50-15 F50-15-06, E39-45N, E39-45N-02, A60-42
					Potable water	481	Gulf 3401T HiD 9302T, 9306T
	REA PE-14				Sheathed cables	219	Fortiflex D18-30-05, D18-170-05
	REA PE-15				Multi-pair dist. wire	219	Fortiflex D18-170-05
	REA PE-17				Parallel dist. wire	219	Fortiflex D18-30-05, B45-90
	REA PE-22,23, 38					778	Nor. Pet. NPE 190–cable jacket
	REA PE-44					778	Nor. Pet. NPE 190–jacket, 270 foam ins.
	REA PE-200				Appx. E	778	Nor. Pet. NPE 190–cable jacket
PE-CTFE	ASTM D3275	I II III				37	Halar 100, 200–comp. & blow mldg. Halar 300–mldg. & extr.; 400–inj. mldg. Halar 500–hi visc. inj. mldg. & extr. Halar 5001–pwdr.; 5002–fine powdr –roto mldg. Halar 5003–powdr., fluid bed ctg. Halar 5004- powdr., elect'st. ctg.
PE-TFE	ASTM D3159					335	Tefzel 200–mldg. & extr. Tefzel 280–high stress, thick sectn. Tefzel 70G-25–25% glass reinf.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYPHENYLENE SULPHIDE	FDA CFR-121-2621					843	Ryton—coating grade
	NSF 14				Potable water	843	Ryton V1, P2, P3, P4, R6
POLYPROPYLENE	AEC NV-IC1-8, 10 NV-RF1-3				Copolymer pri. ins.	504	Profax SE153
	ASTM D2146	I			Cell 29500	72	Amoco 1011—extr.
		I			Cell 55100		Amoco 2356—flame ret., inj. mldg.
		I			Cell 57100		Amoco 2226—reinf., inj. mldg.
		I			Cell 59100		Amoco 1016—inj. mldg.
							Amoco 2126, 2626—reinf., inj. mldg.
							Amoco 1046, 1156—heat res., inj. mldg.
							Amoco 4016—FDA, inj. mldg.
		I			Cell 69100		Amoco 4017—FDA
		I			Cell 79100		Amoco 4018—FDA
		II			Cell 28900		Amoco 6011—extr.
		II			Cell 56600		Amoco 6114—inj. mldg.
		II			Cell 57400		Amoco 6014—inj. mldg.
		II			Cell 57500		Amoco 6126—reinf., inj. mldg.
		I			Cell 29507	370	Exxon E612—extr., blow mldg., FDA; E622—extr., LTHA
					Cell 29510		Exxon CD491—extr., blow mldg.
					Cell 39000		Exxon CD263—extr., FDA
					Cell 39317		Exxon CD67A—inj. mldg., LTHA
					Cell 49000		Exxon CD551—extr., FDA
					Cell 49208		Exxon DC449, CD496—inj. mldg., FDA
					Cell 49210		Exxon CD305—extr., FDA, antistat.; 417—extr., UV res.; 419, 416, 507—extr., FDA, film; 465—extr.; 476—extr., monofil., FDA; 305M—inj. mldg., FDA, antistat.; 540—inj. mldg., nucl.
					Cell 49217		Exxon CD2D—extr., FDA
					Cell 49218		Exxon CD100, 474—inj. mldg., pwdr., LTHA; 300—inj mldg., LTHA; 398—inj. mldg.; 316—extr., FDA; E115—inj. mldg., FDA, LTHA
					Cell 58000		Exxon CD530—extr., FDA, fiber
					Cell 58100		Exxon CD460—inj. mldg., FDA; 541—Inj. mldg. nucl.; 481—extr. & mldg., pwdr., FDA
					Cell 58107		Exxon CD490—inj. mldg., low warp., FDA
					Cell 58108		Exxon CD350—inj. mldg., LTHA; 475A, E117—inj. mldg., FDA
					Cell 67100		Exxon CD545—inj. mldg., FDA, low warp
					Cell 68000		Exxon CD523—extr., FDA, fiber
		II			Cell 25970		Exxon CD347—hi imp., inj. mldg., LTHA
					Cell 36870		Exxon E813HC—hi imp., extr.
					Cell 36877		Exxon E803HC—hi imp., inj. mldg., LTHA
					Cell 38320		Exxon CD152A—med. imp., UV res., inj. mldg.
					Cell 44977		Exxon CD391, 432—hi imp., inj. mldg., LTHA
					Cell 46558		Exxon CD484, 544—med. imp., inj. mldg., LTHA
					Cell 46568		Exxon E805HC—hi imp., inj. mldg., LTHA
					Cell 47430		Exxon CD280C, 461—med. imp., inj. mldg., LTHA
					Cell 47450		Exxon E825MC—med. imp., inj. mldg., FDA
					Cell 47458		Exxon E805MC—med. imp., inj. mldg., LTHA
		I			Cell 39207	843	Marlex HGZ030-01—UV res., fiber, FDA
					Cell 49107		Marlex HGZ080-02—inj. mldg., FDA
					Cell 49207		Marlex HGH050-01—heat stab., inj. mldg.
							Marlex HGV050-01—UV res., inj. mldg.
							Marlex HGZ050-02—FDA, extr. & mldg.
							Marlex HGV040-01—UV stab., monofil.
							Marlex HGZ040-01—FDA, monofil.
							Marlex HGZ040-02—heat stab., monofil.
					Cell 59107		Marlex HGZ120-01, HGN120-01—inj. mldg.
							Marlex HGZ120-02—heat stab., FDA, inj. mldg.
							Marlex HLN120-01—antistat, FDA, inj. mldg.
							Marlex HGZ120-03—FDA, film, monofil.
					Cell 44660		Marlex CGH040-01—med. imp., inj. mldg.
					Cell 45550		Marlex CHL040-02—med. imp., antistat., inj. mldg.
		I			Cell 49200	785	Moplen F040—inj. mldg., food pkg.
		I			Cell 49200		Moplen C040Y—carpet backing
		I			Cell 49200		Moplen C040F—ind. fabrics
		I			Cell 49200		Moplen FT080W—antistatic closures
		I			Cell 49200		Moplen FT120Z—antistatic closures, dark col.
		I			Cell 49200		Moplen L040D—fil extr.
		II			Cell 45670		Moplen CX040W—inj. mldg., dish washers
		II			Cell 46550		Moplen DH040W—inj. mldg., imp. res.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYPROPYLENE (Cont'd)	ASTM D2146 (Cont'd)	I		D	Cell 29508	504	Pro-fax 6723, 6823–extr.
				D	Cell 49209		Pro-fax 6523–inj. mldg.
				D	Cell 59109		Pro-fax 6323–inj. mldg.
		II		D	Cell 26907		Pro-fax 7723, 7823–high imp., extr.
				D	Cell 34907		Pro-fax 8623–hi imp., inj. mldg.
				D	Cell 36607		Pro-fax 7623 -med imp., inj. mldg.
				D	Cell 37700		Pro-fax 7623N–med. imp., inj. mldg.
				D	Cell 44607		Pro-fax 8523–hi imp., inj. mldg.
				D	Cell 47500		Pro-fax 7523N–med. imp., inj. mldg.
				D	Cell 47507		Pro-fax 7523–med imp., inj. mldg.
		I			Cell 29200	536	Propathene GSE20–extr., film yarn
		I			Cell 38400		Propathene 22/44/9040–inj. mldg., asb. filled
		I			Cell 39200		Propathene GWE23–extr., film yarn
		I			Cell 49200		Propathene GWM22, LYM41, GXM43–inj. mldg.
		I			Cell 49200		Propathene GWE21, 26, 27, 28–extr., film yarn; LXF44, 50, 51–film
		I			Cell 49200		Propathene HWM25–inj. mldg., heat stab.
		II			Cell 16900		Propathene GPM106–inj. mldg.
		II			Cell 16900		Propathene GPE102, HPE103–extr.
		II			Cell 26900		Propathene GSM109–inj. mldg.
		II			Cell 26900		Propathene GSE108, HSE110, GSE111, GSF113, 112/00/9897–extr.
		II			Cell 35900		Propathene GWM201, 203–inj. mldg.
		II			Cell 37200		Propathene 101/24/–inj. mldg., 40% talc.
		II			Cell 43200		Propathene 202/33/–inj. mldg., fl. ret.
		II			Cell 45600		Propathene GYM202–inj. mldg.
		II			Cell 47600		Propathene GWM101,LWM104,GY621M–inj. mldg.
		II			Cell 47600		Propathene HWM107–inj. mldg., heat stab.
		II			Cell 47600		Propathene GWE105–extr.
		I		D	Cell 49209	928	Rexene PP11-53 10,11-H-3-10,11-W-3-10–inj.
		I		D	Cell 49209		Rexene PP31-S-4, 41-S-3-7, 41-E-3, 51-S-3-10–extr.
		II		D	Cell 47607		Rexene PP15-S-3-10, 15-H-3-10, 15-W-3-10–inj.
		II		D	Cell 48208		Rexene PP13-S-5-10–inj.
		II		D	Cell 48208		Rexene PP32-S-5, 42-S-5–extr.
		II		D	Cell 48308		Rexene PP44-S-3–extr.
		II		D	Cell 48408		Rexene PP54-L-5, 54-N-5–extr.
		II		D	Cell 48408		Rexene PP54-U-5–extr.
		II			Cell 48408		Rexene PP14-S-5-10, 14-H-5-10, 14-W-5-10–inj.
		I			Cell 27300	995	Shell 5120–extr., FDA
		I			Cell 27300		Shell 5220–extr., FDA, blow mldg.
		I			Cell 48100		Shell 5520–inj. mldg., FDA
		I			Cell 48100		Shell 5550–inj. mldg., FDA, heat res.
		I			Cell 48100		Shell 5524–inj. mldg., FDA, nucleated
		I			Cell 58100		Shell 5820–inj. mldg., FDA
		I			Cell 58100		Shell 5824–inj. mldg., FDA, nucleated
		II			Cell 25900		Shell WM110–hi. imp., extr., FDA
		II			Cell 35900		Shell WM110.2–hi. imp., extr., inj. mldg., FDA
		II			Cell 45500		Shell 7825–hi. imp., inj. mldg.
		II			Cell 47400		Shell 7521–med. imp., inj. mldg., FDA
	DIN 7740, B1.2	560			1PCD pipe	378	Hostalen PPH2250–extr.
		562			1PCD pipe		Hostalen PPH2222–extr.
	Fed. L-P-394	I		E		72	Amoco 1016, 1046, 1156, 4016–inj. mldg.
		III		E			Amoco 1011–extr.
		I		E		370	Exxon E115, CD449–FDA, inj. mldg.; CD300–inj. mldg., LTHA; CD398–inj. mldg.
		III	A	E			Exxon CD67A–LTHA; E805MC–med. imp., inj. mldg.
		III	B	E			Exxon E803HC–hi imp., inj. mldg.
		IV	A	E		q	Exxon CD484–med. imp.; E805HC–hi imp., inj. mldg.
		IV	B	E			Exxon E803HC, CD391–hi imp., inj. mldg. CD347–hi imp., extr.
		I				785	Moplen F-040–inj. mldg., food pkg.
		II					Moplen L-040E–U.V. res.
		III		A			Moplen AM-040W–inj. mldg., imp. res.
		III		B			Moplen CX-040W–inj. mldg., dishwashers
		I		E			Pro-fax 6623–inj. mldg.
		II		E			Pro-fax 6626–UV, inj. mldg.
		III	A	E			Pro-fax 6723, 7523–extr., med. imp., inj. mldg.
		III	B	E		Pr	Pro-fax 7623–med. imp., inj. mldg.
		IV	A	E			Pro-fax 7623–med. imp., inj. mldg.
		IV	B	E			Pro-fax 7723–high imp., extr.
		IV	B	E			Pro-fax 8623 very high imp., inj. mldg.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYPROPYLENE (Cont'd)	Fed. L-P-394 (Cont'd)	I III III IV IV	 A B A B			995	Shell 5520, 5520S, 5524, 5524S, 5550 - gen. purp. Shell 7621 - med. imp.; 7525 - hi imp. Shell WM110, WM110-2 - high imp. Shell 7525 - hi imp. Shell WM110, WM110-2 - high imp.
		I I I III III III IV IV	 A A B A B			346	Tenite 4220A, 4230A - inj. mldg., FDA Tenite 4231A - inj. mldg. Tenite 4232A - inj. mldg., heat res. Tenite 4P31A - inj. mldg., med. imp. Tenite 4P32A - inj. mldg., med. imp., heat res. Tenite 4E11 - inj. mldg., high imp. Tenite 5020A - inj. mldg., FDA, 5021A - inj. mldg. Tenite 5B20A - inj. mldg., FDA; 5B21A, 5321A - inj. mldg.
	MIL-C-19978 MIL-C-39022					928	Rexene PP41E-3 - film extr.
	MIL-P-46109	I II III •		2 3 2 3 2 3	40% glass reinf. 40% glass reinf. 30% glass reinf. 30% glass reinf. 20% glass reinf. 20% glass reinf.	634	Thermocomp MFX 1008 Thermocomp MF 1008 Thermocomp MFX 1006 Thermocomp MF 1006 Thermocomp MFX 1004 Thermocomp MF 1004
	MIL-B-52472					928	Rexene PP54-U-5 - slit film & fibre extr.
						785	Moplen L395 - sand bags
	REA PE210, PE22, PE23, PE28, PE50					504	Pro-fax SE153 - prim. ins.
	REA PE210					346	Tenite M7853-78E, P7673-664E-extr. wire
	USP-XVIII				V1-121C med. syringes	785	Moplen F120
					Nonabsorb. surg. sutures	785	Moplen F-040 - spe. nat. & blue
POLYSTYRENE	ASTM D703	II III IV V				72	Amoco G2, G3, G4 - inj. mldg. Amoco G1, H2, R5, M2, M9 - inj. mldg. Amoco H3, H4, H4R, M8 - inj. mldg. Amoco R3 - extr.
		I III				1016	Solar E-Z Flow - inj. mldg. Solar Regular Flow - inj. mldg.
	ASTM D1892				Cell 3162B Cell 3363B Cell 3454B Cell 4251B Cell 4352B Cell 4443B Cell 5352B Cell 5433B	995	Shell 318 - med. imp., inj. mldg. Shell 316 - med. imp., inj. mldg. Shell 314 - med. imp., heat res., inj. mldg. & extr. Shell 327 - hi. imp., inj. mldg. Shell 324A - hi. imp., inj. mldg. Shell 325A - hi. imp., heat res., inj. mldg. & extr. Shell 333 - hi. imp., inj. mldg. Shell 338 - hi imp., inj. mldg. & extr.
						1016	Solar 505, 512, 515 - med. imp., inj. mldg. Solar 2006 - high imp., inj. mldg. Solar 2007 - heat res., inj. mldg. Solar 2610 - high imp., inj. mldg.
	ASTM D3011				112 20% glass 233 30% glass 345 40% glass	634	Thermocomp CF 1004 Thermocomp CF 1006 Thermocomp CF 1008
	Fed. L-P-396	III IV V		1,2 1,2 1,2		624	Dylene 2 - inj. mldg. & extr. Dylene KPD-1272 - inj. mldg. & extr. Dylene 8, 8E, 8G - inj. mldg. & extr.
	Fed. L-P-398	I				72	Amoco H3, H4R - inj. mldg.
		I I II II III III		 2 1 2 1 2		624	Dylene 305, 308, 315, 505, 601, 989 Dylene 308 Dylene 505, 535, 601, 989 Dylene 308, 315, 989 Dylene 305, 315, 505, 601, 989 Dylene 315, 989, KPD1340

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYSTYRENE (Cont'd)	Fed. L-P-398 (Cont'd)	II II III III		1 2 1 2		995	Shell 316–med. imp., inj. mldg. Shell 314–med. imp., heat res., inj. mldg. & extr. Shell 324A, 327, 333–high imp., inj. mldg.; 338–high imp., inj. mldg. & extr. Shell 325A–high imp., heat res., inj. mldg. & extr.
	Fed. L-P-506	I			Sheet & film	624	Dylene 8
	Fed. HH-I-524	I II III		A A A	Insul. board Insul. board Insul. board	624	Dylite SE57 Dylite SE57 Dylite SE57
	Fed. L-C-770	II			Cup & lid	624	Dylite F40-C, KFP246-C, KFP270-T
	Fed. PPP-C-850	I		1,2, 3,4	Cushioning mat'l	624	Dylite F40
	FDA CFR 121.2610				Butadiene-styrene	843	K-Resin KR01, KR03
	MIL-S-676				Spoon, knife, fork	624	Dylene 308
					Spoon, knife, fork	995	Shell 314–med. imp.
	MIL-P-19644	I I I II II II III III		1 2 3 1 2 3 1 3	Foam Foam Foam Foam Foam Foam Foam Foam	624	Dylite F40, F64, KFP246 Dylite F43 Dylite F40, F64, KFP246 plus 3% color Dylite SE57 Dylite F53 Dylite SE57 plus 3% color Dylite KFP524 Dylite KFP524 plus 3% color
	MIL-P-21347	I II			High HDT 35% glass High imp. 35% glass	634	LNP CF1007 LNP CF1007HI
	MIL-C-26861		D C-D	3 4,5	Cushioning mat'l Cushioning mat'l	624	Dylite F40, SE57, KFP246 Dylite F40, SE57, KFP246
	MIL-P-40619		A,B A,B	1 2	Cellular mat'l Cellular mat'l	624	Dylite F40, F64, KFP246 Dylite SE57
	MIL-P-60312	I II		1 1	Molded parts Molded parts	624	Dylite SE53 Dylite SE57
POLYSULFONE	MIL-P-46120					1117	Udel P1700, P1710, P3500, P3510–mldg. & extr.
	MIL-P-46133				Polyarylsufone ether	1090	Astrel 360–inj. mldg.
PTFE	ASTM D1457	I IV IV III		6 3 6,7		536	Fluon G3–gran. mldg. & extr. Fluon G163–gran. mldg. Fluon G307, 301G–gran. mldg. & extr. Fluon CDI, CD123, CD4, CD042–dispers., extr.
		I I IV IV IV IV		2 6 3 3 6 7		37	Halon G10–gran., mldg. & extr. Halon G50–gran., mldg. & extr. Halon G80–gran., high strength, mldg. & extr. Halon G700–gran., low cold flow, mldg. Halon G83–gran., mldg. & extr. Halon G183–gran., mldg. & extr.
						55	Hostaflon TF 1620, 1640–auto. & isostat. mldg. Hostaflon TF 1665–extr. & auto. mldg. Hostaflon TF 1740 hi str. mldg. Hostaflon TF 2026, 2053–wire, hose & tubing
		I III III IV		7 1,2 2 1,3,4	Granular Fine Powder Fine Powder Granular	335	Teflon 8,8A–gran. high flow Teflon 6C, 62–fine pwdr., extr., hose & tubing Teflon 6, 6C, 6H–fine pwdr., wire coating Teflon 7A, 7B, 7C–gran., high strength
	Fed. L-P-403	I II IV IV IV V		2 3 2 2 3		37	Halon G10–gran., mldg. & extr. Halon G50–gran., mldg. & extr. Halon G80–gran., high strength, mldg. & extr. Halon G700–gran., low cold flow, mldg. Halon G83–gran., mldg. & extr. Halon G183–gran. mldg. & extr.

Column heads: "Specification" spans Designation and number through Description; "Supplier, trade name[a] and grade[b]" spans Supplier code and Trade name.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[d] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
PTFE (Cont'd)	Fed. L-P-403 (Cont'd)	III III IV V		1,2 2 1,2,3	Fine powder Fine powder Granular Granular	335	Teflon 6,6C,6H–fine powdr., wire coating Teflon 61,6C–fine pwdr., extr., hose & tubing Teflon 7A,7B,7C–gran., high strength Teflon 8,8A–gran., high flow
	UK-DTD5517					536	Fluon G163,G3,G307,301G gran.
POLYURETHANE (t' PLASTIC)	MIL-I-4997 MIL-C-5898				Wire & cable	466	Estane 58300
POLYVINYLIDENE FLUORIDE	AC Spark Plug ES7454					834	Kynar 200, 300, 450 (homopolymer–all grades)
	Autom Electric 5873				Ins. wire	834	Kynar 300, 450
	Brand Rex BR212 Div. Amer. Enka				Wire wrap		
	Dow-Rocky Flats 310641-37				Glove box	834	Kynar Laminates
	IBM3111				Ins. wire	834	Kynar 300, 450
	Martin MMS B642				Bar, rod, tube	834	Kynar 300, 300, 450 (homopolymer all grades)
	Martin MMSA 667				Sheet		
	MIL-W-5086				Wire, jacket, 110°C.	834	Kynar 300, 450
	MIL-C-7078				Jacket, aerosp.		
	MIL-W-16878	B			Wire, 600V, 105°C.		
	MIL-W-22759				Ins., wire		
	MIL-I-23053/8				Heat shrink ins., crosslinked		
	MIL-P-46122	I II			Homopolymer Copolymer	834	Kynar 200, 300, 450 (all grades) Kynar 5200, 7200 (all grades)
	MIL-W-81044				Wire, jacket, X linked	834	Kynar 300, 450
	MIL-W-81822	A30			Ins., wire		
	Rocketdyne RBO-0130-062				Resin, sheet & molded parts	834	Kynar 200, 300, 450 (homopolymer (all grades)
	UL 1327			105°C.	Wire wrap	834	Kynar 300, 450
	UL 1351			80°C.	Wire wrap		
	UL 1422, 1423 1426			105°C.	Wire wrap		
SAN	ASTM D1431	III III III III		9 7 3 2		288	Cevian N040–inj. mldg. Cevian N050–inj. mldg. Cevian N010 inj. mldg. Cevian 020 inj. mldg.
	ASTM D3011				322, 20% glass 443, 30% glass 443, 35% glass 453, 40% glass 243, 30% glass	634	Thermocomp BF 1004 Thermocomp BF 1006 Thermocomp BF 1007 Thermocomp BF 1008 Thermocomp BFL 4036 – 15% PTFE lubr.
VINYL	AFP 88-007-3				Extr. Sheet extr.	466	Geon 7082 Geon 7084, 85821
	ASTM D1047				Wire jacket, 1/22	466	Geon 8804
						818	Kohinor W200, W202 ins. & jacket
	ASTM D1755	GP GP GP GP GP			Cell 415303 Cell 41503 Cell 515403 Cell 416203 Cell 22603	818	Kohinor 651 resin, ins. & jacket, dry blend Kohinor 683–resin, ins. & jacket, dry blend Kohinor 681, 681E ins. & jacket, dry blend Kohinor 667 pipe & rigid extr. Kohinor 688 low M.W., G.P.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
VINYL (Cont'd)	ASTM D1784				Cell 12454	169	Borden 3028–pipe, DWV & pot. water, single screw
					Cell 12454		Borden 3038–pipe, DWV & pot. water, multi. screw
					Cell 13454		Borden 3044–fittings
		II	1		Cell 14314		Borden 3018–blow mldg. & sheet
		II	1		Cell 15314		Borden 3042–blow mldg. & sheet
					Cell 13454	363	Ethyl 5009, 7031–inj. mldg., fittings
					Cell 13464		Ethyl 5025–rigid extr., UV res.
					Cell 14333		Ethyl 7008–inj. mldg., fittings, conduit
					Cell 14343		Ethyl 8237–rigid, blow mldg., food grade
					Cell 14343		Ethyl 9110–rigid., blow mldg.
					Cell 14454		Ethyl 7051–inj. mldg., fittings
					Cell 15344		Ethyl 7042–inj. mldg., gen.
					Cell 16234		Ethyl 7045–rigid, extr., med. imp.
					Cell 16344		Ethyl 7020–rigid, extr.
					Cell 12454A	466	Geon 85781
					Cell 12454B		Geon 85796–inj. mldg.
					Cell 12454C		Geon 7082, 82662, 85277–prof. extr.
					Cell 12454C		Geon 7084, 8750, 85821–prof. & sheet extr.
					Cell 12463A		Geon 85707–extr.
					Cell 13334C		Geon 8714–extr.
					Cell 13454B		Geon 85713–inj. mldg.
					Cell 14333D		Geon 8700A–prof. extr.
					Cell 15343C		Geon 85690–inj. mldg.
		IV	1		Chlor. PVC		Geon 3007–extr.
		IV	1		Chlor. PVC		Geon 3010–inj. mldg.
					Cell 14344D	818	Kohinor R860–rigid, cond.
					Cell 15353		Kohinor R802–FDA, clear, blow mldg.
					Cell 14353		Kohinor R864–FDA, clear, low-odor, blow mldg.
					Cell 15353		Kohinor R873–high imp., clear, extr.
		I	1		Cell 12454B	469	Pliovic R1178, R1179, R1181–pipe, pot. water, & DWV, multi. screw
					Cell 03323D	466	Vynaloy V450–transp. sheet, vac. form.
					Cell 03323D		Vynaloy V455–transp. & col. sheet
					Cell 13324D		Vynaloy V353–transp. sheet, lids
					Cell 13324D		Vynaloy V453, 452–transp. sheet, vac. form
					Cell 13324D		Vynaloy V813–transp. sheet, tin stab., food
	ASTM D1785				Pipe, sched. 40, 80, 120	466	Geon 3007 gry. 250, 3007 tan 309
					Pipe, sched. 40, 80, 120		Geon 8761, gry. 270, 85555 gry. 271 & wht. 127, 85781, gry. 271, wht. 127, 8548 gry. 271 nat. 025, wht. 127 & gry. 760, 85707 gry. 271, wht. 130, nat. 025 & 021 extr.
					Pipe sched. 40, 80, 120		Geon 85672 gry. 260, 85660 gry. 260, 8714 gry. 260, 85642 gry. 260 extr.
					Pipe, sched. 40, 80, 120	469	Pliovic R1178, R1179, R1181–extr.
	ASTM D2241				Pipe, SDR-RR,TT	466	Geon 3007 gry. 250 & tan 309 Geon 8761 gry. 270, 85555 gry. & wht. 127 85781 gry. 271 wht. 127, 85483 gry. 271 & nat. 025, wht. 127 & gry. 760, 85707 gry. 271, wht. 130, nat. 025 & nat. 021 extr. Geon 85672 gry. 260, 85660, 8714, 85642 gry. 260 (all) extr.
					Pipe, SDR-RR,TT	469	Pliovic R1178, R1179, R1181–extr.
	ASTM D2287				Cell 5550531	818	Kohinor W200, W202916–ins. & jacket
					Cell 5650431		Kohinor W203–ins.
					Cell 4560431		Kohinor W204–ins.
					Cell 5570331		
					Cell 5450531		Kohinor W205, W320–ins.
					Cell 5460531		Kohinor W304, W406–ins. & jacket
					Cell 6450631		Kohinor W311–ins.
					Cell 6460631		Kohinor W319–ins.
					Cell 6360301		Kohinor P500–clear, extr., inj. mldg.
					Cell 3130501		Kohinor P502–clear, extr.
					Cell 4250501		Kohinor P503–clear, extr.
					Cell 5250301		Kohinor P504–clear, extr.
					Cell 3350901		Kohinor P507–clear, low-temp., fungus res., extr.
					Cell 6370001		Kohinor P520–clear, medical, inj. mldg. & extr.
					Cell 4250001		Kohinor P523–clear, medical, inj. mldg. & extr.
					Cell 5260001		Kohinor P524–clear, medical, inj. mldg. & extr.
					Cell 4540001		Kohinor W513–prof. extr.
					Cell 3540601		Kohinor W575–inj. mldg.
					Cell 5550501		Kohinor P536
					Water stop		
					Cell 4250001		Kohinor 570–inj. mldg.
					Cell 5260001		Kohinor 571–inj. mldg.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier, trade name[a] and grade[b]: Supplier code[d]	Trade name, material grade designation and description[e]
VINYL (Cont'd)	ASTM D2287 (Cont'd)				Cell 5550601		Kohinor 587
					indoor tel. cable jacket Cell 7660301		Kohinor 702–ins.
					serv.drop & line wire Cell 7470531		Kohinor 703–prim. ins.
					Cell 6460531		Kohinor 704–prim. ins.
					Cell 7470431		Kohinor 735
					wire ins. Cell 4640601		Kohinor 904–entr. & inj. mldg.
					Cell 5640601		Kohinor 905–extr. & inj. mldg.
					Cell 5250531		Kohinor 906–clear SPT 60°C.
					Cell 5840501		Kohinor 907–low cl., fl. res. jacket
					Cell 5550831		Kohinor 908–low temp. jacket
					Cell 6660531		Kohinor 912–jacket, low volt. ins.
					Cell 5350921		Kohinor 915
					2 cond. rip cord Cell 555063-1		Kohinor 917–jacket
					Cell 4250901		Kohinor 919–low temp. jacket
	ASTM D2464				THR. fittings, sched. 80	363	Ethyl 5009, 7051
					THR fittings, sched. 80, chlor. PVC	466	Geon 3007 gry. 250, 3007 tan 309–extr.
					THR. fittings sched. 80		Geon 85690 wht. 127 & gry. 260–inj. mldg.
	ASTM D2466				Socket fittings, sched. 40	363	Ethyl 5009, 7008, 7051
					Socket fittings, sched. 40 chlor. PVC	466	Geon 3010 gry. 250 & tan 309 – Inj. mldg.
					Socket fitting, sched. 40		Geon 85796 wht. 127 & gry. 271–inj. mldg.
	ASTM D2467				Socket fitting, sched. 80	363	Ethyl 5009, 7008, 7051
					Socket fittings sched. 80 chlor. PVC	466	Geon 3010 gry. 250 & tan 309–inj. mldg.
					Socket fitting, sched. 80		Geon 85713 wht. 127 & gry. 271–inj. mldg.
	ASTM D2665				DWV pipe & ftgs.	363	Ethyl 5009, 7031, 7051
					DWV pipe & ftgs.	466	Geon 85796, 85644, 85297–inj. mldg.
					DWV pipe & ftgs.	469	Pliovic R1178, R1179, R1181–extr.
	ASTM D2729				Sewer pipe & ftgs.	363	Ethyl 5009, 7031, 7051
					Sewer pipe & ftgs.	466	Geon 85690–inj. mldg.
					Sewer pipe & ftgs.	469	Pliovic R1178, R1179, R1181–extr.
	ASTM D2740				Tubing	466	Geon 8761, 85555, 85781, 85483, 85707, 85672, 85660, 8714, 85642–extr.
					Tubing	469	Pliovic R1178, R1179, R1181–extr.
	ASTM D2846				CPVC hot water dist. syst., chlor. PVC	466	Geon 3007 gry. 250, tan 309–extr.
					CPVC hot water dist. syst., chlor. PVC		Geon 3010 gry. 250 & tan 309–inj. mldg.
	ASTM D2949				DWV 3 in. thin wallpipe & ftgs.	363	Ethyl 7031
	ASTM D3033				PSP sewer pipe & fittings	466	Geon 85672, 85660, 8714, 85642–extr.
					PSP sewer pipe & fittings	469	Pliovic R1178, R1179, R1181–extr.
	ASTM D3034				PSM sewer pipe & fittings	466	Geon 8761, 85555, 85781, 85483, 85707, 87209–extr.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material designation and description[e]
VINYL (Cont'd)	ASTM D3034 (Cont'd)				PSM sewer pipe & fittings	469	Pliovic R1178, R1179, R1181–extr.
	Chrysler MS-DC-218	V			Ext. side & body trim	466	Geon 83715 bld. 390
	Chrysler MS-DC-232					818	Kohinor 571–inj. mldg.
	Chrysler MS-DC-233					818	Kohinor 570–inj. mldg.
	MIL-C-572				water stop	394 818	Firestone FPC1087 Kohinor P536
	CS 230				Weather stripping	394	Firestone FPC 1238, 1239, 1240
	CS 272					466	Geon 85713–inj. mldg.
					DWV pipe & ftgs.	469	Pliovic R1178, R1179, R1181–extr.
	CS PS21				Chlor. PVC	466	Geon 3007 gry. & tan 309–extr. Geon 8761, 85555, 85781, 85483, 85707, 85672 85660, 8714, 85642–extr.
					Pipe, sched. 40, 80, 120	469	Pliovic R1178, R1179, R1181–extr.
	CS PS22				Chlor. PVC	466	Geon 3007 gry. & tan 309–extr. Geon 8761, 85555, 85781, 85483, 85707, 85672 85660, 8714, 85642–extr.
					Pipe, SDR	469	Pliovic R1178, R1179, R1181–extr.
	CS PS26				Extr. Sheet extr.	466	Geon 82662, 85277, 8700A Geon 8750
	CS PS55				Extr. Sheet extr.	466	Geon 7082 Geon 7084, 85821
	DIN 7748	2233				378	Hostalit H2070–inj. mldg., flame ret.
		3333 3333 3533 3533 3534 3633 3633				338	Trosiplast 3221–inj. mldg., med. imp., hi flow Trosiplast 3231–inj. mldg., med. imp., UV res. Trosiplast 2040–blow mldg., hi imp., nontoxic Trosiplast 3321–inj. mldg., hi imp., hi flow Trosiplast SW1056–extr., med. imp., flame ret. Trosiplast 2060–blow mldg., hi imp., nontoxic Trosiplast 3311–inj. mldg., hi imp., nontoxic
		4142 4142					Trosiplast 3121–inj. mldg., clear Trosiplast 3122–inj. mldg., hi flow
		4143					Trosiplast 3111–inj. mldg., nontoxic
		4144 4143 4244 4345					Trosiplast 3161–inj. mldg. Trosiplast 2020–blow mldg., med. imp., nontoxic Trosiplast 2000–blow mldg., nontoxic Trosiplast 1001–extr., flame ret.
	Edgewood Ars. 197-54-839A	I			Flexi. film	818	Pantasote film
	Fed. HH-I-595				Elec. tape, pres. sens.	818	Pantasote film
	Fed. L-R-335	I	M	1,2	Ribbons, flag, surveyor	818	Pantasote film
	Fed. L-P-375	I,II		142	Sheeting, life pres.	818	Pantasote film
	Fed. L-P-535				Extr. Sheet extr.	466	Geon 81661, 85177, 8700, 7082 Geon 8750, 7084, 85821
	FDA CFR121.2597				Ca.-Zn. stab.	466	Geon 85542 trans. 002, 85755 trans. 002
					Tin stab.		Geon 85747 trans. 002–blow mldg.
	Ford ESB-M40-284	IV			Ext. side & body trim	466	Geon 83700 blk. 290
	Ford ESP-M4D-244					818	Kohinor W575–inj. mldg.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specifications					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
VINYL (Cont'd)	GM-Fisher Body FBM82-8	V			Ext. side & body trim	466	Geon 8815-287
	IPCEA S61-402				60°C. rating 75°C. rating	257	Conoco 80128 Conoco 80123
					60°C. rating 75°C. rating	394	Firestone FPC 5360 Firestone FPC 5175
						818	Kohinor W200 - ins. & jacket Kohinor W202 - ins. & jacket Kohinor 704 - prim. ins.
	Los Angeles D164-R				Serv. drop & line wire	818	Kohinor 702 - ins.
	MIL-C-17	I			Coax. cable	257	Conoco 80128 - ins.; 80124 jacket
		I			Coax. cable	466	Geon 8804 - jacket
		IIa					Geon 8720 - jacket
					RF cable, coax., twin	818	Kohinor W200, W202 - ins. & jacket
	MIL-W-76					466	Geon 8025, 8291, 8801
						818	Kohinor W200, W202
	MIL-I-631	F	C	1	Form U, elec. ins.	818	Pantasote film
	MIL-C-915				Ship cable, cord & wire	257	Conoco 80128 - prim. ins. Conoco 80224 - flex. jacket Conoco 80154 - non-flex. jacket
						466	Geon 8022, 8290, 8804
					Ship cable, cord & wire	818	Kohinor 908 - low temp. jacket Kohinor W-205 - ins.
	MIL-C-3432					257	Conoco 80124, 80128 - jacket
					Elec. power cable & wire	818	Kohinor W205 - ins.
	MIL-C-3884				Cord, AF low temp.	257	Conoco 80124 - jacket
					Elect. cord	818	Kohinor 908 - low temp. jacket
	MIL-I-3930				Wire & cable	257	Conoco 80128 - jacket
		IP JP			Wire & cable Wire & cable	466	Geon 8801 021, 288 - ins. Geon 8804 - jacket
					Wire & cable	818	Kohinor W200, W202 - ins. & jacket
	MIL-W-5086				Hook-up wire	818	Kohinor W319, W320 - ins.
	MIL-P-6264				Thin sheet, copol.	818	Pantasote film
	MIL-W-7072				Aircraft wire, alum.	818	Kohinor W319, W320 - ins.
	MIL-C-7078				Aerospace vehicle cable	818	Kohinor W319, W320 - ins.
	MIL-I-7444					818	Kohinor P507 - clear, low temp., fungus res., extr.
	MIL-B-8571	2		1	Storage bag, drinking water	818	Pantasote film
	MIL-C-15452				Coax. tow cable	818	Kohinor 908 - low temp. jacket
	MIL-C-15479				Subm. power cable	818	Kohinor W200, W202 - ins. & jacket
	MIL-W-16878	B,C			105°C. 1/64 high temp. wire	394	Firestone FPC 1372
		B,C,D			High temp., flame res. aircraft wire	818	Kohinor W319, W320 - ins.
	MIL-C-23437				Sh. pr. cable	818	Kohinor 917 - jacket
	MIL-C-27072				Electr. cable	818	Kohinor W319, W320 - ins.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier, trade name[a] and grade[b]: Supplier code[d]	Trade name, material grade designation and description[e]
VINYL (Cont'd)	MIL-C-55036				Teleph. cable	818	Kohinor 919–low temp. jacket
	NSF 14					363	Ethyl 7031, 5009, 7008, 7051–inj. mldg., fittings for potable water & DWV systems
	NAS 702					818	Kohinor W319, W320–wire ins.
	NEMA WC5				Wire, 60°C. Wire, 75°C.	394	Firestone FPC 5360 Firestone FPC 5175
						818	Kohinor K704–prim. ins.
	REA PE7				Parallel drop wire	818	Kohinor #406–ins. & jacket
	REA PE15 PE72				Teleph. wire & cable	818	Kohinor W406–ins. & jacket
	REA PE220				Appx. 1, indoor teleph. cable	818	Kohinor K587–jacket
					Teleph. wire & cable	394	Firestone REA I-1–prim. ins.
						818	Kohinor 735–ins. Kohinor W406–ins. & jacket
	UL 62			11	Spt. 60°C. wire	257	Conoco 80325
				11 12 12 12	60°C., wire 75°C., wire 90°C., wire 105°., wire	394	Firestone FPC 5060 Firestone FPC 5360 Firestone FPC 5290 Firestone FPC 5505
				1,2,3	Spt. 75°C. wire	818	Kohinor 905
	UL 83				T,TW,THW, 60°C., oil T,TW,THW, 75°C., oil T,TW THWN	257	Conoco 80123, 80857 Conoco 80853 Conoco 80102, 80110, 80128 Conoco 80123
					T,TW,60°C. oil, wire THW, TW, 60°C. oil, wire	394	Firestone FPC 5060, 5360 Firestone FPC 5075, 5175
					T,TW,60°C. Oil, wire THW,THWN, THHN, wire	818	Kohinor W200,W303,W204 Kohinor 704
	UL 758				80°C. AWN wire 90°C. AWN, 1000V 105°C. AWN wire	257	Conoco 80128 Conoco 80857 Conoco 80455
					60°C., AWN, wire 80°C., AWM, wire 90°C., 3/64, wire 90°C., 1/32, wire 90°C., 1/64, wire 90°C., rad. heating wire 90°C., AWM, 1000V, wire 105°C., 1/32, wire	394	Firestone FPC 5060 Firestone FPC 5360 Firestone FPC 5075 Firestone FPC 5175 Firestone FPC 1308 Firestone FPC 5290 Firestone FPC 1372 Firestone FPC 5305, 5405, 5505
					80°C., THW, AWM, wire 90°C., AWM, 1000V, wire 105°C., AWM, wire 105°C., AWM, wire 105°C., AWM, wire 105°C., AWM, 1/64,wire	818	Kohinor W200 Kohinor W202 Kohinor W311, W320 Kohinor W304–non migratory, refrigerator Kohinor W319–aircraft missile Kohinor 735
	VDE 0209/3.69					338	Trosiplast 7000–wire ins. & cable sheath Trosiplast 8002 elect. plugs
	Western Elect. 534				Jacket	257	Conoco 92213

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Supplier, trade name[a] and grade[b]: Trade name, material grade designation and description[e]
VINYL (Cont'd)	Western Elect. 644				Insulation	257	Conoco 92214
						818	Kohinor 735–ins.
	Western Elect. 750					818	Kohinor W406–ins. & jacket
THERMOSET MOLDING COMPOUNDS AND RESINS							
ALKYD MC	ASTM D1201	I				336	Durez 24060*,24668–min.,comp.,transf., inj. mldg.
		I					Durez 24060*–glass,comp.,transf.,inj.mldg.
		I					Durez 39376–glass & min., comp., transf., inj. mldg.
		I					Durez 24150*,27962–min.,flame ret., arc res. comp.,transf.,inj.mldg.
		II					Durez 23410,24337–min.,comp.,transf.,inj. mldg.
		IV				1094	Toshiba AP 301 BG–pellet, comp., transf. inj. mldg.
							Toshiba AP 301 BF–flake,transf.,comp.mldg.
							Toshiba AP 301 BL–heat, flame & track res. comp.,transf.mldg.
	MIL-M-14				MAG	336	Durez 23511*–min.,24060*–glass; 24150*–min., flame ret., arc res.–comp., transf., inj. mldg.
					MAI 30	51	Glaskyd 2051B*–comp. & transf. mldg., glass fld., rope
					MAI 60		Glaskyd W300C*–comp. & transf. mldg., bulk, long glass
					MAG	37	Plaskon AMC 420, 422; min. granular
					MAG		Plaskon AMC 417; putty, encaps.
					MAI 30		Plaskon AMC 760; rope, med. imp.
					MAI 60		Plaskon AMC 446, 940; flake, high imp.
					MAT 30		Plaskon AMC 785; rope, med. imp., track res.
					MAG	857	Plenco 1504–elect.
					MAG	1059	Synres 420–min., comp. & transf. mldg.
					MAG		Synres 422, 429–min.,comp. & transf. mldg., flame ret.
					MAI 60		Synres 446–long glass, flame ret., comp. & transf. mldg.
					MAG	1135	U.S. Poly. 3D20–min.; 3D20F–min., flame ret.–gran.,comp.,transf.mldg.
					MAI 60		U.S. Poly. 3D36–flake, hi imp., flame ret., comp., transf. mldg.
DAP MC	ASTM D1636 (type, grade and class) and MIL-M-14 (other classification)	I	A	1	GDI 30	37	Diall 28*, 52-20-30*; long glass, transf. & comp. mldg.
		I	C	1	GDI 30		Diall FS4*; long glass, heat res., transf. & comp. mldg.
		I	B	1	GDI 30 & 30F		Diall 52-40-40*; long glass, flame ret. transf. molding
		I	D	1	GDI 30 & 30F		Diall FS8O*; long glass, heat res., flame ret., transfer mldg.
		I	A	2	SDG		Diall 73-01*; med. glass, inj. & transf. mldg.
		I	A	3	SDG		Diall 52-01*; short glass, inj. & transf. mldg.
		I	C	3	SDG		Diall FS5*; short glass, heat res., inj. & transf. mldg.
		I	B	2	SDG		Diall 73-70-70*; med. glass, flame ret., inj. & transf. mldg.
		I	B	3	SDG & SDGF		Diall 52-70-70*; short glass, inj. & transf. mldg.
		I	D	2	SDG & SDGF		Diall FS40*; med. glass, heat res., flame ret., inj. & transf. mldg.
		I	D	3	SDG & SDGF		Diall FS10*; short glass, heat res., flame ret., inj. & transf. mldg.
		II	A	1	MDG		Diall 51-01*, 51-01C*, 51-01CI*; mineral inj. & transf. mldg.
		II	A	2	MDG		Diall 51-04*, 51-08*, 775*; min. & organic fibre, imp. res. inj. & transf. mldg.
		II	B	1	MDG		Diall 51-60*, mineral, flame ret., inj. & transf. mldg.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
DAP MC (Cont'd)	ASTM D1636 & MIL-M-14 (Cont'd)	II	C	1	MDG		Diall FS6*; mineral, heat res., inj. & trans. mldg.
		II	D	1	MDG		Diall FS60*; min., heat res., flame ret. inj. & transf. mldg.
		III	A	1	SDI 5		Diall 50-01*; short glass & syn. fiber, inj. & transf. mldg.
		III	A	2	SDI 30		Diall 30-51*; long glass & syn. fiber, imp. res., inj. & transf. mldg.
		III	A	3	SDI 30		Diall 50-51*; milled glass & syn. fiber, imp. res., inj. & transf. mldg.
		I	B	3		336	Durez 22761* - 1.71SG, glass, flame ret.
		I	B	3	SDGF		Durez 24776* - 1.78SG, glass, flame ret.
		II	A	1	MDG		Durez 23603* - 1.78SG, min.
		III	A	1	SDI 5		Durez 16694* - 1.31SG, acrylic
		I	A	1	GDI 30	1135	Poly-Dap 6130-long glass; 1D30HI - hi str. flake - comp., transf. mldg.
		I	C	1	GDI 30		Poly-Dap 6230-long glass, heat res., comp., transf. mldg.
		I	B	1	GDI 30F		Poly-Dap 6130F-long glass, flame ret.; 1D30HIF-hi str. flake, flame ret., -comp., transf. mldg.
		I	D	1	GDI 30F		Poly-Dap 6230F - long glass, heat res. flame ret., comp., transf. mldg.
		I	A	3	SDG		Poly-Dap 6120-sht. glass, gran., transf., inj. mldg.
		I	C	3	SDG		Poly-Dap 6220-sht. glass, gran., heat res., transf., inj. mldg.
		I	B	3	SDGF		Poly-Dap 6120F-sht. glass, gran., flame ret., transf., inj. mldg.
		I	D	3	SDGF		Poly-Dap 1M20F-sht. glass, gran., heat res., flame ret., transf., inj. mldg.
		II	A	1	MDG		Poly-Dap 6160-min., transf., inj. mldg.
		II	B	1	MDG		Poly-Dap 6160F-min., flame ret., transf., inj. mldg.
		III	A	1	SDI 5		Poly-Dap 1D40-sht. glass, orlon, imp. res., transf., inj. mldg.
		III	A	2	SDI 30		Poly-Dap 1D50-sht. glass, dacron, imp. res., transf., inj. mldg.
		I	A	1	GDI 30	1059	Synres 52-20-30-long glass, comp., transf. mldg.
		I	C	1	GDI 30		Synres FS-4-long glass, heat res., comp., transf. mldg.
		I	B	1	GDI 30 & 30F		Synres 52-40-40-long glass, flame ret., comp., transf. mldg.
		I	D	1	GDI 30 & 30F		Synres FS-80-long glass, reat res., flame ret., comp., transf. mldg.
		I	A	3	SDG		Synres 52-01 - sht. glass, comp., transf. inj. mldg.
		I	C	3	SDG		Synres FS-5-sht. glass, heat res., comp., transf., inj. mldg.
		I	B	3	SDG & SDGF		Synres 52-70-70-sht. glass, flame ret., comp., transf., inj. mldg.
		I	B	2	SDG & SDGF		Synres 73-70-70-med. glass, flame ret., comp., transf., inj. mldg.
		I	D	3	SDG & SDGF		Synres FS-10-sht. glass, heat res., flame ret., comp., transf., inj. mldg.
		II	A	1	MDG		Synres 51-01 -min., comp., transf., inj. mldg.
		II	A	2	MDG		Synres 51-04,775-min., organic fibon, comp., transf., inj. mldg.
		II	C	1	MDG		Synres FS-6-min., heat res., comp., transf., inj. mldg.
		II	D	1	MDG		Synres FS-60 -min., heat res., flame ret., comp., transf., inj. mldg.
	MIL-M-14				GDI 30	16	Acme 1-530*, 2-530*; transf. & comp. mldg.
					GDI 30 & 30F		Acme 3-1-530*,3-2-530*, transf. & comp. mldg.
					SDG		Acme 1-520*, 1-525, 2-520*; inj. & transf. mldg.
					SDG & SDGF		Acme 3-520*, 3-1-525*, 3-2-520*; inj. & transf. mldg.
					MDG		Acme 1-501*, 1-501A*, 1-510*; inj. & transf. mldg.
					SDI 5		Acme 1-503*, transf. & comp. mldg.
					SDG	949	Rogers RX-1310* short glass
					SDGF		Rogers RX-1365*, 1366*; short glass
					SDI 5		Rogers RX-1100*; orlon fld.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[c]
DAP MC (Cont'd)	MIL-M-14 (Cont'd)				GDI 30 GDI 30F SDG SDGF MDG	1046	Sumikon AM200; transf. & comp. mldg. Sumikon AM 260; transf. & comp. mldg. Sumikon AM101; inj. & transf. mldg. Sumikon AM 160, transf. & comp. mldg. Sumikon AM 301, inj. & transf. mldg.
					GDI 30 GDI 30F SDG SDGF MDG	1059	Synres 52-20-30, FS4; transf. & comp. mldg. Synres 51-40-40, FS80; transf. & comp. mldg. Synres 52-01, FS5; inj. & transf. mldg. Synres 52-70-70, 73-70-70, FS10; inj. & transf. mldg. Synres 51-01, 51-04, 775, FS6, FS60; transf. & comp. mldg.
EPOXY MC	ASTM D3013				Cell 13202–D31405FO	37	Epiall 1288BX; long glass, inj. & transf. mldg.
					Cell 14133–D21505FO	37	Epiall 1970, 1860; min. & glass, inj. & transf. mldg., encaps.
					Cell 14233–D41405FO	37	Epiall 1906; min. & glass, inj. & transf. mldg.
					Cell 14234–D31404FO D31405FO D31405F3 D41405F0	37	Epiall 1961; min. & glass, inj. & transf. mldg. Epiall 1907; short glass, heat res., inj. & transf. mldg. Epiall 2061; min. & glass, flame ret., encaps. Epiall 1908; short glass, heat res., inj. & transf. mldg.
					Cell 14235–D31305F0 D31305F0 D41305F3	37	Epiall 1914; short glass, heat res., inj. & transf. mldg. Epiall 1904; min. & glass, heat res., inj. & transf. mldg. Epiall 2004; min. & glass, flame ret., heat resis., inj. & transf. mldg.
					Cell 14435–D41404F0 D41404F3	37	Epiall 1988; long glass, flake, high imp., inj. & transf. mldg. Epiall 2088; long glass, flake, high imp., flame ret., inj. & transf. mldg.
					Cell 24133–D31304F0	37	Epiall 1950; min. & glass, encaps., inj. & transf. mldg.
					Cell 24233–D31305F3	37	Epiall 2060; min. & glass, flame ret., encaps., inj. & transf. mldg.
					Cell 24235–D41305F3	37	Epiall 2008; short glass, flame ret., heat res., inj. & transf. mldg.
					Cell 12112–D22403F2 D42103F2	812	Pacific EMC 90B1, 90B1S–min., transf. mldg., encaps. Pacific EMC 272B2–min., fast cure, transf. mldg., encaps.
					Cell 13112–D11505F2	812	Pacific EMC 91B1, 96B1–min., encaps., transf. mldg.; EMC 60B1–min., encaps., comp. mldg.
					Cell 13123–D21205F2	812	Pacific EMC 117B6–min. & glass, encaps., transf., inj. mldg.
					Cell 13124–D11505F3	812	Pacific EMC 480–min. & glass, semi-cond., encaps., transf., inj. mldg.
					Cell 14222–D21404F1	812	Pacific EMC 114B2–min. & glass, encaps., transf., inj. mldg.
					Cell 14223–D21305F1	812	Pacific EMC 117B1–min. & glass, encaps., transf., inj. mldg.
					Cell 14232–D11505F2 D11505F3	812	Pacific EMC 707, 707-1, 707-3, 708–min. & glass, encaps. transf., inj. mldg. Pacific EMC 707-4–min. & glass, flame ret., encaps., transf., inj. mldg.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Supplier, trade name[a] and grade[b]: Trade name, material grade designation and description[e]
EPOXY MC (Cont'd)	ASTM D3013 (Cont'd)				Cell 14133–D21505F0	1059	Synres 1860, 1970–min. & glass, encaps., transf., inj. mldg.
					Cell 14233–D41405F0	1059	Synres 1906–min. & glass, transf., inj. mldg.
					Cell 14234–D3140F0 D31405F0 D31405F3 D41405F0	1059	Synres 1961–min. & glass, encaps., transf., inj. mldg. Synres 1907–sht. glass, heat res., comp., transf., inj. mldg. Synres 2061–min. & glass, flame ret., encaps., transf., inj. mldg. Synres 1908–sht. glass, heat res., comp., transf., inj. mldg.
					Cell 14235–D31305F0 D31305F0 D41305F3	1059	Synres 1914–sht. glass, heat res., comp., transf., inj. mldg. Synres 1904–min. & glass, comp., transf., inj. mldg. Synres 2004–min. & glass, flame ret., comp., transf., inj. mldg.
					Cell 14435–D41404F0 D41404F3	1059	Synres 1988–long glass, comp., transf. mldg. Synres 2088–long glass, flame ret., comp., transf. mldg.
					Cell 24233–D31305F3	1059	Synres 2060–min. & glass, flame ret., encaps., transf., inj. mldg.
					Cell 24235–D41305F3	1059	Synres 2008–sht. glass, flame ret., comp., transf., inj. mldg.
	MIL-M-24325				MEG, MEH & MEI 5	37	Epiall 2008; min. & glass, flame ret., heat res., inj. & trans. mldg.
					MEC	812	Pacific EMC 707-4–min. & glass, flame ret., encaps., transf., inj. mldg.
					MEH	812	Pacific EMC 480 min. & glass, flame ret. semi-cond. encaps., transf., inj. mldg.
					GEI 5	812	Pacific EMC 66–min. & glass, flame ret., comp. mldg.
					MEC	1059	Synres 2060, 2061, encaps., inj. & transf. mldg. Synres 1904, 1906, 1907, 1908, 1914, inj. transf. & comp. mldg.
					MEG & MEH	1059	Synres 2004, 2008, flame ret., inj. & transf. mldg. Synres 1988; high imp., transf., comp. mldg.
					MEI 5	1059	Synres 2088; high imp., flame ret., transf. & comp. mldg.
					MEC	1059	Synres 2060–min. & glass, flame ret., encaps., transf., inj. mldg.
					MEC & MEE	1059	Synres 2004, 2061–min. & glass, flame ret. encaps., transf., inj. mldg.
					MEH & MEI 5	1059	Synres 2008–sht. glass, heat res., flame ret., comp., transf., inj. mldg.
					MEI 5 & MEI 20	1059	Synres 2088 long glass, flame ret., comp., transf. mldg.
					MEC	1135	U.S. Poly. E7052–min., encaps., inj. mldg.
					MEE	1135	U.S. Poly. E7001F min., flame ret., encaps., transf., inj. mldg.
					MEG & MEH	1135	U.S. Poly. E7050 min., encaps., transf., inj. mldg.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Supplier, trade name[a] and grade[b]: Trade name, material grade designation and description[e]
	MIL-M-24325 (Cont'd)				MEH & GEI 5	1135	U.S. Poly. E7032 min. & glass, heat res., transf., inj. mldg.
					GEI 5	1135	U.S. Poly. E7074, E7076, 2S20–min. & glass, heat res., transf., inj. mldg.
					GEI 20	1135	U.S. Poly. 2S30–long glass, flake, comp., transf. mldg.
					GEI 100	1135	U.S. Poly. 2S32–long glass, spheroid, comp. mldg. U.S. Poly. E7302–long glass, flake, heat res., comp. mldg.
MELAMINE MC	ASTM D704	I I				37	Plaskon MFG, MFP, TWG; comp. mldg. Plaskon MIG; inj. mldg.
	DIN 7008/3	150, 152, 156, 157				338	Ultrapas; inj. & transf. mldg. (see supplier for specific grade designations)
	Fed L-M-181	I				37	Plaskon MFG, MFP, TWG; comp. mldg. Plaskon MIG; inj. mldg.
	MIL-M-14				CMI 5 MME MMI 5 MMI 30	391	Fiberite M2015; transf. & comp. mldg. Fiberite M6204; inj. & transf. mldg. Fiberite M2840; transf. & comp. mldg. Fiberite M2880; transf. & comp. mldg.
					CMG	37	Plaskon MFG, MFP, TWG*; comp. mldg. Plaskon MIG; inj. mldg.
					CMI 5 MMI 5 MMI 30	1135	U.S. Poly. M4020 chp. cotton, comp. mldg. U.S. Poly. M4136–sht. glass, gran., comp., transf. mldg. U.S. Poly. M4136 long glass, bulk, comp., transf. mldg.
MELAMINE PHENOLIC MC	MIL-M-14				CMG	857	Plenco 701, 704, 705, 706, 709, 710, 711, 712, 713, 714, 716, 718, 732, 740, 741, 742, 744, 755, 757, 760, 762, 767, 797, 850, 852
PHENOLIC MC	ASTM D700	2			GP, wood flour	336	Durez 265 blk, 740 brn, 791 blk, 792 blk, 1898 scarlet, 13527 blk, 16038 brn, 18403 blk, 21028 blk, 21206 blk & brn, 22486, 22787 brn, 28169 blk Durez SI 11 blk; screw inj. mldg. Durez 2271 blk, 21210 blk, 21372 blk; elect. Durez 22256 blk; heat res. Durez 15528 blk, 18441 blk; single stage Durez 3948 brn, 3949 blk, 18420 blk, 23390 blk; single state, non-bleed, overlay
		2,3			GP, wood flour GP, cellulose	336	Durez 7928 blk Durez SI 18 blk; screw inj. mldg.
		3			GP, cellulose, imp.	336	Durez 1544 blk, 16378A blk, 17641 blk, 21955 blk, 22532 blk, 28650 blk Durez 22829 blk; single stage Durez SI 23 blk, SI 28 blk; screw inj. mldg.
		4			Moderate imp.	336	Durez 17156 blk, 18683 blk
		8			Very low loss, min.	336	Durez 16274 nat
		9			Heat res., min.	336	Durez 18975 brn, 23639 blk; imp. res.
		10			GP heat res., min.	336	Durez 11864 blk, 19089 blk
		11			GP wood flour, mech.	336	Durez 23654 blk & brn; single stage
		12			Shock res.	336	Durez 13124 blk, 17080 blk Durez 1900 blk, 13856 blk; single stage
		13			Low G, heat res., min.	336	Durez 1308 blk, 1328 brn, 21426 blk, 22042 blk, 22197 blk, 22262 blk, 27260 blk Durez 55 blk, single stage Durez SI 51 blk, SI 56 blk; screw inj. mldg.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification					Supplier, trade name[a] and grade[b]	
	Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
PHENOLIC MC (Cont'd)	ASTM D700 (Cont'd)	18			Heat & flame res., min.	336	Durez SI 53 blk, screw inj. mldg.
		22			Heat, flame & arc res., min	336	Durez 16090 blk, 16744 blk, 18001 blk, 18423 grn, 22065 blk Durez SI 42 blk, SI 45 blk, screw inj. mldg.
		25			Low loss, heat, flame & arc res., glass	336	Durez 23570 blk
		4			Moderate imp.	391	Fiberite FM1132P; transf. & comp. mldg
		5			Med. imp.	391	Fiberite FM7700; inj. transf. mldg.
		6			Med. high imp	391	Fiberite FM 3510; transf. & comp. mldg.
		7			Low loss, min.	391	Fiberite FM4005, inj. & transf. mldg.
		12			Shock res.	391	Fiberite FM510; inj. & transf. mldg.
		20			Heat, flame & arc res.	391	Fiberite FM11547; transf. & comp. mldg.
		21			Heat & flame res.	391	Fiberite FM8130, transf. & comp. mldg.
		25			Low loss, heat, flame & arc res.	391	Fiberite FM4004, 4005; inj. & transf. mldg.
					Types 7, 8, 10, 22 & 25; min. fld.	37	Phenall 8000, 8010, short glass, inj. & transf. mldg. Phenall 8020, 8700; glass & min., inj. & transf. mldg.
		2			GP, wood flour	857	Plenco 106, 300, 304, 307, 308, 348, 369, 386, 433, 480, 482, 503, 512, 528, 535, 544, 548, 557, 571, 585
		3			GP, cellulose, imp.	857	Plenco 503
		8			Very low loss, min.	857	Plenco 343
		9			Heat res., min.	857	Plenco 397, 407, 558
		11			GP, wood flour, mech.	857	Plenco 4541, 4542, 4543, 567
		12			Shock res.	857	Plenco 321, 331
		13			Low G, heat res., min.	857	Plenco 308, 349, 400, 414, 440, 466, 485, 527, 551
		22			Heat, flame & arc res., min.	857	Plenco 578
		2			GP wood flour	1094	Toshiba KM 13N
		3			GP, cellulose, imp.	1094	Toshiba KM 22B
		4			Moderate imp.	1094	Toshiba KM 508 (I, A, D)
		20			Heat, flame & arc res.	1094	Toshiba KM 116B
	ASTM D700 and Fed. L-P-1125	3			GP, cellulose, imp.	949	Rogers RX525, 950, 950A
		4			Moderate imp.	949	Rogers RX431; rag
		5			Med. Imp.	949	Rogers RX475, rag
		7			Low loss, min.	949	Rogers RX610N, 611, 660; short glass
		8			Very low loss, min.	949	Rogers RX610N, 611, 630; short glass
		9			Heat res., min.	949	Rogers RX-462, 467, 465, 468, 468A, 490
		10			GP, heat res., min.	949	Rogers RX465, 466, 467, 468, 468A, 610N 611, 640
		12			Shock res.	949	Rogers RX419, 448, 469, 525, 950, 950A
		19			Heat res., asb.	949	Rogers RX495

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier, trade name[a] and grade[b]: Supplier code[d]	Trade name, material grade designation and description[e]
PHENOLIC MC (Cont'd)	B.S. 771	G			GP wood flour	384	Nestorite A1–comp. mldg.; A2122–inj. mldg.
		GX			Imp. GP		Nestorite A411–comp. transf. mldg.
		HD			Hi diel., wood flour		Nestorite A1809–comp., transf. mldg.
		MS			Med. imp., cotton		Nestorite A645–comp., transf. mldg.
		MHS			Med. hi. imp. cotton		Nestorite A975–comp. mldg.
		L			Low loss, mica		Nestorite A803–comp., transf. mldg.
		LI			Low loss, nylon		Nestorite A864–comp., transf. mldg.
		L2			Low loss, nylon & cellulose		Nestorite A1587–comp., transf. mldg.
	DIN 7708/2				Types 12, 31, 31.5, 31.9, 32, 51 51.5, 51.9, 52 71, 74, 83	338	Trolitan; inj., transf. & comp. mldg. (see supplier for specific grade designations)
	ISO R 800				Grades A, B, C, D, E	338	Trolitan; inj., transf. & comp. mldg. (see supplier for specific grade designations)
	MIL-M-14				MFH	16	Acme P1000*, 1050*, 1200*, inj. & transf. mldg.
					CFG	336	Durez 13527 blk*, 15528 blk*; GP
							Durez 1308 blk*, 1328 brn*, 16744 blk; heat res.
							Durez 1544 blk*, 22532 blk*; imp.
							Durez SI 23 blk*, SI 51 blk*, SI 53 blk*, screw inj. mldg.
					CFI 5		Durez 1900 blk*, 17080 blk*, imp.
					CFI 10		Durez 17156 blk; imp.
					MFE		Durez 16274 nat*, elect.
					MFG		Durez 18975 brn*, imp.
					MFH		Durez 23570 blk*
							Durez 11864 blk*, heat res.
							Durez 18423 grn*; elect.
					CFI 5	391	Fiberite FM1914, inj., transf. mldg.
					CFI 10		Fiberite FM1132P; inj. transf. mldg.
					CFI 20		Fiberite FM3510, 7700; inj. transf. mldg.
					CFI 40		Fiberite FM9294, transf., comp. mldg.
					CFI 100		Fiberite FM8130, 4030-190; transf., comp. mldg.
					MFH		Fiberite FM4004, 4005, inj., transf. mldg.
					MFI 20		Fiberite FM11547, 17610; transf., comp. mldg.
					MFE, MFH	37	Phenall 8000, 8010, short glass, inj., transf. mldg.
							Phenall 8020, 8700, glass/min., inj., transf. mldg.
					CFG	857	Plenco 307, 368, 414, 500, 582, elect.
					CFI 5		Plenco 321; imp.
					MFE		Plenco 343; elect.
					MFG		Plenco 407, 558; imp.
					MFH		Plenco 450, 475, 552; elect.
					CFG	949	Rogers RX525*, 950*
					CFI 5		Rogers RX448*; nodul., med. imp.
					CFI 10		Rogers RX431*; nodul., med. imp.
					CFI 20		Rogers RX475*; nodul., med. imp.
					MFE		Rogers RX610N*, short glass
					MFH		Rogers RX610N, 611*, 640*, 660*; short glass
					MFG		Rogers RX466*, 467*, 468*, asbest.
					MFI 10		Rogers RX490*; asbest.
					MFI 20		Rogers RX495*, asbest.
					CFG	1046	Sumikon PM20, reinf., comp. mldg.
					CFI 5		Sumikon PM700; transf., comp. mldg.
					CFG	1094	Tecolite KM-M-22B; inj., transf. mldg.
					CFI 5		Tecolite KM-M-91N; transf., comp. mldg.
					CFI 10		Tecolite KM-M-92N, transf., comp. mldg.
Polyester (thermoset)	FDA CFR-121				Food additives Sub. F, 121.2576	475	Marco GR28C, 210 63003, 63004; resins, rm. temp. cure, thermoplastic additives, comp. mldg.
							Marco GR40R, 41R, 9520; resins, inj. & transf. mldg., no shrink
	Fed. L-P-383	I			Mat	475	Vibrin Mat G 2702; SMC, low press.

* See p. 266 for footnote references.

SPECIFICATIONS/MATERIALS CHART* (Cont'd)

Plastics and resins qualified under ASTM, ISO, Military, Federal, DIN, AMS, British Standard and other specifications. Appendix D gives numerical specification index.

Material	Specification: Designation and number[c]	Type	Grade	Class	Description or other classification	Supplier code[d]	Trade name, material grade designation and description[e]
POLYESTER (THERMOSET) (Cont'd)	Fed. GGG-H-211				Helmet & shield, welders	475	Vibrin Mat 5281F; SMC
	MIL-M-14				MAI 60	391	Fiberite S642; transf. & comp. mldg. compd.
						475	Vibrin Mat 4445RL; SMC
	MIL-T-27				Transf., ind. encaps.	418	Stypol 40-1602; resin
	MIL-R-7575				Lam. resin, low pressure	391	Fiberite S6413, S6414; transf. & comp. mldg.
			A A,B A,B A,B	1 1 2 3	Lam. resin	624	Koppers 3401–flame ret. Koppers 2000–gen. Koppers 1000–gen. Koppers 3403–flame ret.
			A,B,C			475	Marco GR28C,GR941; resin, rm. temp. cure
			A A A A	2 2 2 3		418	Stypol 40-2407; resin, GP comp. mldg. Stypol 40-2025; resin, high temp., comp mldg Stypol 40-1029; resin, low pressure lam. Stypol 73-7202; resin, flame ret., comp. mldg
	MIL-R-21607			A	Lam. resin	624	Koppers 3401, 3403–flame ret.
				A,B	Lam. resin, low press, flame ret.	475	Vibrin Mat F2700, E3000; SMC, inj., transf., comp. mldg.
	MIL-R-25042				Lam. resin, low press., high heat res.	475	Marco GR135; resin
	MIL-P-43038				Lam. resin, low press., hi temp.	418	Stypol 40-1029; resin
	MIL-P-43043				Mldg. comp., glass	475	Vibrin Mat G1600, L1703; SMC, inj., transf. comp. mldg.
	MIL-G-46905				Grommets	475	Marco GR654; resin, fil. winding
SILICONE MC	MIL-M-14				MSI 30	330	Dow Corning 302; comp. mldg.
UREA MC	ASTM D705 Fed. L-P-401	I I				37	Plaskon SMG, FCG, HGFCG, GPSMG, GPFCG, GPHG; comp. mldg. cmpds. Plaskon UIG, GPUIG; inj. mldg. cmpds.
	DIN 7708/3	131.5				338	Pollopas (see supplier for specific grade design)

* See p. 266 for footnote references.

APPENDIX D. NUMERICAL SPECIFICATION INDEX

SPECIFICATION	MATERIAL
AC Spark Plug	
DS-7454	Polyvinylidene fluoride
AEC	
NV-IC 1-8, 10	Polypropylene
NV-RF 1-3	Polypropylene
AFP	
88-007-3	Vinyl
AMS	
3628	Polycarbonate
ANS	
1—C8.35	Polyethylene
ASTM D	
700	Phenolic MC
703	Polystyrene
704	Melamine MC
705	Urea MC
706	Cellulose acetate
707	CAB
788	Acrylic
789	Nylon
1047	Vinyl
1201	Alkyd
1248	Polyethylene
1430	CTFE
1431	SAN
1457	PTFE
1547	Acrylic
1562	CAP
1636	DAP
1755	Vinyl
1784	Vinyl
1785	Vinyl
1788	ABS
1892	Polystyrene
2103	Polyethylene
2116	FEP
2133	Acetal
2146	Polypropylene
2241	Vinyl
2287	Vinyl
2464	Vinyl
2466	Vinyl
2467	Vinyl
2473	Polycarbonate
2665	Vinyl
2729	Vinyl
2740	Vinyl
ASTM D (Cont'd)	
2846	Vinyl
2848	Polycarbonate
2897	Nylon
2948	Acetal
2949	Vinyl
3011	ABS, polystyrene, SAN
3013	Epoxy MC
3033	Vinyl
3034	Vinyl
3159	PE-TFE
Automatic Electric	
5873	Polyvinylidene fluoride
British Stds.	
B.S. 771	Phenolic
Brand Rex (Amer. Enka)	
BR 212	Polyvinylidene fluoride
Chrysler Corp.	
DC 218	Vinyl
DC 232	Vinyl
DC 233	Vinyl
CS	
197	Polyethylene
227	Polyethylene
276	Vinyl
PS 21	Vinyl
PS 22	Vinyl
PS 26	Vinyl
PS 55	Vinyl
DIN	
7708	Melamine MC Phenolic MC Urea MC
7740	Polyethylene Polypropylene
7742	Cellulose acetate
7743	CAB
7744	Polycarbonate
8074	Polyethylene
8075	Polyethylene
16975	Acetal
16976	Acetal
16977	Acetal
16985	Acetal

NUMERICAL SPECIFICATION INDEX (Cont'd)

SPECIFICATION	MATERIAL
Edgewood Arsenal	
197-54-839	Vinyl
Dow-Rocky Flats	
310641-37	Polyvinylidene fluoride
FAA	
E-2072	Polyethylene
FDA	
CFR 121	Polyester (thermoset)
CFR 121.2501	Polyethylene
CFR 121.2502	Nylon
CFR 121.2597	Vinyl
CFR 121.2610	Polystyrene
CFR 121.2621	Polyphenylene sulfide
CFR 125.2502	Nylon
Federal	
L-R-335	Vinyl
L-C-770	Polystyrene
L-M-181	Melamine MC
L-P-315	Polyethylene
L-P-349	CAB
L-P-375	Vinyl
L-P-378	Polyethylene
L-P-380	Acrylic
L-P-383	Polyester (thermoset)
L-P-385	CTFE
L-P-389	FEP
L-P-390	Polyethylene
L-P-392	Acetal
L-P-393	Polycarbonate
L-P-394	Polypropylene Polyallomer
L-P-395	Nylon
L-P-396	Polystyrene
L-P-397	Cellulose acetate
L-P-398	Polystyrene
L-P-401	Urea MC
L-P-403	PTFE
L-P-410	Nylon
L-P-506	Polystyrene
L-P-507	Acrylic
L-P-512	Polyethylene
Federal (Cont'd)	
L-P-1125	Phenolic MC
L-P-1183	ABS
HH-I-524	Polystyrene
HH-I-595	Vinyl
WW-P-541	Acetal
GGG-H-211	Polyester (thermoset)
PPP-C-850	Polystyrene
Ford Motor Co.	
ESF-M4D-244	Vinyl
ESB-M4D-284	Vinyl
GM Co. (Fisher Body)	
FBMS 2-8	Vinyl
IBM	
3111	Polyvinylidene fluoride
IPCEA	
S 61-402	Polyethylene, vinyl
ISO (TC 61)	
R800	Phenolic MC
R 1874	Nylon
DIS 2580	ABS
Los Angeles, City of	
D 164-R1	Vinyl
Martin	
MMS B642	Polyvinylidene fluoride
MMS A667	Polyvinylidene fluoride
MIL	
M-14	Alkyd MC DAP MC Melamine MC Melamine phenolic MC Phenolic MC Polyester (thermoset) Silicone MC
C-17	Polyethylene, vinyl

NUMERICAL SPECIFICATION INDEX (Cont'd)

SPECIFICATION	MATERIAL
MIL (Cont'd)	
T-27	Polyester (thermoset)
W-76	Vinyl
C-572	Vinyl
I-631	Vinyl
S-676	Polystyrene
C-915	Vinyl
C-3432	Vinyl
C-3884	Vinyl
I-3930	Vinyl
I-4997	Polyurethane (t'plastic)
W-5086	Polyvinylidene fluoride, vinyl
C-5898	Polyurethane
P-6264	Vinyl
W-7072	Vinyl
C-7078	Polyvinylidene fluoride, vinyl.
I-7444	Vinyl
R-7575	Polyester (thermoset)
B-8511	Vinyl
C-9660	Polyethylene
W-11477	Acetal
C-15452	Vinyl
C-15479	Vinyl
W-16878	Polyvinylidene fluoride, vinyl
U-17336	Acetal
F-18240	Acetal
S-19015	Acetal
F-19017	Acetal
S-19114	Acetal
C-19547	Polyethylene
P-19644	Polystyrene
M-19887	Nylon
C-19978	Polypropylene
M-20693	Nylon
P-21347	Polystyrene
R-21607	Polyester (thermoset)
S-21894	Polyethylene
P-22096	Nylon
W-22759	Polyvinylidene fluoride
I-23053	Polyvinylidene fluoride
C-23437	Vinyl

SPECIFICATION	MATERIAL
MIL (Cont'd)	
P-23536	Polyethylene
M-24325	Epoxy MC
R-25042	Polyester (thermoset)
C-26861	Polystyrene
C-27072	Polyethylene, vinyl
I-28964	Acetal
C-39022	Polypropylene
P-40619	Polystyrene
P-46131	Phenylene oxide based resin
S-41821	Polyethylene
P-43038	Polyester (thermoset)
P-43043	Polyester (thermoset)
C-43103	Polyethylene
P-46074	CAP
P-46109	Polypropylene
P-46120	Polysulfone
P-46122	Polyvinylidene fluoride
P-46133	Polysulfone
P-46137	Acetal
P-46160	Polyester (t'plastic)
P-46161	Polyester (t'plastic)
G-46905	Polyester (thermoset)
B-52472	Polypropylene
C-55036	Vinyl
P-60312	Polystyrene
W-81044	Polyvinylidene fluoride
P-81390	Polycarbonate
W-81822	Polyvinylidene fluoride
NAS	
702	Vinyl
NEMA	
WC 5	Vinyl
NSF	
14	Acetal
	Nylon
	Polyester (thermoplastic)

NUMERICAL SPECIFICATION INDEX (Cont'd)

SPECIFICATION	MATERIAL	SPECIFICATION	MATERIAL
NSF (Cont'd)		UK	
14	Polyethylene	DTD 5517	PTFE
	Polyphenylene sulphide		
	Vinyl	UL	
		62	Vinyl
		83	Vinyl
REA		758	Vinyl
PE 7	Vinyl	1327	Polyvinylidene fluoride
PE 14	Polyethylene		
	Vinyl	1351	Polyvinylidene fluoride
PE 15	Polyethylene		
	Vinyl	1422	Polyvinylidene fluoride
PE 17	Polyethylene		
	Vinyl	1423	Polyvinylidene fluoride
PE 20	Vinyl		
PE 22	Polyethylene, polypropylene	1426	Polyvinylidene fluoride
PE 23	Polyethylene, polypropylene	USDA	
		Meat hooks	Acetal
PE 28	Polypropylene		
PE 38	Polyethylene	USP	
PE 44	Polyethylene	XVIII	Polypropylene
PE 50	Polypropylene		
PE 71	Vinyl	VDE, VDI/VDE	
PE 72	Vinyl	0730	Polyester (thermoplastic)
PE 200	Polyethylene		
PE 210	Polypropylene	0209-3.69	Vinyl
PE 220	Vinyl	2477	Acetal
		Western Electric Co.	
Rocketdyne		534	Vinyl
RB0-0130-062	Polyvinylidene fluoride	644	Vinyl
		750	Vinyl

EXPLANATORY NOTES ON SPECIFICATIONS/MATERIALS CHART

a Registered trade name.

b Information contained in this chart is based entirely on data submitted by suppliers of the materials listed.

c For a complete listing of military and government specifications for plastics and their applications, see PLASTEC Note 6B, revised June 1969, entitled Government Specifications and Standards for Plastics. This excellent reference, prepared by PLASTEC, Picatinny Arsenal, Dover, N. J., and available from the National Technical Information Service (NTIS), 5285 Port Royal Rd., Springfield, Va. 22151, also lists the names and addresses of the agencies responsible for preparing and revising these specifications. An updated abstract, PLASTEC Note N6C, was issued in May, 1973. Another excellent reference, which references many worldwide standards in addition to Military and US Government specifications and which is elaborately subject indexed, is National Bureau of Standards Publication 352, World Index of Plastics Standards, dated Dec., 1971, available from the Government Printing Office, Washington, D.C. 20402, Catalog No. SD C13.10.352.

Some of the agencies responsible for specifications referred to in this chart and sources of their documents are the following:

AMS – Society of Automotive Engineers, Inc., Aerospace Material Specifications, Dept. 010, 400 Commonwealth Drive, Warrendale, Pa., 15096.

ASTM – American Society for Testing and Materials, 1916 Race St., Philadelphia, Penna. 19103.

CS/PS – Commercial Standards/Product Standards; available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

Corps of Engineers – Department of the Army, Attn. ENGMC-ES, Washington, D. C. 20315.

Fed – Federal Specifications, Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19120

GSA – General Services Administration, Federal Supply Service, Washington, D. C. 20405.

ISO – International Organization for Standardization, Central Secretariat, 1, Rue de Varembe, 1211 Geneva 20, Switzerland.

Mil – (See PLASTEC Note 6B – address above).

NAS – American National Standards Institute, 1430 Broadway, New York, N. Y. 10018.

NEMA – National Electrical Manufacturers' Assn., 155 E. 44 St., New York, N. Y. 10017.

NSF – National Sanitation Foundation, P.O. Box 1468, NSF Bldg., Ann Arbor, Mich. 48106.

UK-DTD – Her Majesty's Stationery Office, York House, Kingsway, London W.C. 2, England.

UL – Underwriters' Laboratories, 1285 Walt Whitman Rd., Melville, Long Island, N. Y. 11746.

USDA – U.S. Department of Agriculture, Washington, D. C. 20250.

d Full names of material suppliers numbered in the chart will be found on page 267.

e Asterisked products are listed on the Qualified Products List of the specification for which they are listed.

APPENDIX E

MANUFACTURERS/SUPPLIERS OF MATERIALS AND EQUIPMENT LISTED IN APPENDIX C

1. AAA Plastics Equipment Co.
2. AEG Isolier-und Kunststoff GmbH
3. AFEX AG
4. AGA Corp.
5. AKU Goodrich B. V.
6. AMSCO Division, Union Oil Co. of California
7. AMUT S.p.A.
8. ARCO Chemical Co.
9. ARCO/Polymers, Inc.
10. A&S Corp.
11. A.S.C. Industries Inc.
11A. ASEA
12. Aarlite, Inc.
13. Abbott Machinery Div., U. S. Packaging Corp.
14. Aceto Chemical Co., Inc.
15. Acme Plastics Machinery Corp.
16. Acme Resin Co., Unit of CPC International
17. Adams & Associates, Inc.
18. Adams Bros. Plastic
20. Adell Plastics, Inc.
21. Adem Works
22. Advanced Machine Planning, Inc.
23. Air Products & Chemicals, Inc.
24. Air-Vac, Inc.
25. Akron Extruders, Sub. Bolton-Emerson, Inc.
26. Akzo Chemie bv
26A. Akzo Chemie GmbH (Interstab)
26B. Akzo Chemie U.K. Ltd., Interstab Div.
27. Akzo Plastics nv
28. Alambres Dominicanos C por A
29. Al-Be Industries, Inc.
30. Albis Corp.
31. Albright & Wilson, Ltd., Industrial Chemicals Division
32. Alcan Metal Powders, Div. Alcan Aluminum Corp.
33. Alchem Plastics, Inc.
34. Alcolac, Inc.
35. Alframine Corp.
36. Alliance Mold Co., Molding Equipment Div.
37. Allied Chemical Corp., Plastics Div.
37A. Allied Chemical Corp., Specialty Chemicals Division
38. Allied Color Industries, Inc.
39. Allwood Hydraulic Press Co.
40. Alnor Instrument Co.
41. Alpha-Monarch Corp.

42. Alpine American Corp.
43. Aluminum Co. of America
44. Amaco, Inc.
45. Amacoil Machinery, Inc.
45A. Amcel, Ltd.
46. Amco Plastic Processors, Inc., Colorant Div.
47. American Acrylic Corp.
48. American Barmag Corp.
50. American Chemical Corp.
51. American Cyanamid Co., Industrial Chemicals & Plastics Div.
52. American Cyanamid Co., Elastomers & Polymer Additives Dept.
53. American Cyanamid Co., Dies & Chemicals Dept.
54. American Cyanamid Co., Plastics Div.
55. American Hoechst Corp.
56. American Hoechst Corp., Film Div.
57. American Hoechst Corp., Chemicals & Plastics Div.
58. American Hydrotherm Corp., Sub. Ecological Science Corp.
59. American Instrument Co., Div. Travenol Laboratories, Inc.
60. American Insulator Corp.
61. American Packaging Corp.
61A. American Polymers, Inc.
62. American Pyroxylin Corp.
63. American Renolit Corp.
64. American Resin Corp.
65. American Stuebbe Div., Demag Plastic Machinery
67. American Thermoplastics Corp.
68. Americhem, Inc.
69. Ames, B.C., Co.
70. Ametek/Instruments and Controls
71. Ametek/Westchester Plastics
72. Amoco Chemicals Corp.
73. Amoco Chemicals Corp., Industrial Products Div.
74. Ampacet Corp.
75. Amprobe Instrument
76. An-Cor Industrial Plastics, Inc.
77. Anderson Development Co.
78. Andouart, Societe des Establissements
79. Andria Plastics Corp.
80. Ankerwerk, Div. Demag Machinery Group
81. Ankerwerk Nurnberg GmbH
82. Apache Foam Products, Div. Millmaster Onyx Corp.
83. Applied Fluidics, Inc.
84. Applied Plastics Co.
85. Applied Systems Corp.
86. Aquitaine-Organico
87. Aragon Div., Certain-Teed Machinery Corp.
88. Arapahoe Chemicals, Div. Syntex Corp.
89. Arburg Maschinenfabrik
90. Argus Chemical Corp., Halby Div.
91. Argus Chemical Corp.

92. Arkansas Co.
93. Arlon Products, Inc.
94. Armak Chemicals Div.
95. Armen, Inc.
96. Armstrong Cork Co.
97. Armstrong Products Co., Inc.
98. Aro Corp.
99. Arrow Industries Inc.
100. Artmor Plastics Corp.
101. Arvey Corp., Lamcote Div.
101A. Asahi Chemical Industries Co., Ltd.
101B. Asahi-Dow, Ltd.
101C. Asahi Glass Co., Ltd.
102. Asahi Yukiazi Kogyo Co., Ltd.
103. Ashland Chemical Co., Div. Ashland Oil & Refining Co.
104. Associated Lead Mfg., Ltd.
105. Astronautic Industries, Inc.
106. Athena Controls, Inc.
107. Atlantic Laminates, Div. Oak Industries, Inc.
108. Atlantic Powdered Metals, Inc.
109. Atlas Coatings Corp.
110. Atlas Hydraulic Div., Hussong-Walker Davis
111. Atlas Machine & Tool Corp.
112. Atlas Minerals & Chemicals Div., ESB, Inc.
113. Atlas Vac Machine Div., Planet Products Corp.
114. Autojector, Inc.
115. Automatic Packaging Machinery Co.
116. Automatic Timing & Controls, Inc.
117. Automation Devices, Inc.
118. Automation Products, Inc.
119. Auto-Place, Inc.
120. Autotron, Inc.
121. Auto-Vac Co.
122. Avecor, Inc.
123. Aviaplastique, S.A. (KAP)
124. Avnet Machinery, Div. Avnet, Inc.
125. Avnet Shaw Div., Avnet, Inc.
126. Axel Plastics Research Laboratories, Inc.
127 Aztec Chemicals, Div. Dart Industries, Inc.
128. BASF Canada, Ltd.
129. BASF Wyandotte Corp.
130. BASF AG
131. B.B.I., Inc.
132. BP Chemicals International, UK Plastics Dept.
134. Babcock & Wilcox Co., Refractories Div.
135. Bailey, J. W., Machinery, Ltd.
136. Bakelite, La
137. Bakelite Xylonite, Ltd.
138. Baker Castor Oil Co., Product Development
139. Baker Perkins, Inc.

140. Barber-Colman Co., Industrial Instruments Div.
141. Barnes Engineering Co.
142. Barr Polymer Systems, Inc.
143. Battenfeld Corp. of America
144. Bausano & Figli
145. Baychem Corp., Verona Div.
146. Bayer AG
147. Beckman Instruments, Inc.
148. Beetle Plastics, Inc.
149. Bekum Maschinenfabriken GmbH
150. Belding Chemical Industries.
151. Beloit Corp., Plastics Machinery Div.
152. Berdon, Inc.
153. Berges, C. W., Machinenfabrik
154. Bernel Foam Products Co.
155. Berstroff, Hermann, Maschinenbau GmbH (Transmares Corp., U.S. Rep)
156. Betol Machinery, Ltd.
157. Bielloni Construzioni Italiane
158. Billion S.A.
159. Bin-Dicator Co.
160. Bipel International, Inc., (Sales Ramco)
161. Black Clawson Co., Dilts Div.
162. Blane Chemical Div., Reichhold Chemicals, Inc.
163. Bleiberger Bergwerks Union
164. Bogert Machine Corp. (U.S. Rep. for Mauser KG)
165. Bohme, Dr. Th., KG
166. Bolling, Stewart, & Co., Div. Intercole Automation, Inc.
167. Bolton-Emerson, Inc.
168. Bone Cravens, Ltd.
169. Borden Chemical Corp., Thermoplastic Div.
170. Borden Chemical, Div. Borden Inc.
171. Borg-Warner Corp., Chemicals-Plastics
172. Boron Oil Co.
174. Brabender, C.W., Instruments, Inc.
175. Bradley & Turton, Ltd.
176. Brandenburger, Joachim, Spezialmaschinenbau
177. Brandywine Fibre Products Co.
178. British Celanese, Ltd.
179. British Industrial Plastics, Ltd., Engineering Div. (U.S. sales rep. Ramco Ind.)
180. British Oxygen Chemicals, Ltd.
181. Brookfield Engineering Laboratories, Inc.
182. Brooks Instrument Div., Emerson Electric Co.
183. Brown Machine Div., Koehring Co.
184. Brown Plastics Engineering Co., Inc.
185. Brummer & Co. (Diamat)
186. Brunswick Corp., Technical Products Div.
187. Bucher-Guyer, Ltd.
188. Buckman Laboratories International, Inc.
189. Budd Co./Polychem Div.

189A. Budd. Plastic Products Div.
190. Buhler Bros. (England), Ltd.
191. Bulova Watch Co.
192. Butler Mfg. Co., Salina Div.
193. CDI Dispersions
195. CIBA-GEIGY Marienberg GmbH
196. CIBA-GEIGY Corp., Polymer Additives Dept.
197. CIBA-GEIGY Corp., Plastics & Additives Div.
198. CIBA-GEIGY (UK) Ltd.
199. CIBA-GEIGY Ltd., Plastics Dept.
200. CTL-Dixie, Inc.
201. Cabot Titanita, Inc., Cabot Corp.
202. Cadillac Plastics & Chemical Co.
203. Califoam Div., Mobay Chemical Co.
204. Callery Chemical Co., Div. Mine Safety Appliances Co.
205. Cambridge Industries Co.
206. Canadian Industries, Ltd., Industrial Chemicals Div.
207. Canada Machinery Corp.
208. Canrad Hanovia Industries, Inc.
209. Caradco Div., Scovill Mfg. Co.
210. Carborundum Co.
211. Cardinal Chemical Co.
212. Carlon, an Indian Head Co.
213. Carolina Color Corp.
214. Carpenter, E. R., Co.
215. Carus Chemical Co., Inc.
216. Carver, Fred S., Inc.
217. Castall, Inc.
218. Celanese Piping Systems, Inc.
219. Celanese Plastics Co.
221. Cement Asbestos Products Co.
222. Certain-Teed Products Corp., Plastic Div.
223. Chase Chemical Corp.
225. Chemanox, Inc.
225. Chemetron Corp., Inorganic Chemicals Div.
226. Chemetron Corp., Organic Chemicals Div.
227. Chemetron Corp., Pigments Div.
228. Chemical Farmaceutici S.p.A.
229. Chemical Development Corp.
230. Chemical Products Corp.
231. Chemical Sales Co.
232. Chemische Werke Huls AG
233. Chemplex Co.
234. Chevron Chemical Co.
234A. Chisso Corp.
235. Chroma Corp.
236. Cincinnati Development & Mfg. Co.
237. Cincinnati Milacron Austria GmbH
238. Cincinnati Milacron Chemicals, Inc.
239. Cincinnati Milacron, Plastics Machinery Div.

240. Cities Service Co.
241. Cities Service Co., Plastics Div.
242. Claremont Polychemical Corp.
243. Clifton Hydraulic Press Co.
244. Clopay Corp.
245. Clow Corp., Plastics Div.
246. Colonial Kolonite Co.
248. Color Chip Corp.
249. Colorco, Inc.
251. Comet Industries, Inc.
252. Commerical Solvents Corp.
253. Compo Industries, Inc.
254. Conair, Waeschle Systems, Inc.
255. Conap, Inc.
257. Conoco Chemicals, Div. Continental Oil Co.
258. Conolite Div., Woodall Industries, Inc.
259. Conrac Corp., Cramer Div.
260. Consoweld Corp.
261. Construcciones Margarit S.L.
262. Continental Oil Co.
263. Continental Plastics Industries, Inc.
264. Control Process, Inc.
265. Cooke Color & Chemical Div., Reichhold Chemicals, Inc.
267. Cosden Oil & Chemical Co.
267A. Cosmo Plastics Co.
268. Cosmoplastics S.R.L.
268A. Cottrell Paper Co., Inc.
269. Covema Plastics Processing Machinery, Covema SRL
270. Coz Chemical Co., Div. Allied Products Corp.
271. Cresline Plastics Pipe Co., Inc.
272. Crest-Foam Corp.
273. Crimsco, Inc.
274. Crompton & Knowles Corp., Chemicals Group
275. Crompton & Knowles Corp., Plastics Color Div.
275A. Crown Engineered Materials, Div. Crown-Line Plastics, Inc.
276. Crown Products Corp.
277. Crown Zellerbach Corp.
278. Cupples Coiled Pipe, Inc.
279. Curry Arts Molding & Laminating Co.
280. Curtin-Herbert Co.
281. Curwen & Newbery, Ltd.
282. Custom Chemicals Co., Inc.
283. Customcolor, Inc.
284. Custom Compounding Corp.
285. Custom Machine Design Corp.
285A. Custom Resins Inc.
286. DSM
286A. Dai Nippon Ink & Chemical Inc.
287. Dai Nippon Tokyo Co.
288. Daicel, Ltd.

289. Daikin Kogyo Co., Ltd.
290. Dake Corp.
291. Daniels Hamilton, Ltd.
292. Danly Machine Corp.
293. Danson Corp., Ltd.
294. Dart Industries Inc., Chemical Group
297. Davies Nitrate Co.
298. Davis, Frank D., Co., Sub. Rockwood Industries, Inc.
299. Davis Meter & Supply Co.
300. Davis-Standard/Goulding/Hobbs Div., Crompton & Knowles Corp.
301. Dayco Corp., Packaging Film Div.
302. Day-Glo Color Corp.
303. DeBell & Richardson, Inc.
304. Decar Plastics Corp.
305. Decor Laminates, Inc.
306. Deelite Blacklite Corp.
307. Deerfield Plastics Co., Inc.
308. DeGussa, Inc.
309. Dekoron Div., Samuel Moore & Co.
310. Delavan Mfg. Co.
312. Delta-Chicago Inc., Clad Rex Div.
313. Demag Kunstsofftechnik GmbH
314. Denki Kagaku Kogyo K.K.
315. Design Center, Inc.
316. Devcon Corp.
317. Dew-Foam Industries
318. Di-Acro, Div. Houdaille Industries, Inc.
320. Diamond Shamrock Chemical Co., Plastics Div.
320A. Dia-Premix Co., Ltd.
321. Dillon, W. C., & Co.
322. Dimensional Pigments, Inc.
323. Ditron, S.R.L.
324. Dixon Corp.
324A. Dodge Fluorglas, Dodge Industries Inc., Oak Materials Group
325. Dohrman Envirotech
325. Dolci, Ing. L., S.p.A
327. Donray Products Co.
328. Double A Products Co., Sub Brown & Sharpe Mfg. Co.
329. Dover Chemical Corp.
330. Dow Chemical Corp.
331. Dow Corning Corp.
332. Drabert Sohne, Mashinenfabrik
332A. Drainage Engineering Co.
333. Drouet-Diamond
334. Dunning & Boschert Press Co.
335. du Pont, E.I., de Nemours & Co., Inc.
335A. du Pont, E.I., de Nemours & Co., Inc., Film Div.
335B. du Pont, E.I., de Nemours & Co., Inc., Textile Fibers Div.
336. Durez Div., Hooker Chemical Co.
337. Dynachem Corp.
338. Dynamit Nobel AG

339. Dyanmit Nobel of America, Inc.
340. Dynisco
341. EG & G, Cambridge Systems
342. Eagle-Picher Industries, Inc.
343. Eagle-Picher Industries, Inc., Chemicals & Fibers Div.
344. Eagle Signal, a Systems Div. G & W Industries
345. East Coast Chemicals Co.
346. Eastman Chemical Products
347. Egan Machinery Co.
349. Electric Trading Co.
350. Electro-Flex Heat, Inc.
351. Electro-Mechano Co.
352. Emerson & Cuming, Inc.
353. Emser Werke AG
354. Emery Industries, Inc.
355. Engle, Ludwig, KG
356. Engineering Plastics, Inc.
356A. Engineering Plastics, Ltd.
357. Engineering Plastic Machinery Co.
358. Enka Glanzstoff Plastic NV, Engineering Plastics Dept.
359. Erie Foundry Co.
360. Eronel Industries
361. Esgo Plastics Machinery, Ltd.
361A. Essex International Inc., Copolymer Products
362. Essex Wire Corp.
362A. Ethyl Corp., Industrial Chemicals Div.
363. Ethyl Corp., Polymer Div.
364. Eurotherm Corp.
365. European Plastic Machinery Mfg. Co.
366. Evans Chemetics, Inc.
366A. Ex-Cell-O
367. Extruders, Inc.
368. Extrudyne Co.
369. Exxon Chemical Co. U.S.A., Film Div.
370. Exxon Chemical Co. U.S.A., Plastics Lab.
371. FMC Corp., Industrial Chemicals Div.
372. FMC Corp., Packaging Machinery Div.
373. FMC Corp., Parts & Materials Handling Div.
374. Fabricon Products, Div. Eagle-Picher Industries, Inc.
375. Fahr Bucher GmbH
376. Fairmount Chemical Co.
377. Famco Plastics Mfg. Co., Div. Familian Corp.
378. Farbwerke Hoechst AG
379. Farrel Co., Div. USM Corp.
380. Fast Heat Element Mfg. Co.
380A. Federal Mogul Corp., Colonial Plastics Div.
381. Fellows Corp.
382. Felten & Guilleaume Dielektra AG
383. Fenwal, Inc.
384. Ferguson, James, & Sons, Ltd.
385. Ferro Corp., Color Div.

386. Ferro Corp., Composites Div.
386A. Ferro Chemical, Div. of Ferro Corp.
387. Ferry Machine Co.
388. Fibco Plastics, Inc.
389. Fibercast Co., Div. Youngstown Sheet & Tile Co.
390. Fiberfil Div., Dart Industries, Inc.
391. Fiberite Corp.
392. Fincor Div., North American Rockwell
393. Fine Organics, Inc.
394. Firestone Plastics Co., Div. Firestone Tire & Rubber Co.
395. Firestone Synthetic Fibers Co.
396. Firestone Synthetic Rubber & Latex Co.
397. Fischer Blow Molding Equipment
398. Fischer & Porter Co.
399. Fischer Scientific Co.
399A. Fischer-Voith Plastics Machines, Inc.
400. Fjellman American, Inc.
401. Flexible Products Co.
402. Flexiplast, Inc.
403. Flex-O-Glass, Inc., Plastics Div.
404. Flintkote Co.
405. Florin, Ltd.
406. Fluidyne Instrumentation
407. Fluorocarbon Co.
408. Ford Motor Co., Paint & Vinyl Operations
409. Formica Corp.
410. Formica, Ltd.
411. Fortin Laminating, Div. Monogram Industries, Inc.
412. Fortin Plastics, Inc.
413. Foster Grant Co.
414. Fostoria-Fannon, Inc.
415. Foxboro Co.
416. Fox Valve Development Co.
417. Franklin Fibre-Lamitex Corp.
418. Freeman Chemical Corp., Sub. H. H. Robertson Co.
419. French Oil Mill Machinery Co.
420. Fried Novelties
421. Frieseke & Hoepfner GmbH
422. Frilvam S.p.A.
423. Froendenberger Maschinen & Apparatebau GmbH
423A. Fudow Chemical Co.
424. Fuller Co.
425. Furane Plastics, Inc.
426. Furukawa Electric Co.
427. GAF Corp.
428. G.B.F. Costruzioni Meccanische S.p.A.
429. GKN Winder Ltd.
431. GSE, Inc.
432. Gammaflux, Inc.
433. Garden State Chemical
434. Gardner Laboratory, Inc.

435. Gart Mfg. Co.
436. Gelman, Herman A., Co.
437. Gem-O-Lite Plastics Corp.
438. General Color Co., Div. H. Kohnstamm Co.
439. General Engineering Co.
440. General Electric Co., Industrial Control Products Div.
441. General Electric Co., Industrial Sales Div.
442. General Electric Co., Insulating Materials Dept.
443. General Electric Co., Laminated Products Dept.
444. General Electric Co., Engineering Polymers Product Dept.
444A. General Electric Co., Plastics Div.
444B. General Electric Co., Noryl Operations
445. General Electric Co., Silicone Products Dept.
445A. General Electric Plastic NV
446. General Foam Plastics Corp.
446A. General Industries Co.
446B. General Instrument Corp., Semi Conductor Div.
447. General Mills Chemicals, Inc.
448. General Plastics Corp.
449. General Plastics Mfg. Co.
450. General Tire & Rubber Co., Chemical Plastics Div.
451. Gentran, Inc.
452. Getty Machine & Mold, Inc.
453. Gifford-Hill Co., Inc.
455. Gilman Bros. Co.
456. Glamorgan Pipe & Foundry Co.
457. Glassoloid Plastics, Inc.
458. Glastic Corp.
459. Glidden Pigments, SCM Corp.
460. Glitterex Corp.
461. Global Process Equipment, Inc.
462. Gloucester Engineering Co., Inc.
463. Gluco
464. Glyco Chemicals, Inc.
465. Gold Leaf & Metallic Powders, Inc.
466. Goodrich, B. F., Chemical Co.
467. Goodyear Aerospace Corp.
469. Goodyear Tire & Rubber Co., Chemical Div.
469A. Gould Inc., Electric Motor Div.
470. Grace, W. R., & Co., Construction Products Div.
471. Grace, W. R., & Co., Cryovac Div.
472. Grace, W. R., & Co., Davison Chemical Div.
473. Grace, W. R., & Co., Ellay Rubber Div.
474. Grace, W. R., & Co., Hatco Chemical Div.
475. Grace, W. R., & Co., Marco Chemical Div.
476. Graham Engineering Corp.
477. Great Lakes Chemical Corp.
478. Great Lakes Foundry Sand Co., Mineral Products Div.
479. Guardian Chemical Corp.
479A. Guardian Electric Mfg. Co.

480. Gulf Oil Chemicals Co., Gulf Adhesives
481. Gulf Oil Chemicals, Plastics Div.
482. Gyromat Corp.
483. HITCO, Defense Products Div.
484. Haake, Inc.
485. Hall, C. P., Co.
486. Hallikainen Instruments
487. Hammond Plastics, Inc.
489. Harrel, Inc.
490. Harshaw Chemical Co., Div. Kewanee Oil Co.
491. Harte & Co., Inc., Sub. Diamond Shamrock Corp.
492. Harvey Hubbell, Inc., Plastics Div.
493. Harwick Chemical Corp.
494. Hasting Plastics, Inc.
495. Haveg Industries
495A. Hawley Products Co.
496. Haysite Div., Synthane-Taylor Corp
497. Hayssen Mfg. Co.
498. Heath Tecna Corp., Precision Structures Div.
499. Heil Process Equipment Corp.
499A. Helman Co., E. Div. U.S. Industries Inc.
500. Henkel, Inc., Chemical Specialties Div.
501. Henkel International GmbH
502. Herbert Associates, Ltd.
503. Herbert Machine Tools, Ltd.
504. Hercules, Inc.
507. Hightemp Resins, Inc.
508. Hillard Industries, Inc.
509. Hills-McCanna Div., Pennwalt Corp.
510. Hills-Davis Chemical Co.
511. Hitachi Chemical Co., Ltd.
512. Hobbs Mfg. Co., Davis Standard Div.
513. Hobbs-Williams Machinery, Ltd.
514. Hoke, Inc.
516. Hommel, O., Co.
517. Honeywell, Apparatus Controls
518. Honeywell, Industrial Div.
519. Hooker Chemical Corp.
521. Hoover Ball & Bearing Co., Uniloy Div.
522. Hoover Ball & Bearing Co., Reynolds Chemical Products Div.
523. Horton Hydraulics, Div. Edward Horton Co.
524. Houghton, E. F., & Co.
525. Howard Industries, Inc.
526. Howe Industries, Inc.
527. Howell Industries, Inc.
528. Hull Corp.
529. Humphrey Chemicals Corp.
530. Hunkar Laboratories, Inc.
531. Hupfield Bros.
532. Husky Injection Molding Systems, Ltd.

533. Hydrates, Inc.
534. Hydrodynamics, American Instruments Co., Div. Travenol Lab, Inc.
535. Hysol Div., Dexter Corp.
535A. IBM
536. ICI America, Inc.
536A. ICI Lankro Plasticizers Ltd.
537. ICI Ltd., Plastics Div.
538. IRIS Corp., Sub American Silk Label Mfg. Co.
539. ITT Thompson, Plastics Div.
540. ITT Vulcan Electric
541. Idemitsu Petrochemical Co.
542. Identification Service Corp.
544. Ikegai Iron Works, Ltd.
546. Illig, Adolf, Maschinenbau
547. Ingersoll-Rand/Negri Bossi Div.
550. Incoe Corp.
551. Indev, Inc.
552. Indol Chemical Co.
553. Indussa Corp.
554. Industrial Chemical & Dye Co., Inc.
554A. Industrial Dielectric Inc.
555. Industrial Nucleonics Corp.
556. Industrial Plastic & Bearing Sales Div.
557. Industrial Plastic Fabricators, Inc.
558. Industrial Temperature Control Co.
559. Industrial Timer Corp.
560. Industrie-Werke Karlsruche A.G., Packaging Machinery Div.
561. Infra Systems, Inc., Sub. Industrial Nucleonics
562. Infrared Industries, Inc., Electronics
563. Inmont Corp.
564. Insulating Fabricators of New England, Inc.
567. International Foam Div., Holiday Inns of America, Inc.
568. International Industrial Products Corp.
569. Interox Chemicals, Ltd.
570. Interplastics Corp., Commerical Resins Div.
571. Interstab, Ltd.
572. Ionac Chemical Co., Div. of Sybron Corp.
573. Ircon, Inc.
574. Ishihara Sangyo Kaisha Ltd., International Sales Dept.
575. Ishikawajima-Harima Heavy Industries Co., Ltd., Industrial Machinery Div.
576. Island Co.
577. Isochem Resins Co.
578. Isola S.p.A.
579. Isola Werke AG
580. Iten Fibre Co.
581. Jaco Mfg. Co.
582. Jamieson Laboratories
582A. Japan Interstab Ltd.
583. Japan Steel Works, Ltd.
584. Jarecki Corp.

585. Jefferson Chemical Co., Inc.
586. Jeffrey Mfg. Co.
587. Jet Stream Plastics, Ralph Jones Co.
588. Joanna Western Mills Co., Plastic Fabric Div.
589. Johns-Manville
590. Johnson Plastics Machinery Div., Leesona Corp.
591. Jomar Industries, Inc.
592. Jordon Controls, Inc.
593. Jordon Valve Div., Richards Industries, Inc.
594. Kalle Aktiengesellschaft
595. Kanegafuchi Chemical Industries Co., Ltd.
596. Kard Corp.
597. Kato-Riki Mfg. Co.
598. Kaufman SA
599. Kautex Machines, Inc.
599A. Kawaguchi Ltd.
600. Kayeness, Inc.
601. Kay-Fries Chemicals, Inc.
603. Keil Chemical Co.
604. Kelley-Pickering Chemical Corp.
605. Kenrich Petrochemicals, Inc.
606. Kenro Corp.
607. Kent Cambridge Instrument Co., Div. Kent Cambridge Corp.
608. Kent Machine Co., Div. Lamson & Sessions Co.
609. Kerona, Inc.
610. Kerona Plastics Extrusion Co.
611. Kerr-McGee Chemical Corp.
612. Kiefel GmbH
613. Killion Extruders, Inc.
614. Kleen Chemical Mfg. Co.
615. Kleinewefers Industrie-Companie GmbH
616. Klockner-Moeller GmbH
617. Knox, Inc., Controls Div.
618. Koch, H., & Sons Inc.
619. Koehring Co., HPM Div.
619A. Koehring Co., Prodex, HPM Div.
620. Kohler General, Inc.
621. Kohnstamm, H., & Co.
622. Kohnstamm Co., Ltd.
623. Kontrols, Inc.
624. Koppers Co., Organic Materials Div.
625. Kornylak Corp.
626. Kras Corp.
627. Krauss & Lensing GmbH
628. Krauss-Maffei Corp.
629. Kreier, George, Jr., Inc.
630. Kristal Kraft, Inc.
631. Kroll Equipment Co.
632. Kronos Titan-GmbH
632A. Kronos SA/NV (Belgium), Sub. NL Industries

632B. Kronos Titan A/S (Norway), Sub. NL Industries
633. LFE Corp., Process Controls Div.
634. LNP Corp.
635. Laminations, Inc.
636. Landers-Segal Color Co.
637. Land Instruments, Inc.
638. Landis & Gyr, Inc.
639. Lankro Chemicals, Ltd.
639A. Lasco Industries
640. Latex Fiber Industries
641. Lati Industria Thermoplastica S.p.A.
642. Lawter Chemicals, Inc.
643. Lawton, C.A., Co.
644. Leader, Denis, Ltd.
645. Leathertone, Inc.
646. Leeds & Northrup Co.
648. Leopold Co.
649. Leslie Co.
650. Lester, Gerd, Corp.
651. Lester Engineering Co.
652. Lewis, J. P., Co.
653. Lewis, G. B., Co.
654. Lewis Welding & Engineering Corp.
656. Lion Precision Corp.
657. Liquid Nitrogen Processing Corp.
658. Lithium Corp. of America, Sub. Gulf Resources & Chemical Corp.
659. Lonza, Inc.
661. Love Controls Corp.
662. Lowey, Gene, Inc.
664. Lucther Instruments
665. Lumar Optical Mfg. Co., Inc.
666. Lumeca, S. A.
667. Lunn Laminates, Inc.
668. MAS S.p.A.
669. MEK Chemical Co., Inc.
670. M & N Modern Hydraulic Press Co.
671. M & Q Plastics Products
672. M R Plastics & Coatings, Inc.
673. M-R-S- Chemicals, Inc.
674. M & T Chemicals, Inc., Sub. American Can Co.
674A. M & T Chemicals Inc., Apogee Products
675. Machine Factory & Foundry Netstal, Ltd.
676. Machine Tool Works, Oerlikon Buhrle Ltd.
677. Mallinckrodt Chemical Works
677A. Manning Paper Div., Hammerhill Paper Co.
678. Marblette Corp.
679. Margolis, A., & Sons
680. Marine Plastics, Div. Northern Petrochemical Co.
682. Marlin Mfg. Corp.
683. Mannesnann-Meer AG

684. Marplex, W. M. F., a Hitco Co.
685. Marschall Div., Miles Laboratories, Inc.
686. Masonite Corp.
687. Matsuda Seisakusho Co.
688. Matsushita Electric Works, Ltd., Plastics Molding Div.
689. Matrix Controls Co.
690. May & Baker, Ltd.
691. Maynard Plastics, Inc., Div. Chelsea Industries
693. McKesson Chemical Co.
695. McNeil-FEMCO-McNeil Corp.
696. Mearl Corp
697. Mecha Design, Inc.
698. Meiwa Kasei KK
700. Mereco Products
701. Metrix Chemical Co.
702. Merck Chemical Div., Merck & Co.
703. Metalmeccania Plast S.p.A.
704. Mica Corp.
705. Michel, M., & Co., Inc.
706. Michigan Chemical Corp.
707. Michigan Chrome & Chemical Co.
708. Midland-Ross Corp., Hartig-Machinery Div.
708A. Midland Ross Corp., Unit Plastics Div.
709. Midwest Mfg. Corp.
710. Miljac, Inc.
711. Miller, Harry, Corp.
712. Millmaster Onyx Corp.
714. Mitsubishi Gas Chemical Co.
715. Mitsubishi Monsanto Chemical Co.
716. Mitsubishi Plastics Industries, Ltd.
717. Mitsubishi Rayon Co.
718. Mitsui Petrochemical Industries, Ltd.
718A. Mitsui Toatsu Chemicals, Inc.
719. Mobay Chemical Co., Div. Baychem Corp.
720. Mobil Chemical Co., Films Dept.
722. Mobil Chemical Co., Industrial Chemicals
723. Mobil Oil Corp.
724. Modern Controls, Inc.
725. Modern Plastics Machinery Corp., Injection Molding Div.
726. Moi (Packaging Industries Sales Corp. - U.S. rep)
727. Mokon Div., Protective Closures Co.
728. Molded Fiber Glass Co.
729. Molex Products Co.
730. Monitor Equipment Corp.
731. Monitor Mfg., Inc.
732. Mono-Sol Div., Chris Craft Industries, Inc.
733. Montrose Chemical Div., Sobin Chemicals, Inc.
734. Mooney Chemicals, Inc.
735. Moore & Munger, Inc.
736. Monmouth Plastics, Inc.
738. Monsanto Industrial Chemicals Co.

739. Montedison S.p.A.
739A. Monti & Martini S.p.A.
739B. Morrell, Goerge, Corp.
740. Morgan Industries, Inc.
741. Morris Enterprises
742. Morrison Industries, Inc.
742A. Morrison Molded Fiber Glass Co.
743. Morton Chemical Co., Div. Morton-Norwich Products, Inc.
744. Moslo Machinery Co.
745. Motion Indicating Devices, Inc.
746. Mount Vernon Mills, Inc.
747. Mycalex, Div. Spaulding Fibre Co., Inc.
748. N L Industries, Industrial Chemicals Div.
749. N L Industries, Titanium Pigments Div.
750. NRM Corp., Sub. Condec Corp.
750A. N V Chemische Fabriek v/h Dr. A. Haagen
751. N V F Co., Molded Products Div.
751A. N V F Co., Technical Products Div.
752. National Automatic Tool Co.
753. National Industrial Chemical Co.
754. National Tel-Tronics Div., Eastern Air Devices Co.
755. Natvar Corp.
757. Nelmore Co., Inc., Sub. Entwistle Co.
758. Neville Chemical Co.
759. Neville-Synthese Organics, Inc.
760. New Arden Chemical Corp.
761. New Britain Plastics Machine Div., Litton Industrial Products, Inc.
762. New England Butt Co., Div. Wanskuck Co.
763. New England Plastics Corp.
764. Newbury Industries, Inc.
765. New England Laminates Co., Inc.
766. New Jersey Zinc Co., a Gulf & Western Co.
767. Nichem
767A. Nicolet Industries, Inc.
767B. Nippon Steel Chemical Ltd.
768. Nippon Zeon Co., Ltd.
769. Nissei Plastics Industrial Co.
769A. Nitto Electric Industries Co., Ltd.
770. Nopco Chemical Div., Diamond Shamrock Chemical Co.
771. Norac Co., Inc.
772. Norcross Co.
773. Nordberg Machinery Group, Rexnord Inc.
774. Nordisk Elisolation AB
774A. Normandy Products Co.
775. Norplex Div., Universal Oil Products
776. Norse Laboratories
778. Northern Petrochemical Co.
779. Northland Plastics, Inc.
780. Norton Co., Plastics & Synthetics Div.
781. Norton Laboratories, Inc.

782. Noury Chemical Corp.
783. Nourgy & van der Lande NV
784. Nouvelle Mapre S.A.
785. Novamont Corp.
787. Nupla Corp.
788. Nylene Corp.
789. Nylon Engineering, Inc.
790. Nypel, Inc.
791. Officine Meccaniche Veronesi
792. Ogden Sales, Inc.
794. Olin Corp., Chemical Div.
795. Olin Corp.
796. Olin Corp., Plastics Div.
797. Olympia Tool & Machine Co.
798. Omega Engineering, Inc.
799. Opticon Chemical, Div. Dynalysis Inc.
800. Optimum Machinery Sales, Ltd.
801. Orbit, Inc.
802. Orbitex, Inc.
803. Ore & Chemical Corp.
805. Osaka Soda Co.
806. Osborn Mfg. Corp.
806A. Otalite Co., Ltd.
807. Owens-Corning Fiberglas Corp.
808. PFD/Penn Color, Inc.
809. PPG Industries, Inc., Chemical Div.
810. PPG Industries, Inc., Coating & Resins Div.
811. PVO International, Inc.
811A. Pacific Plastic Pipe Co.
812. Pacific Resins & Chemicals, Inc., Plastics Div.
812A. Pacific Vegetable Oil Corp.
813. Package Machinery Co., Reed-Prentice Div.
814. Packaging Industries Sales Corp.
815. Pak-A-Matic Equipment, Ltd.
816. Pall Corp.
817. Pan Chemical Corp.
818. Pantasote Co.
819. Paramount Industries, Inc.
820. Parnall & Sons, Ltd.
822. Partlow Corp.
823. Pasadena Hydraulics, Inc.
824. Passaic Color & Chemical Co.
825. Pathex (Canada) Ltd.
827. Pearsall Chemical Co.
827A. Peerless Plastics, Inc.
828. Pelron Corp.
829. Pemco Products, SCM Corp.
830. Penick, S. B., & Co., Parsons-Plymouth Chemical Group
831. Pennsylvania Industrial Chemical Corp.
832. Pennwalt Corp., Harchem Div.

833. Pennwalt Corp., Lucidol Div.
834. Pennwalt Corp., Plastics Dept.
835. Penreco, Inc., Div. of Pennzoil Co.
836. Permali, Inc.
837. Perstorp AB Fack, Industrial Products Div.
839. Pfizer Inc., Special Chemicals Dept.
840. Pfizer Inc., MPM Div.
841. Philadelphia Gear Corp.
842. Philadlephia Quartz Co.
842A. Philips, NV
843. Phillips Petroleum Co.
843A. Phillips Products Div., Phillips Petroleum Co.
844. Photobell Co., Inc.
845. Pierrefitte-Auby S.A.
846. Pigment Dispersion, Inc.
847. Plamvo GmbH
848. Plastex Co., Div. Standard Oil of Ohio
849. Plastics Equipment & Assessories Co., Ltd.
850. Plastic Fabrication, Inc.
851. Plastics Laminating Corp.
852. Plastic Molders Supply Co.
857. Plastics Engineering Co.
858. Plasticolors, Inc.
860. Plastifoam Corp.
861. Plastigage Corp.
862. Plastimac s.r.l.
863. Plastimation, Inc.
864. Plastimer, S.A.
865. Plasti-Vac, Inc.
866. Plastomer Corp.
867. Plumb Chemical Corp.
868. Podell Industries, Inc.
869. Poloron Products, Inc.
870. Polychemical Co., Ltd.
871. Poly Foam, Inc.
871A. Polygon Co., Div. Plas-Steel Products Inc.
872. Poly-Plax Films, Inc.
872A. Polychemicals, Div. of Stepan Chemical Co.
873. Polychrome Dispersions, Inc.
874. Polymer Corp. Polypenco Div.
875. Polymer Dispersion Industries.
876. Polymer Machinery Corp.
877. Polyplastex United, Inc.
878. Polyplastics Co., Ltd.
879. Polysar Plastics, Inc.
880. Polytex Industrial Finishes Corp.
881. Polytherm Plastics, Div. Polysar Plastics, Inc.
882. Porter, H. K. Co.
883. Potters Industries, Inc.
884. Power Instrument & Control Supply Corp.

885. Precision Laminates Corp.
886. Precision Polymers, Inc.
887. Premier Thermo Plastics Co.
888. Premix, Inc.
890. Price-Driscoll Corp.
891. Prideaux, Don, & Assoc.
892. Princo Instruments, Inc.
895. Products & Systems Mfg. Co.
895A. Pultrusions Corp.
896. Purethane Div., Easton RS Corp.
897. Pylam Products Co.
898. Pyrometer Instrument Co.
899. Pyro-Serv Instrument Co.
900. Quaker Oats Co., Chemicals Div.
901. Quinn, K. J., & Co.
902. RdF Corp.
903. RPM Sales, Inc.
903A. Radiation Technology, Inc.
904. Rainer Plywood Co.
905. Rainville Co.
906. Ram Chemicals
908. Raybestos Manhattan, Inc., Equipment Sales Div.
909. Raychem Corp., Plastics & Chemicals Div.
911. Reed Plastics Corp.
912. Reeve Electronics, Inc.
913. Reeves Bros., Inc.
914. Reeves Bros. Canada, Ltd.
916. Refined Onyx, Div. Millmaster Onyx
916A. Rehau Plastics of Canada Ltd.
917. Reichhold Chemicals, Inc.
918. Reichhold Chemicals, Inc. Reinforced Plastics Div.
919. Reifenhauser U. S. Sales Corp.
920. Reinforced Plastics, Inc.
921. Reiss Associates, Inc.
923. Rempac Foam Corp.
924. Ren Plastics
925. Resart-IHM AG
926. Research, Inc.
926A. Resopal Werk H. Rommler GmbH
927. Reynolds Metals Co., Packaging & Can Div.
928. Rexene Polymers Co., Div. Dart Industries, Inc.
928A. Rex Roto Corp.
929. Rezolin, Div. Hexcel
930. Rheinstahl AG Maschinbau, Henschel Plastics Machinery
931. Rheinstahl Plastics International, Ltd.
932. Rheinische Stahlwerke Maschinenbau
933. Rhodia, Inc., Polyimide Div.
934 Rhone-Poulenc-Textile
935. Rhone-Poulenc, Soc. des Usines Chemiques
936. Richardson Co., Polymeric Systems Div.

937. Ridat Engineering Co.
938. Rika Kogyo Co.
940. Rilsan Corp.
940A. Risho Kogyo, Ltd.
941. Riverdale Color Corp.
942. Robertshaw Controls Co., Fulton Sylphon Div.
943. Robertshaw Controls Co., Industrial Instrumentation Div.
944. Robintech, Inc.
945. Rocheleau Tool & Die Co.
947. Rodgers Plastics Equipment Div., Package Machinery Co.
948. Rogers Anti-Static Chemicals, Inc.
949. Rogers Corp.
950. Rohm & Haas Co.
951. Rolenn Mfg.
952. Rolf Kestermann Maschinenfabrik
953. Rona Pearl Div., Whittaker Corp.
954. Rosemount, Inc.
955. Rostone Corp.
956. Rowland Products, Inc.
957. Royal Plastics Corp.
958. Royle, John, & Sons
959. Rubatex Corp.
960. Rubbermaid Industrial Products Corp.
961. Ruco Div., Hooker Chemical Corp.
962. Rumianca S.p.A.
963. Ruscoe, W. J., Co.
963A. S. F. Plastics, Inc.
964. SGL Industries, Inc.
965. SIDEL
966. SIEMAG, Siengener Maschinenbau GmbH, Plastics Processing Machinery Dept.
967. S.P.R.E.A.
968. S. & S. Machinery Co., Div. New Machine Tool
969. Samafor
970. Sandoz Colors & Chemicals
971. Sandretto F .lli
972. Sangamo Electric Co.
973. Sangamo Weston Controls, Ltd.
974. Sanjo Seiki Co.
974A. Sanyu Resin Co., Ltd.
975. Savage Mfg. & Sales, Inc.
976. Schnectady Chemicals, Inc.
977. Schloemann-Siemag
978. Schori Process Corp.
979. Schramm Fiberglass Products, Div. High Strength Plastics Corp.
980. Schulman, A., Inc.
982. Scott Bader Co.
983. Scott Paper Co., Foam Div.
984. Scranton Plastic Laminating, Inc.
984A. Sedco Corp.

985. Sedo Corp.
986. Seidl Maschinenfabrik KG
987. Seismograph Service Corp., Seiscor Div.
988. Sekisui Chemical Co., Ltd., Foam Products Div.
989. Sensbey, Inc., Div. Nihon Dennetsu Keiki Co.
990. Sensotec, Inc.
990A. Sentinel/Triulzi (Packaging Industries Inc. - U.S. rep)
991. 7-K Color Corp.
992. Shakespeare Co.
993. Shamban, W. S., & Co.
994. Shaw, Francis, & Co.
995. Shell Chemical Co.
995A. Shell International Chemical Co., Ltd.
996. Shepherd Chemical Co.
997. Sherwin Williams Chemicals, Div. Sherwin-Williams Co.
998. Shima Trading Co., Ltd.
998A. Shin-Etsu Chemical Industries Co., Ltd.
999. Shin-Kobe Electric Machinery Co., Ltd.
1000. Showa Denko Co., Ltd.
1000A. Showa Highpolymer Co., Ltd.
1001. Showa Yuka K.K.
1002. Shuman Co.
1003. Sigma Instruments (Canada), Ltd.
1004. Siberline Mfg. Co.
1005. Simco Co.
1006. Simplomatic Mfg. Co.
1007. Simpson Electric Co., Div. American Gage & Machine Co.
1008. Simpson Extruded Plastics
1010. Singer Co., Climate Control Div.
1011. Singer Co., GPE Controls Div.
1012. Slocum Industries, Plastic Machinery Div.
1013. Smith Chemical & Color Co., Inc.
1014. Sobin Chemicals, Inc.
1015. Societa Italiana Resine
1015A. Societe La Cellophane
1016. Solar Chemical Corp.
1017. Solid Controls, Inc.
1018. Solvay & Cie S.A.
1018A. Some Industries, Inc.
1018B. Somar Mfg. Co., Ltd.
1019. Sommer, Dr. Ing. Fritz, Nachf
1020. Sommers Plastic Products Div., Whittaker Corp.
1022. Spaulding Fibre Co., Industrial Plastics Div.
1023. Spaulding Fibre Co., Insurok Div.
1024. Specialty Products Co.
1025. Spectra-Polymer, Inc.
1026. Square D Co.
1027. St. Joe Minerals Corp.
1028. St. Lawrence Hydraulic Co.
1029. Stallman, M. H., Co.

1030. Stanchel Engineering Co.
1031. Stauffer Chemical Co., Specialty Chemicals Div.
1031A. Stauffer Chemical Co., SWS Silicone Div.
1032. Stepan Chemical Co.
1033. Stepan Chemical Co., Resin Dept.
1034. Sterling, Inc.
1035. Sterling Controls, Inc., Div. National Mfg. Co.
1036. Sterling/Davis Electric
1037. Sterling Extruder Corp.
1038. Sterling Div., Reichhold Chemicals, Inc.
1038A. Stevens Paper Mills, Inc.
1039. Stewart Bolling & Co., Div. Intercoole Automation, Inc.
1040. Sticht, Herman, H., Co.
1041. Stokes Div., Pennwalt Corp.
1042. Strong Plastics, Inc.
1043. Structural Fiberglass, Inc.
1044. Strux Corp.
1046. Sumitomo Bakelite Co., Ltd.
1047. Sumitomo Chemical Co.
1047A. Sumitomo Naugatuck Co., Ltd.
1048. Sun Chemical Corp., Chemicals Div.
1049. Sun Chemical Corp., Pigments Div.
1050. Sund-Akesson AB
1051. Sund-Borg Machines Corp.
1052. Sunshine Scientific Instruments, Inc.
1053. Swedlow, Inc.
1054. Swift Chemical Co.
1055. Swiss Insulating Works, Ltd.
1057. Synthane-Taylor Corp., an Alco Standard Co.
1058. Synthetic Products Co., Div. Dart Industries, Inc.
1059. Synres-Almoco V.
1060. Syscon International, Inc.
1061. Szekely, S., & Sons Co.
1062. Tabata Industrial Machinery Co.
1062A. Taita Chemical Co., Ltd.
1063. Talley Indstries, Inc.
1064. Tamms Industries Co., Chemical Div.
1065. Tanabe Plastics Machinery Co.
1066. Tavannes Machines Co., S.A.
1068. Taylor Instrument Process Control Div., Sybron Corp.
1068A. Tec-Air, Inc.
1069. Techni-Search, Inc.
1069A. Teijin Chemicals, Ltd.
1070. Teknor Apex Co.
1071. Teledyne Taber
1072. Tennant, C., Sons, & Co. of N.Y., Onmi Div.
1073. Tenneco Advanced Materials, Inc.
1074. Tenneco Chemicals, Inc., Tenneco Intermediate Div.
1076. Tenor Co.
1077. Testing Machines, Inc.

1078. Tetrahedron Associates, Inc.
1079. Texstar Plastics
1079A. Tex-Trude, Inc.
1080. Thalco, Uniglass Industries, Div. United Merchants & Mfgs., Inc.
1081. Thermal Systems, Inc.
1082. Thermo Cote, Inc.
1083. Thermo Electric
1084. Thermofil, Inc.
1085. Thermoforming, S.p.A.
1086. Thermoform Tooling Co.
1087. Thermtrol Corp.
1088. Thiokol Chemical Corp., Chemical Div.
1089. Thoreson-McCosh, Inc.
1090. 3MCo.
1091. Thundering Banshee Research & Development Corp.
1092. Tioxide of Canada, Ltd.
1093. Tohoku Polymers Co.
1094. Tokyo Shibaura Electric Co., Chemical Products Div.
1094A. Toray Industries, Inc.
1094B. Toray Silicone Co., Ltd.
1095. Toshiba Machine Co.
1095A. Toyobo Co., Ltd.
1096. Toyo Kagaku Co.
1097. Toyomenka (America), Inc., Machinery Dept.
1098. Tra-Con, Inc.
1100. Transmares Corp.
1101. Triulzi S.p.A.
1102. Trubor Mfg. Co.
1103. Trueblood, Inc.
1104. Trylon Chemicals Div., Emery Industries
1105. Turner Machinery, Ltd.
1106. Tyler Machinery Co.
1107. UCB s.a., Chemical Div.
1107A. UCB-Ftal
1108. UOP Chemical Div., Universal Oil Products Co.
1109. USI-Clearing, Div. U.S. Industries, Inc.
1110. USM Corp., Machinery Div.
1111. USS Chemicals, Div. U.S. Steel Corp.
1112. Ube Cycon, Ltd.
1113. Ugine Kuhlman of America, Inc.
1114. Uhlich, Paul, & Co.
1115. Uniloy Div., Hoover Ball & Bearing Co.
1116. Union Camp Corp.
1117. Union Carbide Corp., Chemicals & Plastics Div.
1118. Union Carbide Corp., Films-Packaging Div.
1119. Uniroyal, Inc.
1123. United Electric Controls Co.
1124. United Foam Corp.
1125. United Mineral & Chemical Corp.
1126. United Plastics Corp.

1127. United Sensor & Control Corp.
1128. U.S. Borax & Chemical Corp.
1129. U.S. Bronze Powders, Inc.
1130. U.S. Chemical & Plastics
1131. U.S. Gypsum Co.
1132. U.S. Industrial Chemicals Co., Div. National Distillers & Chemicals Corp.
1134. U.S. Peroxygen Div., Witco Chemical Corp.
1134A. U.S. Pipe & Foundry Co.
1135. U.S. Polymeric, Div. ARMCO Steel Corp.
1136. U.S. Synthetics Corp.
1136A. Unitika, Ltd.
1137. Universal Dynamics Corp.
1138. Universal Machinery & Equipment Co.
1139. Universal Oil Products Co., Chemical Div.
1140. Upjohn Co., CPR Div.
1141. Upjohn Co., Polymer Chemicals Div.
1142. Valchem Div., United Merchants & Mfrs., Inc.
1143. Valley Metallurgical Processing Co. of N.J.
1144. Van Dorn Plastics Machinery Co., Div. Van Dorn Co.
1145. Vanderbilt, R. T., Co., Vanstay Dept.
1146. Velsicol Chemical Corp.
1147. Ventron Corp., Chemicals Div.
1148. Veresit Sacifi
1148A. Verson Allsteel Press Co.
1150. Vickers Div., Sperry Rand Corp.
1151. Victory Engineering Corp.
1152. Vimm Corp.
1153. Vinylplex, Inc.
1154. Vistron Corp., Film Div.
1155. Vistron Corp., Sub Standard Oil Corp. of Ohio
1156. Voltek, Inc.
1157. WER Industrial, Div. Emerson Electric Co.
1158. Wabash Metal Products Co.
1159. Wacker-Chemie GmbH
1160. Wako Pure Chemical Industries, Ltd.
1160A. Wakefield Engineering, Inc.
1161. Wallace & Tiernan Div., Pennwalt Corp.
1161A. Ward, Blenkinsop & Co., Ltd., (Aceto Chemicals - U.S. rep)
1162. Ware Chemical Corp.
1163. Warren Components Corp.
1164. Watson-Standard Co.
1165. Wayne Machine & Die Co.
1166. Weather Measure Corp.
1168. Weed Instrument Co.
1168A. Wehco Plastics, Inc.
1169. Welding Engineers, Inc.
1170. Weldotron Corp.
1171. Welex, Inc.
1172. Wellman, Inc., Plastics Div.
1173. Werner & Pfleiderer Corp.

1174. West Instrument Div., Gulton Industries, Inc.
1174A. Western Plastics Co.
1175. Westinghouse Electric Corp., Industrial Plastics Div.
1175A. Westinghouse Electric Corp., Distribution & Control Equipment Div.
1175B. Westinghouse Electric Corp., Insulating Materials Div.
1176. Westlake Plastics Co.
1177. Weston Chemical, Div. Borg-Warner Corp.
1177A. Westvaco Co.
1178. Westwood Chemical Co.
1179. Wheaton Industries, General Machinery Div.
1180. White Chemical Co.
1181. Whitlock, Inc.
1182. Whittaker, Clark & Daniels, Inc.
1183. Whittaker Corp., Lenoir Coatings & Resins Div.
1184. Whittaker Corp., Mol-Rez Div.
1185. Whittaker Corp., R & D Div.
1186. Whittaker Corp., Thermoplastics Div.
1187. Wiegand, Edwin L., Div. Emerson Electric Co.
1188. Williams International, Inc.
1189. Williamson Corp.
1190. Williams-White & Co.
1191. Wilson Instrument, Div. Acco
1192. Wilson-Martin Div., Wilson Pharmaceutical Chemical Corp.
1193. Wilson Products Co., Div. Dart Industries, Inc.
1194. Witco Chemical Corp., Isocyanate Products Div.
1195. Witco Chemical Corp., Organics Div.
1196. Witco Chemical Corp., Polymer Div.
1197. Woodall Industries, Inc.
1198. Woodward Plastics Corp.
1199. Wright, P. M. Electrical Co.
1200. XCEL Corp.
1202. Yarway Corp.
1203. Zed Industries
1204. Zenith Products Co.
1205. Zeus Industrial Products, Inc.
1206. Zurn Industries, EEMCO Div.

Custodians:

Army - MR
Air Force - 84
DSA - GS

Review activity:

Army - PA
Navy - SH
Air Force - 84

Preparing Activity

Army - MR

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