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Classroom Analysis of Various Plastics

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Abstract

In the junior high plastics course this writer. teaches, the students display more interest in the manipulative activities of the laboratory than in the sit-down classroom activities. The results of this tend to be a once-over-lightly treatment of the technical aspects of plastics and more hands on craft type activities in the laboratory. To bring more balance to the program, an activity needs to be devised which will have more industrial relevance. Such an activity should allow the students a certain amount of freedom and still provide them with technical information and acquaint them with the properties of various plastics. Such a program could be devised as a result of this study. The program would provide the students with manipulative activities in examining and testing plastics and provide more of an industrial approach in under;.. standing plastics and determining why some polymers are more practical than others for certain job applications.

CLASSROOM ANALYSIS OF

VARIOUS PLASTICS

Approved by:

Graduate Committee Chairman

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CLASSROOM ANALYSIS OF VARIOUS PLASTICS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The Problem

In the junior high plastics course this writer teaches, the students display more interest in the manipulative activities of the laboratory than in the sit-down classroom activities. The results of this tend to be a once-over-lightly treatment of the technical aspects of plastics and more hands on craft type activities in the laboratory. To bring more balance to the program, an activity needs to be devised which will have more industrial relevance. Such an activity should allow the students a certain amount of freedom and still provide them with technical information and acquaint them with the properties of various plastics. Such a program could be devised as a result of this study. The program would provide the students with manipulative activities in examining and testing plastics and provide more of an industrial approach in understanding plastics and determining why some polymers are more practical than others for certain job applications.

Limitations of the Study

This study is not meant to be an in depth research of all properties each plastic possesses. Rather, this study will be a search to identify the most prominent properties of a select number of plastics so that these polymers may be recognized by the beginning student. Accepted testing methods and standards will be noted and altered only as needed to adapt to a practical level for the intended students. Testing apparatus constructed for student use will deviate from accepted standards, if necessary, to meet student needs or construction cost limitations. Testing apparatus will be sufficiently sophisticated to give reliable results. This study will be further limited by the factors of cost incurred and time involved while constructing apparatus and developing the student study unit.

Specific Objectives

The specific objectives of the study are:(1) to investigate pertinent literature for the purpose of learning the properties each selected plastic resin exhibits when various experiments are performed on it: (2) to construct such apparatus as is needed to supplement existing equipment in the laboratory to perform experiments on plastics; (3) to use this equipment to determine such properties as: Flammability, odor, specific gravity, chlorine content, tensile strength, compression strength, mar resistance, and resistance of plastics to chemical reagents; (4) to develop a unit of study for junior high students on identifying unknown plastic resins by the properties they exhibit when analyzed and determine which resins would be most practical for a specific job application.

Plan for Conducting the Study

This study will begin with a thorough search of available reference materials to determine what properties are exhibited by the selected plastic resins when subjected to the various tests. Direct correspondence with industry will be made when detailed information is not available from published sources. Experiments selected for the student use will be conducted to verify both the practicality of the test in identifying a resin and the results as indicated in the research materials. A procedure for students to follow in performing the various steps of an experiment will then be formulated. All this information will then be arranged in an orderly scientific manner.

Definition of Terms

Crazing: Fine cracks which may extend in a network on or under the surface of plastic material. Usually occurs in the presence of an organic liquid or vapor (Baird, 1971, p. 296).

Elasticity: That property of a material by virtue of which tends to recover its original size and shape after deformation (Baird, 1971, p. 299).

Elongation: The fractional increase in length of a material stresses in tension (Baird, 1971, p. 299).

Flammability: Measure of the extent to which a material will support combustion (Baird, 1971, p. 300).

Monomer: A relatively simple compound which can react to form a polymer (Baird, 1971, p. 305).

Polymer: A substance consisting of molecules characterized by the repetition of one or more types of monomeric units (ASTM, D 882-72, p. 351).

Polymerization: A chemical reaction in which the molecules of monomers are linked together to form polymers (ASTM, D 882-72, p. 351).

Resin: Any of a class of solid or semisolid organic products of natural or synthetic origin, generally of high molecular weight (Baird, 1971, p. 309).

Solvent: Any substance, usually a liquid, which dissolves other substances (Baird, 1971, p. 311).

Stress Cracking: An external or internal crack in a plastic caused by tensile stresses less than its short time mechanical strength (ASTM, D 883-72, p. 352).

Yield Value: The lowest stress at which a material undergoes plastic deformation. Below this stress, the material is elastic, above it, viscous (Baird, 1971, p. 313).

CHAPTER II

RELATED INFORMATION

Historical

An ivory shortage in 1863 prompted the firm of Phelen and Collander to offer an award for any satisfactory replacement. Up until this time items such as bone, ivory, shells, and wood were used for fabricating articles such as utensils, buttons, ornaments, toys, handles, and musical instruments. The challenge was accepted by two brothers who were not chemists, but printers. John and Isaiah Hyatt of New York reacted nitric acid with cotton to produce nitrated cellulose (Milby, 1973, p. 2). Hyatts' product, named celluloid, though first intended as a replacement for ivory in billiard balls, found use by 1868 in a variety of articles: combs, brush handles, dental plates, and eventually automobile side curtains. This invention was the start of synthetic plastic product making in the United States. However, records can be found to show that others were doing similar things earlier in other places. A Swiss chemist, Schonbein, in 1845, nitrated cellulose by using sulfuric acid as a catalyst. J. Cutting, of Boston, obtained patents in 1854 to cover this use of gum camphor in collodion for improvement of photography. In 1862, an Englishman, A. Parkes studied the residue left after evaporation of the solvent of photographic collodion (cellulose nitrate in an ether-alcohol mixture) and called this product Parkesine, which contained no camphor, the all important additive that made the celluloid invention the first real synthetic milestone (DuBois, 1974, p. 21).

H. Goodwin in 1887 and H. Reichenback in 1889 independently developed solvent casting processes for making flexible transparent nitrocellulose films for photographic use. The success of celluloid proved the utility of plastics and sparked efforts by others to develop plastics which would have the virtues and none of the drawbacks of celluloid (Park, 1969, p. 3).

It was not until 1909 that another snythetic material appeared commercially. In that year Dr. Leo Baekeland announced a new resin, phenol formaldehyde. This was the beginning of a rapidly developing science of synthetic materials. As the years passed, new techniques along with new scientific discoveries enabled chemists to introduce new plastics with ever increasing properties. Table I is a list of the first plastic resins produced and the year each was developed. Every year new plastic materials are being discovered and created as well as continued innovations in existing plastics.

Industrial-Geographical

The resin manufacturing industries are those concerned with converting raw materials into chemical compounds

TABLE I

DEVELOPMENT OF PLASTIC MATERIALS FROM 1863-1965
(Baird, 1971, p. 10)

Date	Material
1868	Cellulose Nitrate
1909	Phenol Formaldehyde
1927	Cellulose Acetate
1927	Polyvinyl Chloride
1929	Urea Formaldehyde
1935	Ethyl Cellulose
1936	Acrylic
1936	Polyvinyl Acetate
1938	Cellulose Acetate Butyrate
1938	Polystyrene
1938	Nylon
1939	Polyninylidence Chloride
1939	Melamine Formaldehyde
1941	Alkyd
1942	Polyester
1942	Polyethylene
1943	Fluorocarbon
1943	Silicone
1945	Cellulose Propionate
1947	Epoxy
1948	Acrylonitrile-Butadiene-Styrene
1949	Diallyl Phthalate
1954	Polyurethane
1956	Acetal
1957	Polypropylene
1959	Polycarbonate
1962	Phenoxy
1962	Polyallomer
1964	Ionomer
1964	Polyphenylene Oxide
1964	Polyamide
1965	Parylene
1965	Polysulfone

which are processed into the various plastic resins. These resins are produced in many forms, ready to be sold to companies which will process them into finished products. The majority of these manufacturing companies are made up of chemical companies, who have the scientists and equipment to produce plastics, and petroleum companies, who have the raw materials and chemical laboratory experience.

The leading plastic producing countries are the United States, Great Britain, Italy, Germany, and Japan. Growth of a plastics industry is predicated on the availability of low cost materials; a plentiful supply of petroleum, natural gas, or coal is very essential to the making of basic raw materials.

About half of the plastics industry in the United States is located in the eastern section, thirteen per cent on the west coast, thirty-four per cent in the middle west, and the balance scattered through the southern section (DuBois, 1974, p. 24). There is a fast growing tendency to move the materials making facilities into the oil producing areas, where the refineries are located. The fabricating and molding plants are located in the industrials areas, where many industries can be served within a reasonable distance. The petroleum product nations and the refiners are taking over the resin making and the large volume conversion into products at this time.

This writer was unable to locate any plastic resin manufacturers in the state of Iowa. According to the 1975-

1976 Directory of Iowa Manufactures, there are presently one hundred forty-one companies in Iowa engaged in some form of plastics processing.

Field Trips

Because this paper deals with the testing and analyzing of plastics this writer consulted a 1975 listing of Industrial Research Laboratories in the United States and found that there are only three laboratories in the state of Iowa involved in plastics testing. They were: E.I. DuPont deNemours and Company in Clinton, working with cellophane and polyolefins; Berkeley Company in Spirit Lake, working with polyamides and polyolefins; and Eltra Corporation in Marshalltown, working with unspecified plastics. Because of travel time and expense limitations involved in this study this writer was unable to visit any of these three establishments. However, this writer did visit one commercial testing laboratory and four companies manufacturing plastic products.

The commercial testing facility was Corning Laboratories, Incorporated in Cedar Falls. The purpose for visiting this laboratory, even though their area of emphasis is water and air pollution testing, was to have a first hand experience in witnessing scientific laboratory activities.

The four companies manufacturing plastic products visited by this writer were: Gail Industries, Incorporated and Cryovac Division of W.R. Grace and Company both in

Cedar Rapids; Robintech, Incorporated in Grinnell; and Holland Plastic Company in Gilman. Two of these companies do not have sophisticated laboratories or even some equipment for the testing of their plastic products; but instead rely on testing data provided by the producer of the plastic they are using. If the data indicates that the specific plastic exhibits the properties necessary for the forming operations and will withstand anticipated forces encountered during consumer use, that plastic is adopted without further testing by the individual product manufacturing company. Quality controls in these facilities consisted of only a visual inspection or a brief handling of the finished product.

The other two companies did use sophisticated testing apparatus and constant monitoring procedures in their processing. One company conducted six laboratory tests on twelve samples from each rail car of material received before consuming it in production. The other company used an electronic monitoring device throughout the production process. Both of these companies used individual inspection of the finished product in their quality control departments.

On the basis of this very limited random sample it would appear that fifty per cent of the plastic product manufacturing companies in the state of Iowa do not have any type of research and development facility and have only limited quality control checks. There is a need for further study in this direction to determine why this condition exists.

CHAPTER III

FINANCIAL AND CAREER INFORMATION

Financial Trends

One of the most remarkable things about plastics is the growth they have experienced in the past few decades. Plastic production growth in general has far outstripped the rate of growth of the gross national product (GNP). Figure 1 is a line graph comparing plastics production in millions of pounds and the GNP in billions of dollars. The lines shown are the general trend line, disregarding year to year ups and downs.

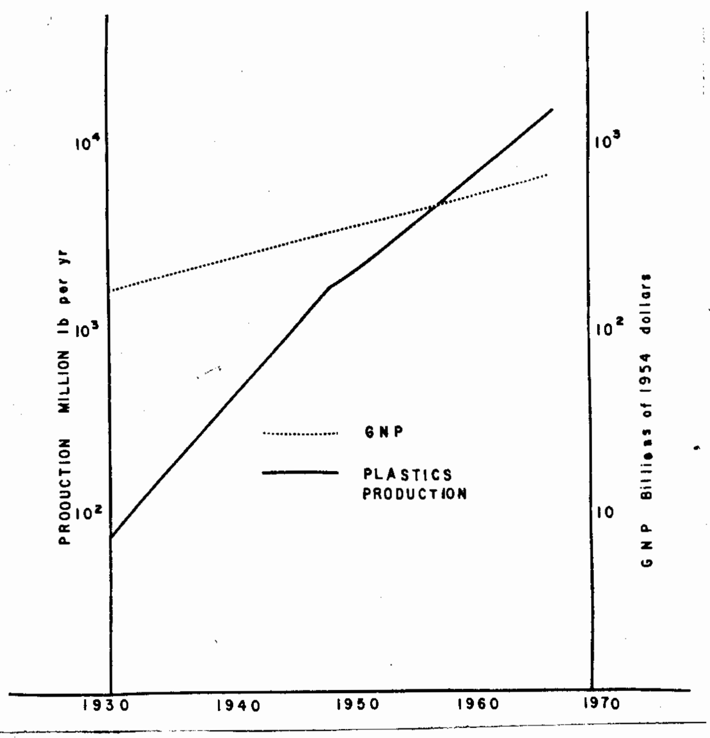

Figure 1. Growth of plastics production vs growth of GNP (Kresser, 1969, p. 7).

One of the most significant factors influencing the future growth of plastics is cost. Up to this time plastics have been relatively expensive materials that have obtained their markets because of their special properties or their efficient processing. Looking into the future of plastics it is difficult to project the production costs. Prices may be lower due to polymerization techniques which are reducing polymerization expenses, but a world wide price increase for petroleum may off-set these polymerization cost savings.

The plastics industry is continually reaching new markets and expanding in all ready established ones. Nearly all packaging makes use of plastic in some form. Markets in the automobile industry are expected to increase because of plastics' ability to be formed into complex shapes, and it's lightness saves weight in a finished automobile. Much of the traditional hardwood frame of upholstered furniture will be replaced with structural foam. The ability to put finishes on this material that closely resembles traditional wood finishes makes it very easy to produce an entire plastic frame at lower cost and with better properties than wood. In building construction, plastics are presently used as waterproofing membranes, wiring insulation, pipe, siding, and thermal insulation. This is only a beginning; it is anticipated that in the near future plastics will be used on a large scale for interior trim, wall and ceiling paneling, doors, and door and window frames. The greatest advantage in cost savings would come from preformed and preassembled units, which would be inexpensively made by mass production techniques. The appliance industry is already using plastics to a large degree in its manufacturing and this trend is expected to continue on an ever larger scale.

In the decade 1970-1980, it is expected that the volume of plastics used will expand another eight-hundred per cent while the use of steel products will increase only fifty-six per cent for the same period. The graph in Figure 2 shows the rapid growth rate of the plastics industry. It is anticipated that the volume of plastics used for all purposes will exceed the volume of iron and steel by 1983, placing the world in the Plastics Age.

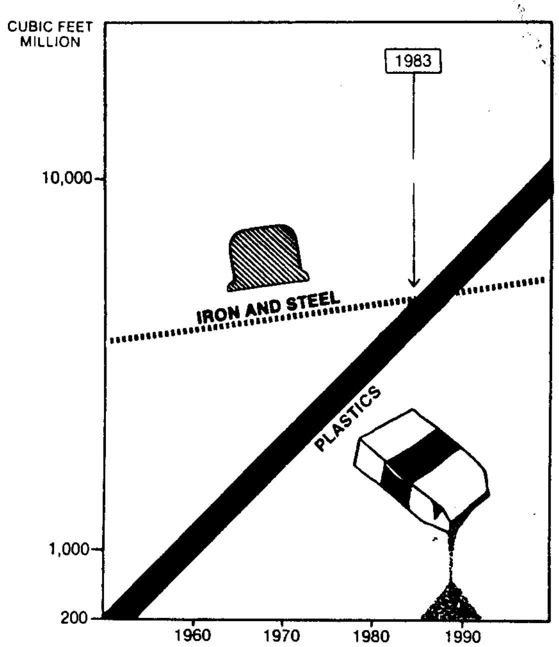

Figure 2. World consumption of raw materials by volume (Milby, 1973, p. 5)

Job Opportunities

The plastics industry is expanding at such a rapid pace that opportunities for careers in this field appear to be almost unlimited. New and varied developments in plastics processing continue to add to the long list of jobs requiring the services of people interested, educated, and dedicated to the field. These job opportunities extend across the whole range of the plastics industry: such jobs might involve either the converting of industrial chemicals into resins, or processing those resins into finished products.

Job classifications in the plastic industry fall under five main categories: (1) semi-skilled; (2) skilled; (3) technical; (4) supervisory; and (5) professional (Baird, 1971, p. 265). A person interested in employment in any area of the plastics industry should have a fundamental knowledge of plastic materials and processes.

Workers whose jobs do not require extensive periods of training or skill are classified as semi-skilled. This type of work usually involves only a few hours of instruction to prepare the worker for the task he is to perform. Typical jobs for this worker might be semi-automatic or automatic molding machine operator; assembling plastic components into a final product; bagging, mixing, or blending various materials; or assisting skilled workers with inspection, maintenance, and repair work.

Skilled workers in the plastics industry are often journeymen machinists who have obtained their skills through apprenticeship or trade training programs. A knowledge of plastic materials and processes is also needed for these workers, and usually this is obtained through on-the-job training. In the resin making field, the better jobs include chemical operator, evaporation men, millers, mixers, stillmen, and control men. In the resin processing field the better jobs include machine set up men and inspectors.

Technicians play a broad role in the industry but are usually specialists in some phase of it. Technicians must have knowledge of the total industry which usually requires at least two years of college with emphasis on math, science, manufacturing processes, and plastics technology. As chemicals are processes, the technician may be the worker who reads instruments that measure pressure, flow of materials, and other conditions or he may be responsible for making technical reports, checking production machine operation, or be involved in quality control or testing.

About one out of four plastics workers holds an administrative, clerical or other non-scientific white collar job. Most of these jobs involve dealing with production and personnel. Being a foreman or supervisor usually requires in depth knowledge of all the necessary processing steps as well as several years of experience in industrial production. Good preparation for this type of position will include several years of college in manufacturing processes with emphasis on plastic processing.

Chemists, chemical engineers, physicists, mechanical and electrical engineers do much of the research and development work in the plastics industry so professional people are continually in demand in this industry; and may be generally classified as those having at least four years of college education. Depending on the background training, the duties for these people might involve development of new polymers, analysis of polymer structure, testing machine and tool design, or quality control.

Employment Outlook

The expanding plastics industry will provide many job opportunities during the foreseeable future. The number of administrators, professionals, technical, and clerical workers will grow faster than the number of plant workers because of the industry's emphasis on research and development. The largest increases will be for chemists, engineers, and science and engineering technicians (Occupational Outlook Handbook, 1974-75, p. 690).

It is estimated that there are fifteen thousand processors of plastics throughout the United States, and there is a growing trend toward locating plants in the smaller communities. In a recent forecast plastics leads all other industries in projected growth rate through 1980 (DuBois, 1974, p. 26). Plastic growth has been predicted to increase from six to twelve per cent a year during the seventies. With the plastics industry expanding at such a rapid pace, there appears to be almost unlimited opportunities for careers in this field in nearly every region of the United States.

CHAPTER IV

TECHNICAL INFORMATION

Chemistry of Plastics

Plastics are synthetic materials, formed through chemistry by taking apart ingredients such as coal, water air, petroleum, limestone, and salt, then putting them together in different, more desirable chemical combinations. Taking a substance apart enables the chemist to analize what it is made of; then by combining the parts in various ways he may produce a completely new substance or materially change a substance that is already available.

The largest volume of raw material comes from the petroleum industry, usually in forms of liquids and gases which contain two or more of the six most common chemical elements that go into the building of a polymer. These six elements are carbon, hydrogen, oxygen, nitrogen, chlorine, and fluorine, of which carbon is considered the backbone of the polymer because it is usually the element that links together all elements in a formula to form a polymer. To understand how plastics are formed it is necessary to know how atoms of elements are combined and the number of possibilities the chemist has for arranging them. Each atom can combine with only a certain number of other atoms and the number depends on the combining power of an atom involved.

The combining ability of an atom to join with another atom is called its "valence". Table II gives the valence ability of the six most often used elements and shows how they would be drawn to represent a diagram of a plastic molecule.

TABLE II

COMMON ELEMENTS IN PLASTICS
(Baird, 1971, p. 17)

Element	Symbol	Valence	Diagram
Carbon	C	4	$-\overset{\vert}{\underset{\vert}{C}}-$
Nitrogen	N	3	$-\overset{\vert}{N}-$
Oxygen	O	2	$-O-$
Hydrogen	H	1	H—
Chlorine	Cl	1	Cl—
Fluorine	F	1	F—

Thermoplastics

Plastics may be classified into one of two groups, either "thermoplastic" or "thermosetting". The basis for this classification is the way in which the monomer was polymerized. Addition polymerization produces thermosetting materials. Thermoplastic polymers are characterized by softening upon heating and hardening by cooling. Because the giant molecules of these materials have no strong bonds between individual atoms they can be softened by heat and remolded over and over. Some of these polymers will burn freely when exposed to an open flame while others are self extinguishing. There are more thermoplastic materials than there are thermosetting materials.

Thermosetting

The thermosetting polymers possess quite different characteristics because of the irreversible reaction by which they polymerize as they form a rigid, hard, infusible mass during condensation polymerization. The cross-linking molecular structure forms double bonds which are so strong that there is no slippage (softening) when the material is heated. Intensive heating of thermosetting plastic after initial forming will cause breakage of the chemical bond resulting in a charring of the material. Figure 3 is a drawing which portrays the difference between flexible bonding of thermoplastic to the irreversible reaction of the thermosets bonding.

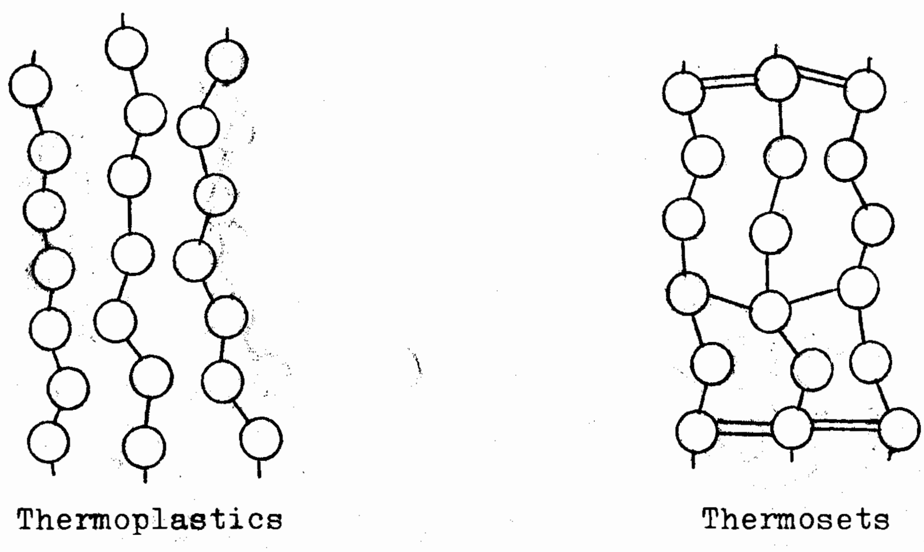

Figure 3. Plastic structure differences
(Dean, 1973, p. 29)

Selected Plastics

The plastics chosen for use in this paper are usually readily available in the writer's classroom for student use. Only those properties and characteristics deemed appropriate for identification and testing purposes are shown. This information is also arranged in a series of tables following the descriptions, making individual comparisions of different plastics less time consuming.

Acrylic

The term acrylic is descriptive of a large class of resins, the most important of which is methyl methacrylate. In 1901, Dr. Otto Rohn began working with acrylic materials and in 1927 the first resin was announced by the Rohn and Haas Company. The raw materials for producing acrylic are petroleum based ethylene and propylene. Acrylic is a thermoplastic which is crystal clear in its natural state but is easily colored in all shades from transparent to opaque. It contains no chlorine atoms and has a specific gravity of 1.18. It has a low softening point, low scratch resistance, and can be attacked by some chemicals including gasoline and cleaning fluid. Acrylic is strong, rigid, has good impact strength and has the unusual ability to transmit light throughout its internal structure (Milby, 1973, p. 299).

Acrylonitrile-Butadiene-Styrene (ABS)

ABS is produced by polymerizing acrylonitrile, butadiene, and styrene and can be made by either mechanically blending styrene-acrylonitrile with nitrile rubber or direct grafting of styrene-acrylonitrile on a polybutadiene backbone. ABS is a strong, rigid thermoplastic with a natural color of light tan, has a specific gravity of 1.04 and a moderate softening point. It contains no chlorine, has good scratch resistance, is attacked by ketones, and is flammable (Ziska, 1974, p. 8).

Nylon

Nylon is the generic term for a class of polyamides containing repeating amide groups connected by methylene units in a polymer structure. Nylon is made by condensing a diamine with a dibasic acid, is a thermoplastic, is self-extinguishing, has a natural color of off white and contains no chlorine. When compared to most other plastics, nylon has better heat resistance. It has a specific gravity of 1.17 and is sometimes referred to as a mechanical or industrial plastic because of its high strength, all round toughness, and good resistance to chemicals, which allows it to compete with metals in many applications (Simonds, 1963, p. 37).

Phenol Formaldehyde (Phenolics)

Phenolics, the oldest thermosetting plastic, are made by combining carbolic acid and formaldehyde as a gas in the presence of an acid catalyst. This formula produces a self-extinguishing, heavier than average, dark gray product with high heat resistance, high mechanical strength, and a resistance to most common solvents and acids. Phenolics contain no chlorine and have a specific gravity of 1.28 and are seldom used in molded products without some type of filler to improve their toughness (Simonds, 1963, p. 40).

Polycarbonate

Polycarbonates are considered to be special types of polyesters in which groups of dihydric phenols are linked through carbonated groups. Polycarbonate is considered one of the most important industrial plastics because of its excellent heat resistance, high impact strength, abrasive resistance and has a specific gravity of 1.20. Polycarbonate is a self extinguishing thermoplastic which is clear in its natural state but can easily be colored. It can be attacked by some hydrocarbons and can be dissolved in ethylene dichloride. Few thermoplastics have the outstanding engineering properties of polycarbonate. It is used in direct competition with metals such as copper, zinc, and brass (Baird, 1971, p. 39).

Polyester

Polyester is produced from the polymerization of certain alcohols and acids. Polyester can take the form of either a film or a liquid resin to which a catalyst must be added to complete the curing during molding. Polyester is a clear thermoset with a specific gravity of about 1.05. It contains no chlorine and has good mechanical strengths when reinforced with cloth or glass fibers. Polyester resists most solvents, acids, and salts and probably is best known as fiberglass which is formed when the resin is combined with glass mat or chopped glass fibers (Milby, 1973, p. 59).

Polyethylene

Polyethylene is a member of the polyolefin group of plastics. All members of this group are thermoplastics which are milky white in color with a specific gravity of less than 1.00. Members of this group contain no chlorine, have moderate mechanical strength, and good abrasive resistance at low temperatures. Polyethylene is made from ethylene gas and is produced in two forms in terms of density. Low density polyethylene is produced by making a short molecular structure with side branching. High density polyethylene is produced by making a long molecular structure with very little side branching. Polyethylene is able to combine the properties of toughness and flexibility (Park, 1969, p. 122).

Polypropylene

Polypropylene is made from propylene gas. The process is similar to the production of high density polyethylene. Polypropylene is also a member of the polyolefin group and as such it has properties very much like polyethylene. In general polypropylene exhibits the same properties as those previously mentioned for polyethylene (Park, 1969, p. 124).

Polystyrene

Polystyrene is made by forcing ethylene through benzene in the presence of a catalyst to produce ethyl benzene. This combination is converted into styrene by splitting hydrogen away from the rest of the molecule. Polystyrene is a non-chlorinated crystal clear thermoplastic with a specific gravity of slightly more than 1.00. It's characteristics include good abrasive resistance, strong mechanical properties at low temperatures, but it does stress crack easily. Softening or deterioration occurs when used with ketones, hydrocarbons, and essential oils. Polystyrene can also be expanded with heat and moisture to make an excellent packaging and insulating material (DuBois, 1974, p. 62).

Polyvinyl Chloride (PVC)

PVC is the largest single volume plastic material in use in the world. Its desirable properties include self-extinguishing, good chemical and abrasive resistance, and good strength properties. PVC is a thermoplastic with a light bluish, clear natural color and does contain chlorine. The compounds can range from soft, flexible films to rigid, high strength products (DuBois, 1974, p. 68).

TABLE III

INSPECTION TESTING TABLE
(Baird, 1971, p. 272, 273)

Plastic	Natural Color	Specific Gravity	Continuous Resistance to Heat in Degrees F.	Compression Molding Temperature	Chlorine Content
Acrylic	Crystal clear	1.18	180	325	None
ABS	Light tan opaque	1.04	200	350	None
Nylon	Off white opaque	1.13-1.20	325	500	None
Phenol Formaldehyde	Dark grey opaque	1.25-1.30	450	325	None
Polyester	Clear	1.01-1.20	250	300	None
Polyethylene	Milky White	0.94-0.96	250	300	None
Polypropylene	Milky White	0.89-0.90	300	350	None
Polystyrene	Crystal clear	1.04-1.10	170	300	None
Polycarbonate	Clear	1.01-1.20	250	450	None
PVC	Light bluish clear	1.16-1.35	175	350	Yes

TABLE IV

DESTRUCTIVE TEST TABLE
(Baird, 1971, p. 272)

Plastic	Tensile Strength	Compression Strength	Impact Strength	Abrasive Resistance
Acrylic	9,000	16,000	0.33	Low Scratch resistance
ABS	7,000	10,000	4.20	Good wear and scratch resistance
Nylon	15,000	13,000	1.50	High abrasive resistance
Phenol Formaldehyde	8,500	34,000	4.00	Good resistance
Polycarbonate	9,500	12,500	8.00	Good resistance
Polyester	30,000*	25,000	0.80	Fair resistance
Polyethylene	5,000	3,200	3.00	Good resistance at low temperatures
Polypropylene	5,300	7,000	2.00	Good surface hardness and scratch resistance
Polystyrene	7,000	15,000	0.70	Good resistance
PVC	4,800	11,000	5.50	Good resistance

Tensile strength is the psi force necessary to pull specimen apart.
Compression strength is the psi force required to rupture or deform specimen.
Impact strength is the ft./lb. of mechanical energy absorbed by sample during fracture blow from pendulum hammer.
*Glass filled polyester

TABLE V

CHEMICAL SUSCEPTIBILITY TABLE

Plastic	Agents
Acrylic	Methylene chloride, ethylene dichloride, gasoline, glacial acetic acid
ABS	Methyl ethyl ketone, ethylene dichloride
Nylon	Strong acids
Phenol Formaldehyde	Resists most common solvents and weak acids
Polycarbonate	Ethylene dichloride, methylene chloride
Polyester	Resists most solvents, acids, and salts
Polyethylene	Oils, gasoline
Polypropylene	Some hydrocarbons, acetone, carbolic acid
Polystyrene	Methyl ethyl ketone, methylene chloride, toluene, lacquer thinner, glacial acetic acid, ethylene dichloride
PVC	Tetrahydrofuran, cyclohexanone, methyl ethyl ketone, isophorone

CHAPTER V

THE PROJECT

Reason for Testing Plastics

Until the past few years, the public's acceptance of plastics has been very slow due to inappropriate uses of plastic in product fabrication which has produced a poor image of the plastics industry. The results of poor fabrication was a product which did not function as it was designed to and the public to become skeptical of any product produced from plastic materials. Failure of these products proved to be very poor publicity, leaving the general public with an assumption that plastic was an inferior material. Changing the attitude of the consumers who experienced the frustration of a plastic product which failed has been a major task for the plastics industry. However, in recent years the image of plastics has changed to that of a miracle material. This is due largely to the research that has taken place to develop an understanding of the properties of each individual plastic (Weede, 1974, p. 2).

When a new product is considered for market, studies are undertaken to select the best possible material. Questions must be answered as to how the product will perform under mild or rugged conditions of service, then tests are conducted to approximate as nearly as possible the actual service enviroment. The purpose of mechanical tests is to learn how a material will react when forces are applied. The factors of cost and method of processing must also be considered. Often the question of how a product is to be made determines the type of material to be used. The more rigid the specifications covering the end use of a product, the easier the selection of an appropriate plastic becomes, if enough research has been done on the resins.

Identifying Plastics

It is difficult, even by experience to identify more than a few plastics by visual inspection or simple mechanical test so a systematic chemical analysis of plastic materials is probably the only method of true identification. However, it is possible to do a number of quick, very simple tests and get a tentative answer to the kind of plastic being tested. The best results are obtained when the unknown plastic is of a simple type and not a mixture of several polymers.

The first step in analysis is to determine if the unknown sample is a thermoset or a thermoplastic. This can be accomplished by pressing a hot glass stirring rod or soldering iron firmly against the sample. The hot glass rod or soldering iron will indent the plastic surface if it is a thermoplastic, but will not soften a thermoset.

The next test used in identifying different unknown plastics is to burn them by exposing them to an open flame. A small propane torch, Bunsen burner, or alcohol lamp can be used for this test. Hold the unknown sample just to the edge of the flame until it ignites. Note the odor, color of flame, and behavior of the material. Because of possible hot dripping plastic, smoke, and fumes, this test should be conducted over a piece of sheet metal or asbestos in a well ventilated area.

By using Table VI it is possible to identify the selected plastics.

Tensile Strength

Tensile properties refer to the behavior of a material when it is subjected to forces that tend to pull it apart. Tensile testing is one of the most common tests used for determining the following mechanical properties of material: (1) proportional limit, (2) yield point, and (3) ultimate tensile strength which are the most important indications of strength in a material.

The American Society for Testing and Materials (ASTM) test D 638-72 (1974, p. 186) gives the specifications for doing tensile testing of plastic materials. Tensile tests can be conducted on various shaped samples but the preferred shape is the dumbbell or dog bone. Care must be used in preparing the specimens to prevent scratches, nicks, or irregularities which will allow stress concentrations and premature failure. Fillet size in the necked-down portion is also an important consideration. The samples may be molded, cast, sawed, milled, routed, or die cut from sheet stock with a minimum of five specimens to be tested. For

TABLE VI

BURNING IDENTIFICATION TABLE
(Baird, 1971, p. 70)

Plastic	Self Extinguishing	Odor	Nature	Behavior of Material
Acrylic	No	Fruit like	Blue flame, yellow top spurts	Softens, usually no drip, little char left
ABS	No	Characteristic*	Bursting yellow flame, black smoke	Softens, usually no drip, chars
Nylon	Yes	Burned wool	Blue flame, yellow top	Melts, drips, froths
Phenolic	Yes	Burned Fabric	Yellow, little black smoke, sparks	Cracks badly, chars swells
Polycarbonate	Yes	Sweet carbon	Yellow, dense black smoke, carbon in air	Softens, spurts, chars decomposes
Polyester	No	Burning coal	Yellow, black smoke burns steadily	Softens, no drips, continues to burn
Polyethylene	No	Burning paraffin	Blue flame, yellow top	Melts, drips may burn, swells
Polypropylene	No	Burning paraffin	Blue flame, yellow top, some white smoke	Melts, swells, drips
Polystyrene	No	Illuminating gas	Orange-yellow flame dense carbon in air	Softens, bubbles
PVC	Yes	Hydrochloric acid Chlorine	Yellow flame, green edges, white smoke	Softens

*Odor difficult to describe but recognizable--use known sample.

this test an injection mold was made, see Figure 4. The specimen is measured for width and thickness of the neck-down portion to the nearest .001 inch and clamped in the jaws perpendicular to the machine base. Stress should be applied at a rate of about .05 inch per minute on the specimen. The formula for finding the ultimate tensile strength (TS) of a specimen is:

$$\text{TS (psi)} = \frac{\text{L (load to cause failure in lb.)}}{\text{A (minimum cross-sectional area in sq. in.)}}$$

Figure 4. Steel injection mold in dog bone shape for producing tensile test specimens.

An excellent testing machine to use in performing this test in a laboratory is either the Vega Non-Metallic Tester or the Universal Testing Machine. Because of the expense of these machines, this writer fabricated a tester using a three ton hand operated hydraulic jack. A two thousand pound gauge was installed in the jack so that pressure on the specimen could be determined. A frame was constructed of channel steel and the jack was mounted in the frame, see Figure 5. To maintain a constant even stress the handle was slowly pumped.

Figure 5. A tensile tester constructed in the laboratory.

With this tensile testing device some of the samples may not be pulled to the point of separation but rather will exhibit an elongation effect, that is they will stretch and distort from their original shape but not break. Because of this fact a pair of gauge marks should be placed on the specimen with a colored felt tip pen prior to inserting in the tensile tester, see Figure 6. The reaction of the material and the pressure on the gauge should be closely monitored. At some point most plastics will begin to elongate because of the strain without any additional force being applied. This will take the form of a slight drop in the pressure reading on the gauge. The material has then reached a stage where it can no longer return to its original shape even if the stress is relieved. If the test sample does not separate during the test the amount of elongation can be determined by measuring the new distance between the gauge marks and comparing it with the original distance prior to testing.

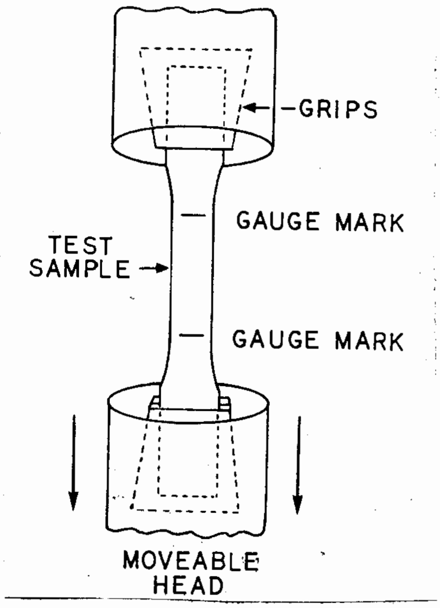

Figure 6. Gauge markings on tensile specimen prior to testing (Beck, 1970, p. 394).

Compression Strength

The ability of a specimen to resist forces that tend to crush or compress it is called compression strength. Ductile materials do not fail suddenly under compression load, but they gradually bulge and increase in area. This increased area is then able to support an increased load. Brittle materials do fail suddenly when their ultimate strength is exceeded.

ASTM test D 695-69 (1974, p. 236) is used for compression testing of plastics. The test specimen can be either a cylinder or prism in shape, with the diameter or principle width half the length to prevent buckling, see Figure 7. Specimens should be carefully made by molding or laminating so that the stress may be absorbed uniformly. See figure 8 for a photograph of the steel injection mold used for making compression strength specimens. The specimen is measured for width and thickness to the nearest .001 inch and placed in the testing machine. The stress should be applied at a fixed rate of .05 inch per minute. The formula for finding the ultimate compression strength (CS) of a specimen is:

$$CS = \frac{L \text{ (load to cause failure in lb.)}}{A \text{ (minimum cross-sectional area in sq. in.}}$$

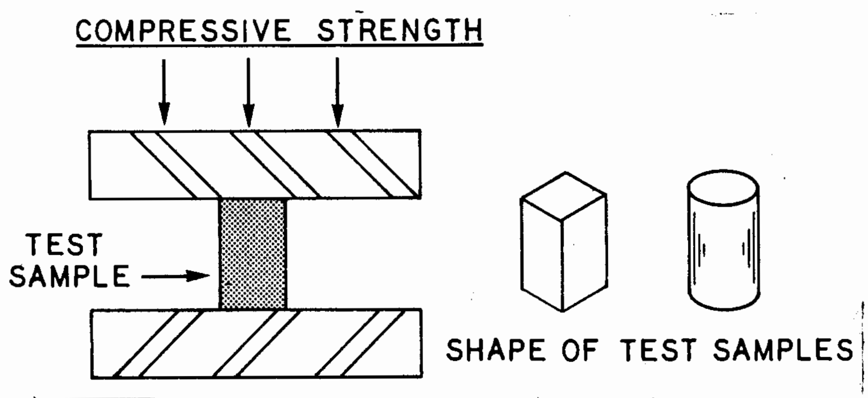

Figure 7. Shape of samples for compression strength test (Beck, 1970, p. 397).

The Vega Non-Metallic Tester works well for compression testing. Because of its expense, this writer modified the frame of the same hydraulic jack testing device used in tensile testing to do compression testing. By holding the top portion of the frame stationary, and placing the specimen between two pad supports satisfactory results can be obtained, see Figure 9. To maintain a constant even stress the handle was slowly pumped.

Figure 8. Steel injection mold for compression strength testing.

The same relationship will hold true for some plastics in this test that was shown in the tensile strength test. Without any additional stress being placed on the specimen strain will cause the specimen to collapse with a resulting loss of reading on the pressure. The plastic has now passed the elastic state and will not return to its original shape.

Figure 9. Compression tester constructed in the laboratory.

Impact Strength

Impact strength is a measure of the energy required to fracture a material by a sharp blow or fall. Impact tests are made on materials because it is recognized that the resistance of some materials to shock is dependent upon factors other than those which control its resistance to a steady or slowly applied load. One form of impact testing consists of dropping a weight on a specimen from successively increasing heights until the specimen fails. As the velocity of a striking body is suddenly changed, there must occur a transfer of energy on the part receiving the blow. The energy of the blow may be absorbed in a number of ways: elastic deformation of a part, plastic deformation of the part, or hystersis effects in the part.

ASTM test D 256-72 (1974, p. 72) governs the procedure for doing impact testing of plastics. There are two types of impact testing apparatus, the Izod type and the Charpy type. The Izod type tester uses a pendulum striker that is swung from a fixed height and strikes a test specimen in the form of a notched bar mounted as a cantiliver beam. After breaking the specimen, the arm follows through in the same direction and moves a pointer that gives a reading in foot-pounds, see Figure 10.

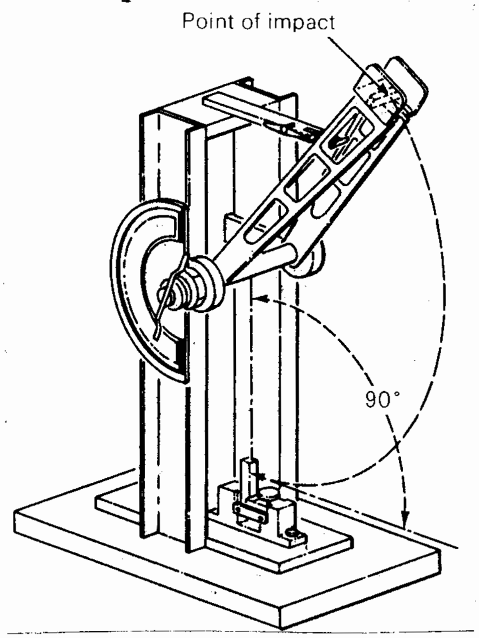

Figure 10. An Izod type impact strength tester (Milby, 1973, p. 484).

The Charpy type tester uses a test specimen in the form of a beam supported at both ends. The beam is broken by a blow delivered midway between supports. The results are reported in foot-pounds per inch, see Figure 11.

In both the Izod and Charpy type testers the specimen may be notched. On the Izod type the notch is positioned to be on the struck surface. On the Charpy type the notch is positioned opposite the impact side (Kazanas, 1974, p. 37).

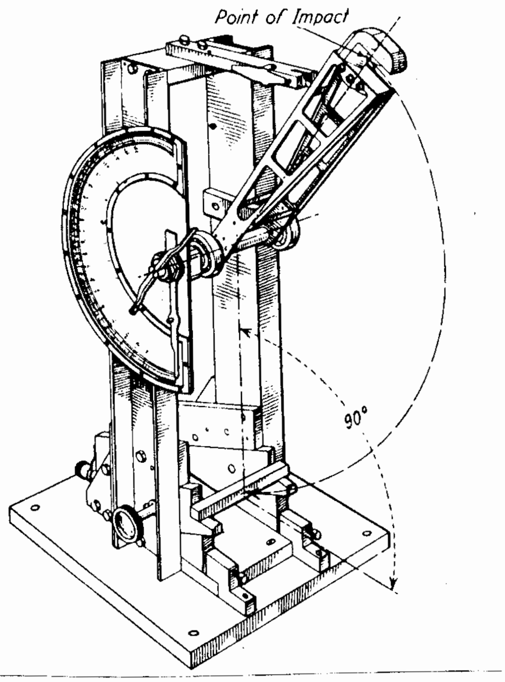

Figure 11. A Charpy type impact strength tester (ASTM, 1974, p. 85).

Both the Izod and Charpy type tester are expensive to purchase. This writer constructed an impact tester similar to the Charpy type tester after reviewing an article by Neher (1976, p. 212), see Figure 12. The procedure begins by mounting the specimen between the supports. The pendulum is drawn to the first calibration and released. If the specimen withstands the impact, the pendulum is drawn back an additional calibration and released. This procedure is repeated until the specimen fails. The last reading is the measurement used in figuring the foot-pound resistance to impact. To find the impact strength (IS) of the specimen in foot-pound per inch the following formula is used:

IS = D (distance of pendulum travel) x W (weight of the pendulum)

Figure 12. Laboratory build impact strength testing apparatus.

Specific Gravity

Specific gravity tests are concerned with the weight of the specimen compared to an equal volume of water. ASTM D 792-70 (1974, p. 295) states the procedure for this test. This test can also be a means in helping to identify some plastics. Two of the selected plastics have a specific gravity of less than 1.00, meaning that they will float. If the specimen sinks it has a specific gravity of more than 1.00. A direct reading specific gravity balance is available, see Figure 13. It eliminates time consuming labor and calculations. However, it is expenseive to purchase.

Figure 13. A direct reading specific gravity balance (Baird, 1971, p. 73)

It is possible to figure specific gravity with a laboratory balance and a piece of wire. To obtain accurate values, this procedure must be carefully followed. Small errors may cause large variations in the results. Specimens about 1/8 x 3/4 x 1 inch in size with no voids work best and are weighed on a laboratory balance and the weight recorded. To weigh the specimen in water a wire is attached to the specimen and to the balance. The balance is positioned over a beaker of water, see Figure 14. The specimen and wire suspended in water are weighed and recorded. Next the wire alone suspended in the water is weighed. This weight is subtracted from the weight of the specimen and wire in the water to find the exact weight of the specimen. This new weight is recorded. The following formula is used to determine specific gravity (SG) of a specimen (Baird, 1971, p. 72)

$$SG = \frac{AW \text{ (weight of sample in air)}}{AW \text{ (weight of sample in air)} - WW \text{ (weight in water)}}$$

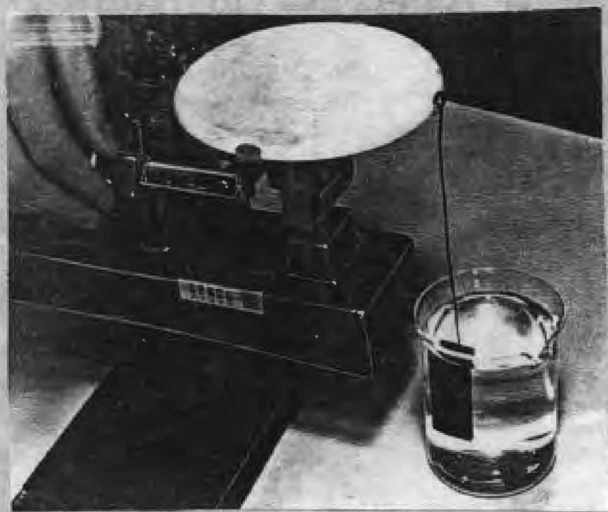

Figure 14. Laboratory method for figuring specific gravity (Baird, 1971, p. 72)

Mar Resistance

The purpose of a mar resistance test is to determine how well a plastic can withstand an abrasive action without dulling or scratching the surface finish. ASTM test D 673-70 (1974, p. 225) indicates the necessary apparatus and procedure for determining the mar resistance a plastic has to falling sand. A certain volume of sand is released from a funnel and allowed to fall through a tube onto a plastic specimen that is tilted at a forty-five degree angle. The tested specimen is then visually compared with an untested specimen and an evaluation is made of the plastics resistance to scratching.

Instead of duplicating this apparatus, this writer felt the same effects could be obtained by using a piece of six hundred grit silicone carbide abrasive paper gently rubbed on the surface of the specimen. A very gentle pressure on one forward and backward pass across the specimen are sufficient to show the mar resistance of each specimen.

Chemical Resistance

The resistance of a plastic to attack by chemicals must be considered when selecting the proper plastic for any product. Each plastic will display different reactions when chemicals make contact with it. Solvents, acids, salts, oils, and water applied separately to a specimen may cause some of the following effects: (1) no change, (2) a change in color, (3) a swelling or shrinking, (4) a surface deterioration, (5) a loss of strength or stiffness, or (6) a change in weight due to absorption.

ASTM test D 543-72 (1974, p. 154) states the procedure for doing this test. This procedure will be modified to the extent that instead of soaking the specimens in beakers of the specific agent, an eye dropper will be used to place a small amount of each agent on the specimen and any reaction noted. The testing agents used include water, acetone, gasoline, lubricating oil, hydrochloric acid, sulfuric acid, glacial acetic acid, ethylene dichloride, methylene chloride, tetrahydrofuran, cyclohexanone, and lacquer thinner.

CHAPTER VI

INSTRUCTION UNIT

Objectives

At the conclusion of this activity the student will be able to accomplish the following: (1) demonstrate his knowledge of the two classifications of plastic materials, (2) identify a minimum of eight types of plastic by completing the worksheet, (3) identify the properties of tensile strength, compression strength, impact resistance, mar resistance, solvent resistance, and specific gravity, (4) list two product applications for the eight types of plastic identified, and (5) identify five methods of processing plastic into finished products.

Safety Procedures

The student will be expected to observe the following safety precautions while performing this activity: (1) wear safety glasses, (2) hold burn samples with a spring clamp over the drip sheet while performing the burn test, (3) when detecting odor of burned samples, smell only for a short time and indirectly by waving a hand gently through the vapors toward oneself, and (5) only one person operate the hydraulic jack to avoid pinching fingers.

Student Procedures

Part I - Identification

The burn test is one of the most reliable tests to determine the type of an unknown plastic. The test involves holding the unknown plastic above a flame and observing if the material burns after it is removed from the flame, identifying the odor given off, noticing the color of the flame, the presence of any smoke, and any dripping of the material.

A burning identification table (Table VI on page 32) has been provided to assist in identifying the sample's burning characteristics. When a sample has been identified place the correct name in the answer sheet and indicate if it is a thermoset or a thermoplastic. The plastic sample will have a code number on it. Place the name of the plastic opposite the code number.

Step 1. Select a sample.

Step 2. To determine if the sample contains any chlorine, heat a copper wire until it is bright red and touch the wire to the plastic in such a way as to retain some of the plastic on the wire. Return the wire to the flame, a green color flame indicates the presence of chlorine. PVC is the only sample which contains this element in the selected samples.

Step 3. Hold the sample by the spring clamp over the alcohol lamp. Observe the burning characteristics and determine the unknown sample's correct name and record.

Step 4. Using a soldering iron, determine if the sample will melt. A thermoplastic will melt but a thermoset will not.

Part II - Research and Development Project

One of the most important aspects of industrial design is the production of a product which will perform the function for which it was intended. If a new product fails to meet this requirement it is of no value. New products will undergo a great deal of testing by a producer before mass production begins so that the consumer will have a product which does serve the intended purpose well.

This process of searching for improved production methods and more satisfactory materials is called research and development. In an industry fabricating products from plastic, the selection of the appropriate plastic is of utmost importance. In the research and development stage of material selection, the materials being considered are tested under all of the anticipated conditions to which the product will be exposed. Sufficient testing must be done to insure the strength and durability of the material finally selected. Additional considerations are costs of materials and production as well as forming methods to be used (Weede, 1974, p. 3).

The assignment for Part II is to select and design a product that will be made of plastic. Groups of four students will make up the members of research and development teams for a plastics manufacturer. The employer wants each team to design and test a new product made of plastic which will then be produced and sold by the company. As part of the research, each group will be expected to do as many of the following tests that are appropriate for the product selected and to determine which plastic best fits its requirements: tensile strength, compression strength, impact resistance, specific gravity, mar resistance, and chemical resistance. These test results will become part of an orderly written paper in which a specific product is proposed, then researched and developed. Such items as the reason for the need of this new product, forming processes used, list of equipment needed for processing, method of distribution of the product, and the possible cost of each finished article should be included in the research paper. At the end of a two week period the members of the research team will give an oral presentation to the class and present the written paper to the teacher.

Each student will be evaluated on his contribution to the team effort as well as the team's ability to develop an original product, the degree of thought involved, the neatness of the finished paper, and the manner in which the oral presentation is made. Suggested resources for the student use are listed under the heading Reference Books.

Student Test

Define the following:

1. Thermoplastic
2. Thermoset
3. Compression test
4. Tensile test
5. Impact resistance
6. Specific gravity
7. Mar resistance
8. Solvent resistance

Answer the following:

9. What is the best way to identify a plastic?
10. Name eight plastics worked with in class and indicate which classification each fits into.
11. From a research unit, recall five methods of forming plastics into finished useable products.
12. From a research unit, recall two product applications for any eight of the ten plastics tested.

Instructor Information

Audio Visual

Appendix A has some transparencies taken from the Secondary Exploration of Technology Program by Dean. There is a transparency series available from DCA Educational Products entitled "Plastics Technology" for $122 available through Brodhead-Garrett Company or Paxton/ Patterson. By writing the Society of the Plastics Industry, Incorporated a free pamphlet can be obtained listing a large selection of free films dealing with several areas of the plastic industry.

Reference Books

The following printed publications should be available for student and instructor use in teaching this unit:

Title: Industrial Plastics
Author: Ronald Baird
Publishing Company: Goodheart-Willcox
Date: 1971

Title: Cope's Plastics Book
Author: Dwight Cope
Publishing Company: Goodheart-Willcox
Date: 1960

Title: General Plastics
Author: Raymond Cherry
Publishing Company: McKnight
Date: 1967

Title: Plastics Technology
Author: Robert Swanson
Publishing Company: McKnight
Date: 1965

Title: Plastic Projects and Techniques
Author: Alvin Lappin
Publishing Company: McKnight
Date: 1965

Title: Plastics and Plastic Products Testing
Author: Gary Weede and Wayne Zook
Publishing Company: Vega Enterprises
Date: 1974

Suggested Equipment

1 Injectron injection molding machine or equal for making tensile and compression testing specimens.

1 Rockwell/Delta combination milling machine or equal for making steel or aluminum molds for tensile and compression testing specimens.

1 Wells soldering gun for plastic identification test.

1 Vega Non-Metallic Materials Tester or equal: if this is too expensive an adequate substitute can be made by using a hydraulic jack in the laboratory.

Supply Information

The plastics and many of the solvents used in this research project can be obtained either from Cope Plastics or Industrial Arts Supply Company. Addresses for these suppliers appear in Appendix C.

Cope Plastics

1/8" Nylon sheet, $1.89 per square foot
1/8" Acrylic sheet, $1.93 per square foot
1/16" Polystyrene sheet, 50¢ per square foot
Ethylene dichloride as #1 cement, $1.10 per pint
Methylene chloride as #3 cement, $2.10 per pint
Glacial acetic acid as CD-94 cement, $3.10 per pint

Industrial Arts Supply Company

ABS pellets, $1.20 per pound
Phenolic granules, $1.00 per pound

1/8" Polycarbonate sheet, $2.80 per square foot

Polyester resin, $1.95 per pint

High Density Polyethylene pellets, 99¢ per pound

Polypropylene pellets, 95¢ per pound

PVC powder, $1.25 per pound

Gasoline and lubricating oil can be obtained at a local gas station. Sulfuric and hydrochloric acid can be obtained from a school's chemistry department and most hardware stores carry acetone, lacquer thinner, and some brand name of PVC pipe solvent which contains tetrahydrofuran or cyclohexanone.

If a laboratory testing device is constructed, the necessary items are a hand operated hydraulic jack (three ton is fine), about eight foot of three inch channel steel for a frame, and a two thousand pound pressure gauge, and some brass fittings. All of these items can be purchased from local auto parts suppliers with the exception of the channel steel. Most local steel product fabricating companies will have this item in stock. If difficulty is experienced in locating a large enough pressure gauge locally, the Mueller Sales Corporation handles the necessary item in a variety of face sizes and pressure ranges. Their address can be found in Appendix C.

CHAPTER VII

SUMMARY

Review of the Project

This paper discusses some of the more common characteristics of ten plastics: Acrylic, ABS, Nylon, Phenolics, Polycarbonate, Polyester, Polyethylene, Polypropylene, Polystyrene, and PVC and how these plastics can be studied in an exploratory manner by a junior high student. Through a series of experiments the student can discover how to identify unknown plastic specimens and proceed to classify them. In the second part of the study unit, a junior high student has the opportunity to do role playing as a member of a research and development team which plans, tests, and selects a plastic for manufacturing into a consumer product, using testing apparatus built for that purpose to assist in making a proper selection of material.

Conclusions

This project does accomplish the purpose that was established in Chapter I in that a unit of study for junior high exploration into identifying and testing of selected plastics has been created. The unit will be used in the following term to establish how well it accomplishes the intended task. If necessary, modifications may need to be undertaken if unforeseen problems arise. Due to the time limitation a field test of the instruction unit was impossible.

Recommendations

The study units set forth in this research paper will need further field testing in the classroom situation to determine what revisions may be required. This investigator has found that as of this date, the first unit on identifying various plastics works well as a learning tool for students in making them aware of selected plastics and their properties. The second unit on student role playing will require some additional information to make it more meaningful. One suggestion would be a series of discussions about industries' research teams and their role in product design.

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APPENDIX A

Overhead transparencies taken from Secondary Exploration of Technology Program.

APPENDIX B

Student answer sheet for Instruction Unit, Part I.

Identification Worksheet

Name____________________

Sample	Plastic's Name	Any Chlorine	TP or TS
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

APPENDIX C

Addresses for equipment and supply houses.

Brodhead-Garrett Company
4560 East 71st Street
Cleveland, Ohio 44105

Cope Plastics
1111 West Delmar Avenue
Godfrey, Illinois 62035

Industrial Arts Supply Company
5724 West 36th Street
Minneapolis, Minnesota 55416

Mueller Sales Corporation
1119 Wenig Road N.E.
Cedar Rapids, Iowa 52402

Paxton/Patterson
5719 West 65th Street
Chicago, Illinois 60638

APPENDIX D

Addresses of Book and Audio Visual publishers.

Goodheart-Willcox Publishing Company
123 West Taft Drive
South Holland, Illinois 60473

McKnight Publishing Company
U.S. Route 66 at Towanda Avenue
Bloomington, Illinois 61701

Vega Enterprises, Incorporated
Route 3, Box 300B
Decatur, Illinois 62526

The Society of the Plastics Industry
250 Park Avenue
New York, New York 10017

APPENDIX E

A sample letter.

Genova

Corporate Headquarters
7034 East Court Street
Davison, Michigan 48423
Phone: 313/744-4500

July 1, 1976

Mr. Paul Harrington

Mt. Vernon, Iowa 52314

Dear Mr. Harrington:

Thank you for your letter of June 21st on the subject of testing plastics, and PVC in particular.

By far the most aggressive solvent for both PVC and CPVC (chlorinated polyvinyl chloride) is tetrahydrofuran. Our solvent cements are predominantly THF, with cyclohexanone and methyl ethyl ketone acting as evaporation rate retardants.

Cyclohexanone, tetra hydro furan, methyl ethyl keton and isophorone are all active PVC solvents, but they dissolve it so slowly that it would take many hours to effect the test. Dimethyl formamide is active too, and comes nearest to tetrahydrofuran, but it has toxicity problems, and it can be absorbed through the skin, so we do not use it.

Applying a match to PVC will cause it to decompose so long as the flame impinges on the specimen. The resultant odor is characteristically hydrogen chloride, causing telltale irritation in the nostril.

I do not regard tetra hydro furan as particularly dangerous in small quantities, excepting only the low flash point. A 50/50 mixture with isophorone is much more stable, (isophorone has the highest boiling point of all of the solvents) yet it would greatly facilitate detection by dissolution.

I hope that these comments prove helpful to you.

Very truly yours

GENOVA, INC.

K. V. Pepper
Vice President - Operations

KVP/mh

Plant Locations:

300 Rising Street
Davison, Michigan 48423
Phone: 313/653-4181

500 N. W. 12th Street
Faribault, Minnesota 55021
Phone: 507/332-7421

Forest Road
Hazleton, Pennsylvania 18201
Phone: 717/459-1436

VITA

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Date of Birth.................

Place of Birth............... Iowa

Wife... .... Diane Marie

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David Adam,

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Graduated 1965

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Marshalltown, Iowa
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University of Northern Iowa
Cedar Falls, Iowa
1967-1969 BA 1969

University of Northern Iowa
Cedar Falls, Iowa
1971-1976

Present Position.............. Lisbon Community Schools
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