BOSTON UNIVERSITY

College of Business Administration

THESIS

A STUDY OF THE MODERN PLASTICS INDUSTRY

by

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INTRODUCTION

Prehistoric man's needs were few and simple, and his resources were the materials immediately at hand. As his wants grew more varied, he exerted himself to seek out what might be useful and to adapt it to new needs.

The natural resources seemed inadequate both in quantity and in quality to cope with the demands of industry. It is greatly to the credit of the scientist, and more particularly to that of the chemist, that the ever-increasing demands of mankind can be satisfied. One outstanding contribution is the development of plastic materials.

In 1868 celluloid, the first plastic, was made. Since that day various new forms of these plastic materials have been produced; innumerable new uses for them are continually being discovered. In industry, in the home, in transportation, in all types of personal belongings, plastics are supplementing metal, wood, glass, rubber, and other materials, for which there has been in the past no practical substitute.

This thesis deals with a study of the modern plastics industry. The purpose of the thesis has been to evaluate the significance of the development of these new products and the creation of an entirely new industry.

The introductory chapter presents the progress of the plastics industry from the early beginnings to the most recent
discoveries in synthetic resins. The second chapter shows the status of the industry in the world today. This chapter is followed by one which sets forth, in some detail, the chemical analysis of all the important plastics, and which justifies, at length, the outstanding place of modern plastics in industry. This, in turn, is followed by a discussion of the limitations and problems connected with the industry. The chapter which follows considers the present-day trends. The final chapter deals with an appraisal of the industry.

The materials and organization have been evolved from textbooks, magazines, and trade journals, from questionnaires submitted to various manufacturing concerns, and from personal interviews with research and production engineers.

The references at the end of the thesis have been selected from a large body of material, of which only the most significant are listed in the bibliography.
CHAPTER I

HISTORICAL DEVELOPMENT OF PLASTICS

"Out of sour milk, carbolic acid, formaldehyde, urea, man has created tough primary materials for industry and the arts." ¹

The story of the growth of the plastics industry is a story of industrial research chemistry, and, as time counts, the industry is comparatively new.

Before modern times, the word "plastics" was used to designate any material, such as rubber, cement, clay, or glass, that could be molded or cast into solid form. But today the term is used in a much more restricted sense. It is applied to natural products, such as casein and shellac together with the synthetic products, phenolic resins, cellulose derivatives, etc.

The history of celluloid is a relatively short one. A little over a hundred years ago, Breconnot discovered nitro-cellulose, which was further developed by Maynard in 1847. A little later, Parkes of Birmingham, England, introduced the first celluloid-like substance of its kind. This material was the forerunner of what we know today as celluloid or pyroxylin.

Then, in 1868, an extraordinary thing occurred. The world supply of ivory was becoming scarce, with a stimulating effect upon the price of billiard balls. As a result, a New York

manufacturer offered a prize of $10,000 to anyone who could find a substitute. Spurred by this offer, John Wesley Hyatt experimented with cotton cellulose and nitric acid and succeeded in producing an ivory-like substance, which he called celluloid. He won the distinction of having created a new material, "a material that was not to be found in nature and could not be converted back again into the substance out of which it was made."²

For the next twenty-two years, no new plastic appeared on the market. Then, in 1890, a German chemist, Dr. Adolph Spitteler, in search for a white blackboard to use in the classroom, happened to mix formaldehyde with casein from cow's milk. The result was a shiny, hornlike substance, man's second plastic. In the United States today this casein plastic is known under the trade names of Ameroid and Aladdinite and is used chiefly in the manufacture of buttons and buckles.

Again, there was an interlude until 1909 when another important new substance emerged. Dr. Leo H. Baekeland, a Belgian-American chemist of Yonkers, New York, made his successful discovery which gave to the world a new material. He called it by the trade name Bakelite. In attempting to find a substitute for shellac and other natural resins, Dr. Baekeland found

²Ibid.
that by joining together phenol and formaldehyde a resin-like material resulted, man's first synthetic resin. It resembled amber in appearance, but differed from amber in its properties.

Further experiment revealed that, by the addition of various solvents and fillers, a variety of resinous materials might be produced. Naphthalene may be used as a plasticizing or softening agent. The filling materials, which include wood flour, asbestos, fabric, and paper, are for the added value given by the special properties of these materials—better molding qualities, greater toughness and strength, and, in the case of mineral fillers, an increased degree of water and heat resistance.

The industrial development of resinous materials, of which Bakelite materials are the foremost representative, is one of the most interesting and important achievements in organic synthesis.

"The synthetic plastic is a glamorous substance and a tribute to the powers of man. In the light of it the layman has been taught to believe that an age of plastics is at hand."

The synthetic resins were first used in the electrical field, but, due to the high cost of manufacture and of raw materials, their general adoption was slow. It was not until the autumn of 1918 that Bakelite entered the market on a competitive

3 Ibid.
basis. After the Armistice, the United States Government found itself the possessor of about forty million pounds of phenol for which it had no further use as a war material. In order to dispense with this surplus, the Government turned this supply over to a large phenol manufacturer, fixing the price at seventeen cents a pound as compared with fifty-five cents a pound, six months before the War ended.

With the growing popularity of the radio in 1920, the demand for insulating materials increased. The low cost of phenol now enabled Bakelite to capitalize its advantages as a material for radio parts and to compete favorably with its rivals—hard rubber and porcelain—in the entire electrical parts field.

The chief objection, however, was that phenol-formaldehyde products could only be molded in dark colors. During the early part of 1920, considerable research was in progress to develop a light-colored plastic molding compound. As a result of this study, a cast urea resin was developed which, although colorless and transparent, was lacking in permanence. The great disadvantage was that it was not suitable for molding.

About this time, the Toledo Scale Company, in search for a substitute for a lightweight material for a scale housing, became interested in a plastic material as a possible substitute and established a fellowship at the Mellon Institute of Research
in Pittsburgh to develop a molding compound in light colors with the properties of the phenol-formaldehyde type. By 1931, the fellowship succeeded in producing a urea-formaldehyde molding powder in a color range from white through the pastel shades to black. By 1935, the Toledo Scale Company added to its regular production a scale housing made of urea-formaldehyde resin plastic.

Thus, down through the years research has continued and has resulted in many new types of materials which are produced by variations in original formulae, and by the addition or substitution of widely varying basic raw materials.
CHAPTER II

PRESENT STATUS OF MODERN PLASTICS IN THE WORLD

The plastics industry now has a recognized place in our national economy. Its progress in world commerce as well as its application in practically every form of industry emphasizes the part it plays in modern existence. The industry is in a state of flux and is constantly increasing its scope. As a matter of fact, it is of so diversified a nature that adequate data showing production in all branches are not available. Present trends undoubtedly point to continued expansion in the plastics and molded products industries. The following quotation exemplifies this fact:¹

"According to a preliminary report compiled from data collected in the recent Biennial Census of Manufacturers, the total production of plastics and plastic products in 1935 (the last Census year) by establishments in the chemical industry is valued at $44,163,055, an increase of 82.6 per cent as compared with $24,188,191 reported for 1933."

Plastic production in Great Britain is on the upward trend but progress has been slower than in the United States due to the fact that British manufacturers have been less successful in linking the skill of the designers to mass production. The place of plastics in British industry may be summed up best in

the following extract:

"In 1936 the Financial Times estimated that 50,000,000 pounds sterling has been invested in the actual development of the British plastics industry. Direct employment was given as between 20,000 and 30,000; indirect employment as some 20,000. Production of plastics in 1935 was stated by the Financial News to be 100% greater than in 1934."

In France the plastics industry is steadily growing. At the present time, more than a dozen manufacturers are engaged in the production of synthetic resins. The output of pyroxylin plastics is said to be approximately 3,000 tons a year.

On the other hand, practically no pyroxylin plastics are being manufactured, at the present time, in Czechoslovakia. There, the plastics industry is very new and the trend is toward synthetic resin production.

Still again, Japan is a large producer of pyroxylin products. This branch of the plastics industry is aided not only by cheap labor, but by the fact that Japan is the home of camphor, a prime material in the manufacture of pyroxylin. This plastic is reported to have grown considerably in recent years and to compare favorably with the same industry in other producing countries. However, a number of firms are engaged in the production of synthetic resins and products, especially

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those of the phenolic type. Molded products are produced by the small household as well as by the large resin manufacturer.

In Germany, as in most countries, the pyroxylin or celluloid industry is the oldest branch of the plastics industry. Next to the United States, Germany is the largest producer of synthetic resins. About 90% of the synthetic resin production is of the phenolic type. In 1936 the total production of plastic materials of all kinds amounted to around one-fifth of the total world supply.

Although phenolic resins still comprise the bulk of the molded synthetic resin output, other types of resins suitable for injection molding (see p. 37 and p. 68) have been developed. The perfection of automatic injection molding machinery considerably increased the demand for injection molded products with indications of their growing importance in the future in the entire plastics field.

An outstanding factor in the expanded production of synthetic resins is also due to the fact that they are purely domestic raw materials and thereby replace imported raw materials including iron, natural varnishes, and gums. Their adoption was so widespread that the German Government was obliged to impose restrictions so that the production of synthetic resin plastics would be devoted exclusively to replacing products based on imported raw materials.
The upward curve of exports has aided in the expanding production of synthetic resins. The great bulk of exports go to practically all of the European countries and even to Latin-American markets, particularly Argentine and Brazil.

The following table affords a comparison of the geographical distribution of Germany's exports of synthetic resins in recent years and reveals the substantial gains recorded in shipments to all leading countries:

**GEOGRAPHICAL DISTRIBUTION OF GERMANY'S EXPORTS OF SYNTHETIC RESINS**

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CHAPTER III
PURPOSE OF THE STUDY OF THE MODERN PLASTICS INDUSTRY

The modern plastics industry deals chiefly with moldable materials manufactured from organic compounds, that is, combinations of carbon with hydrogen, oxygen, nitrogen, and other elements. It does not include such inorganic molding materials as concrete, cement, ceramics, and also rubber, an organic substance. They are not generally included within the scope of the plastic trade, as it is known today, inasmuch as the industries using these materials are much older and were already organized prior to the advent of the newer plastics.

The field of modern plastics is an extremely wide one. The four principal types of organic plastics are synthetic resins, natural resins, cellulose derivatives, and protein substances. In order to show clearly how these plastics are being substituted for other materials, it will be necessary to give, at least, a general description of their chemical origins.

The plastics used in the molding industry may be divided further into two groups based on their behavior toward heat, namely, thermoplastic and thermosetting. The thermoplastic materials are permanently fusible, that is, they melt when heated and harden when cooled. The cellulose derivatives, some synthetic resins, and most of the natural resins are examples of this type.

The thermosetting plastics, on the other hand, are thermo-
plastic at some stage of their existence but under heat become hard and rigid and permanently infusible. Most of the molded products of synthetic resin composition belong to the thermo-setting type.

The formation of plastic materials is caused by both physical and chemical forces. When two compounds unite, there is no clear dividing line between them and the resulting compound behaves differently from either one of its pure compounds. Instead of separating from solutions or solidifying in crystals, these mixtures tend to form structureless masses.

The chemical processes may be divided into two groups: addition reactions (polymerization) and condensation reactions. The formation of resins by strictly addition reactions is limited to compounds containing an unsaturated group capable of reacting within themselves, in other words, the reaction of the molecules of one compound with each other.

Condensation reactions are characterized by the interaction of two or more different compounds yielding essentially new molecules, that is, by the linking together of atoms with the accompanying elimination of elements, such as hydrogen, or nitrogen, or of simple compounds, such as water, hydrochloric acid, hydrogen sulphide, or sodium bromide. By the condensation reactions, in many instances, catalysts (chemical agents which cause other substances to react without entering the compound
itself) are used to accelerate the formation of plastic masses.

The most outstanding and probably the best known of the plastics are the synthetic resins because of their infinite number of uses. They may be subdivided into several chemical types. The phenolic-aldehydic type is the leading member of the synthetic resins. The raw materials are generally formaldehyde CH₂O and phenol (also known as carbolic acid). Phenol is obtained as a by-product of the coal distillation industry, or it is prepared synthetically by processes such as the alkaline hydrolysis of chlorobenzene. Formaldehyde, which is normally a gas, is made by the catalytic oxidation of methyl alcohol. The formation of the resin from phenol and formaldehyde may result in fusible or infusible products depending upon whether acid or alkaline catalysts are used.

Some of the trade names of phenol-formaldehyde molding compositions are Bakelite, Durez, Haveg, Makalot, and Resinox. Cast phenol-formaldehyde resins are variously known on the market as Catalin, Merblette, and Fiberlon. Some of the trade marks of the laminated phenol-formaldehyde products are Formica, Micarta, and Textolite.

Another important resin of the phenolic-aldehydic group is prepared through the reaction of phenol with furfural C₄H₅O.CHO. Furfural, the first and today one of the most important chemurgic by-products, was one of the earliest attempts of the Federal
Government to find an industrial outlet for farm products. Furfural is an aldehyde obtained from oat hulls (at present, the most widely used raw material), cornstalks, and the like by distillation with sulphuric or hydrochloric acid. The products of this reaction may be either liquid or solid depending upon the time of reaction and the percentage of furfural. Acid catalysts produce infusible products; alkaline catalysts yield resins which are better adapted to molding. Durite is the name applied to a phenol-furfural product.

Although many resinous substances can be obtained by the interaction of aldehydes (dehydrogenated alcohols) and amines (ammonium salts), only two of these have become important commercially, namely, the urea-formaldehyde and thiourea-formaldehyde resins.

Pure urea $\text{NH}_2\text{CO-NH}_2$ is a white crystalline substance. The world supply of this chemical is largely controlled by the I. G. Farbenindustry A-G, Germany. The increasing demand for urea of a high-grade quality has led to the development of a number of synthetic processes. The resin is made industrially either from calcium cyanimide or from ammonia and carbon dioxide. In thiourea, which is a by-product of the gas industry, there is an atom of sulphur instead of the oxygen atom in urea. The resins of both the urea and thiourea are
colorless and readily converted into transparent and translucent molded products of many colors. The urea resin, however, is the more widely used because the sulphur in the thiourea resin has a corrosive effect on the molding equipment, thereby requiring expensive chromium-plated molds. Not only are the exterior appearances or properties of the urea resin highly attractive, but the method of manufacture and the nature of the raw materials are such that they make possible the production of this resin in enormous quantities. The molding compositions are known under such names as Beetle, Plaskon, and Unyte.

Vinyl resins \( \text{CH}_2=\text{CH}- \), resulting from the polymerization of vinyl compounds by the action of catalysts or ultra-violet light, have been known to the chemist for over a hundred years, but they lacked the proper physical properties for commercial application.

It was not until recently that extensive study has been made for their adaptation to the plastics industry. The products of polymerization of vinyl chloride and vinyl acetate, esters of vinyl alcohol \( \text{CH}_2=\text{CHOH} \), are known in this country as Vinylite. They are thermoplastic and, in general, are clear, tough, and odorless. They may be applied in solutions, calendered, molded, or extruded with or without fillers or
pigments.

Another resinous product of the vinyl type is made from styrene \( \text{C}_6\text{H}_5\text{CH} = \text{CH}_2 \), sometimes called polystyrene. Styrene occurs ready formed in coal tar and in drip oil of carburetted water gas, but, at present, the most satisfactory process for producing styrene is from ethylene and benzene. It is a colorless liquid, boiling at 143 deg. C., and it can be converted into a hard, tough, transparent, and horny substance, which is almost colorless.

Like many other resinification reactions, the transformation of the liquid styrene to a solid resin is one of polymerization. Styrene polymerizes slowly if left to itself; but it polymerizes quickly if heated to a temperature of 200 deg. C., or if brought in contact with a metal such as sodium.

Styrene is a thermoplastic molding material. The production of this resin is still comparatively expensive. Up to the present time, no process appears to have been developed which puts the price on a par with that of other leading synthetic resins. This fact has prevented it from attaining the industrial position to which its excellent strength and dielectric qualities would otherwise bring it. The trade name Victron is used for a styrene resinous product made in this country.
Among the more recent types of the commercially available resins are the polymers of the esters of acrylic acid, \( \text{CH}_2=\text{CH}-\text{COOH} \), and methacrylic acid, \( \text{CH}_2=\text{C} (\text{CH}_3)-\text{COOH} \). The acrylic resins are prepared by the reaction of ethylene chlorohydrin with acrylic acid esters. Esters of methacrylic acid are prepared by converting acetone cyanohydrin into hydroxyisobutyric acid esters and dehydrating the hydroxy ester with a suitable reagent, such as phosphorus trichloride or thionyl chloride. They are characterized by their colorless transparency, thermoplasticity, stability against aging, and are noted for their optical clarity. The trade name Acryloid is applied to the products of acrylic acid derivatives by one of the manufacturers in this country.

The next group of synthetic resins to be discussed is the hydroxy-cerboxylic or alkyd (from alkyl acid) resin. The resin formation results from the production of large molecules by the esterification of polybasic acids with polyhydric alcohols, for example, the combination of phthalic acid with glycerol. Although these resins are used for molding compounds, their chief outlet is for film-forming bases in varnishes and lacquers. They have, to a large extent, supplanted the natural resins in such products, not because they are produced more cheaply than natural resins but because they combine uniform-
ity of material with valuable properties, such as flex-
ibility, durability, and solubility in the usual varnish
solvents. They are known in the trade under such names as
Glyptal and Rezyl.

The final group of the synthetic resins in my study is
the indene resin type. It is prepared from two compounds,
indene and cumaron and their homologs (compounds which are
chemically related, but differ from member to member in
composition by one atom of carbon and two atoms of hydrogen),
which are obtained from coal-ter distillate.

Pure indene and cumaron are both difficult and expensive
to separate; hence, fractions of solvent naphtha (coal-ter
distillate) rich in cumaron and indene are treated with a
polymerizing agent such as sulphuric acid and are used as raw
materials in resin manufacture. Indene resins, known in this
country as Cumar and Neville, are used chiefly in varnishes
and, to some extent, as thermoplastic molding materials. The
best grades of these resins are light in color and free of
acidity.

The second main division of organic plastics in my survey
deals with the cellulose derivatives. In the early days of the
plastics industry, they were practically confined to the
nitrate product. Today, however, the acetate derivatives are
prominent in the plastics field and many of the cellulose compounds are in the experimental stages.

The chief sources of cellulose are cotton and wood. In a pure state, cellulose is a carbohydrate having the same formula as starch $C_6H_{10}O_5$. Cellulose nitrate for a plastic material is prepared by treating purified cellulose with nitric acid and a dehydrating agent such as concentrated sulphuric acid to take up the water that is formed. The cellulose nitrate must be prepared in such a way that the cellulose raw material has the proper purity and physical condition to insure intimate contact with fibers and nitrating mediums. These chemically prepared nitrates are mixed with solvents, such as alcohol, acetone, and a plasticizer, for example, camphor. Dyes and pigments are added depending upon the specifications of the finished product.

Cellulose nitrate is a thermoplastic material. Its ease of molding and the variety of colors in which it may be obtained are important factors in its extensive use. However, its low-ignition temperature and high rate of burning are serious disadvantages. Some of the trade names of cellulose nitrate plastics are Pyroxylin, Celluloid, Fiberloid, Nixonoid, and Pyralin.

To overcome the disadvantages of flammability of the nitrate plastics, cellulose acetate derivatives were developed.
They resemble the nitrate products in physical properties except that they burn very slowly and have a high-ignition temperature. They are prepared by the esterification of cellulose with acetic acid using some acetic anhydride to combine with the water formed by the action of the acetic acid on the cellulose and a small amount of sulphuric acid to catalyze the reaction.

They are thermoplastic, highly resistant to discoloration through aging, especially on exposure to sunlight. They may be obtained in all colors from transparency through translucency to opacity. They are used for many products formerly molded of cellulose nitrate. However, they are still somewhat more expensive than nitrate products. Cellulose acetate plastics are sold under such names as Lumarith, Fiberloid, Plastacele, and Tenite.

Various cellulose ethers have appeared on the market within the past few years, particularly ethylcellulose. Chemically speaking, this compound is an ether. The ethyl group is joined to the cellulose through oxidation and this structure has a wide and well-founded reputation for stability to chemical action, and to the action of heat and light. In fact, a great advantage of this material over other cellulose derivatives is its flexibility and toughness at low temperatures. Ethylcellulose products are known under the trade
name of Ethocel.

Another cellulose plastic, which has become an important item of commerce, is the transparent wrapping material known as Cellophane. The chemical composition of the finished product, \( \text{C}_6\text{H}_9\text{O}_4.\text{OH} + \text{CS}_2 + \text{NaHSO}_4 \), is similar to that of the original cellulose; but in the process of manufacture sodium cellulose xanthate is first prepared and the cellulose is then regenerated by suitable chemical treatment. The chemical reactions involved may be summarized briefly:

1. Sodium cellulose is prepared by treatment of the wood pulp or cotton linters with an 18% to 20% sodium hydroxide solution.

2. The sodium cellulose, thus formed, is treated with carbon disulphide to yield sodium cellulose xanthate.

3. This product is dissolved in dilute sodium hydroxide to yield an orange-colored sirupy mass, known technically as viscose. After a ripening period, the viscose is forced through narrow slots into a bath containing a solution of sulphuric acid and sodium sulphate, which brings about coagulation and regeneration of the cellulose.

Since it is imperative that the passage of moisture through the film be prevented, the regenerated cellulose is coated with a thin film of cellulose nitrate lacquer. In addition to its use in the production of transparent sheets, this xanthate
method of processing cellulose is also employed in the manufacture of viscose rayon.

The third main division of my chemical analysis is the natural resin group. These resins are of minor importance in the plastics industry, but, in order to make my analysis complete, it is necessary to include this branch in my study. They are largely used as fillers for reinforcement of the molded parts or as lubricating agents to insure an easy flow of the material into the mold cavities.

The natural resins used in plastics may be divided into three groups: those of animal origin, those of vegetable origin, and the asphalts, obtained chiefly from mineral sources.

The only resin of industrial importance in the first group is shellac produced by an insect which grows upon certain species of trees in India and Southern Asia.

The resins of vegetable origin are obtained from various trees. Two examples are dammar gum, which is obtained in Java and Sumatra, and rosin, which is the solid residue left in the still after distillation of turpentine from pine resin extracts in this country.

The asphalts comprise the third group of the natural resins and are sometimes called the mineral resins. They consist of hydrocarbon complexes, called bitumens, and are obtained from mineral deposits in various parts of the world, including
many in this country.

The natural waxes may also be classified according to their sources as animal (beeswax), vegetable (carnauba wax from leaves of a Brazilian pine), and mineral (from peat and brown coal). These products are quite similar chemically and consist largely of fatty acid esters of mono- and dihydric alcohols mixed with the related free acids, alcohols and hydrocarbons.

The fourth and final group of organic plastics to be considered comprises the protein materials. These plastics include the casein obtained from milk, the blood albumins obtained as by-products of slaughterhouse operations, and the soy-bean proteins which remain in the pressed cake after the removal of the oil.

The best known and oldest of these plastics is made from casein obtained from milk. Casein exists in a suspended or colloidal condition in cow's milk. The average milk contains approximately 3% of this protein. It exists probably as a lime compound in combination with calcium phosphate and is best described as a phospho-protein.

In order to obtain useful articles, the protein must be converted into a hard and stable compound. A variety of substances have been proposed for this purpose, such as aldehydes, chromium salts, tannic acid, and the like. In
practice, however, formaldehyde is universally used to harden these protein plastics. The exact nature of the reaction which takes place is not known but there is probably a condensation of the aldehyde with the amino group.

The following description of the manufacturing process for casein plastics applies to the other protein materials as well. After the casein is hardened and dried, it is ground into fine powder and thoroughly mixed with fillers such as wood pulp or dyes for coloring depending upon the specifications of the finished product. This compound is then ready for casting or extruding. It cannot be molded and it absorbs water readily but, where only simple pieces are desired, its application is proper. Casein products are sold under such trade names as Ameroid, Ronyx, and Aladdinite.

The soy bean has been grown in Asia for over five thousand years, but it has been almost a curiosity in this country until recently. Within a decade it has advanced from a position of minor to one of major importance.

"Many years ago it was written by the chemical prophets that some day the lowly soy bean would be transformed into an important industrial material to compete with steel and synthetic plastics. There was nothing particularly complicated about that transformation from a chemical engineering viewpoint; but an economic stimulus was lacking. The industry seemed to need an outside impetus if ever the prophecy
was to be turned into profits.\(^1\)

Henry Ford is supplying just that sort of impetus and is today sponsoring a program that promises a tremendous soy bean development. In devising a closer linkage between agriculture and manufacturing, the Ford Motors Company has spent a considerable amount of time and money in investigating the possibilities of the soy bean with the result that it has very recently begun to use it in its plastic molding. The oil is first extracted and is used for a variety of industrial purposes—in paints and body enamel. Only the meal is used in molding. The extracted meal contains approximately 48% protein, of which the major portion is casein; 38% carbohydrate, 7% cellulose, and 7% ash.

In the early experiments pure casein-formaldehyde plastics were used for molding materials, but it was found that this compound absorbed as much as 20% of moisture over a period of time, resulting in warping and cracking. To overcome this characteristic, a certain amount of phenol is added. This composition of phenol and casein-formaldehyde is both waterproof and durable. As phenol is a good solvent for soy-bean meal, it serves the casein for the formaldehyde reaction and the carbohydrates for filler, thereby reducing the cost con-

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siderably over a straight phenolic plastic. For additional filler, wood flour is used. Although the cost of the soy-bean plastic is greater than steel per pound, the final cost of steel parts is in excess of that for the finished plastic product due to the finishing and polishing of the steel.

The Ford Motors Company owns at the present time only 12,000 acres of land planted in soy beans, but for the bulk of its supply it expects to depend upon independent farmers, thus strengthening mutual relations between agriculture and industry.

The following table shows the use of soy-bean plastics in the manufacture of the Ford automobile:

<table>
<thead>
<tr>
<th>CAR PARTS</th>
<th>Oil-Free</th>
<th>Meal</th>
<th>Soy Beans</th>
<th>Soy Beans</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>in</td>
<td>in</td>
<td>in</td>
</tr>
<tr>
<td></td>
<td>of Cars</td>
<td>Pounds</td>
<td>Bushels</td>
<td>Acres</td>
</tr>
<tr>
<td>Gear shift knobs</td>
<td>1,000,000</td>
<td>66,666</td>
<td>1,460</td>
<td>91</td>
</tr>
<tr>
<td>Horn buttons (large)</td>
<td>&quot;</td>
<td>22,200</td>
<td>487</td>
<td>30</td>
</tr>
<tr>
<td>Light switches</td>
<td>&quot;</td>
<td>80,000</td>
<td>1,800</td>
<td>113</td>
</tr>
<tr>
<td>Distributor caps</td>
<td>&quot;</td>
<td>320,000</td>
<td>7,200</td>
<td>450</td>
</tr>
<tr>
<td>Distributor bars</td>
<td>&quot;</td>
<td>300,000</td>
<td>7,000</td>
<td>440</td>
</tr>
<tr>
<td>Coil caps</td>
<td>&quot;</td>
<td>100,000</td>
<td>2,333</td>
<td>222</td>
</tr>
<tr>
<td>Coil plates</td>
<td>&quot;</td>
<td>140,000</td>
<td>3,100</td>
<td>195</td>
</tr>
<tr>
<td>Window frames</td>
<td>&quot;</td>
<td>3,333,333</td>
<td>74,074</td>
<td>4,560</td>
</tr>
</tbody>
</table>

Ibid. p. 176.
Chemical Analysis of Plastic Materials

Water
  Watergas
  Acetylene
  Ethylene
    Ethylene Chlorohydrin
    Ethylene Cyanohydrin
    Ethylbenzene
  Acetaldehyde
    Calcium Acetate
    Acetone
    Acetone Cyanohydrin
    Methacrylic Acid-Esters
    Polystyrene Resin
      Polyvinyl Resin
        Polycrylic Esters
          Polymethacrylic Esters
          Phenol
          Formaldehyde
          Urea
          Novolak Intermediate Step
    Phenol Plastics
    Condensation Products

Coal
  Carbide
  Carbon Monoxide
  Hydrogen
  Acetaldehyde
  Acetic Acid
  Benzenes
  Methanol

Lime
  Calcium carbonate
  Oxygen
  Nitrogen

Air
  Acetylene
  Ammonia
  Acetaldehyde
  Acetic Acid
  Ethylene
  Ethylene Chlorohydrin
  Ethylene Cyanohydrin
  Ethylbenzene
  Acetaldehyde
  Calcium Acetate
  Acetone
  Acetone Cyanohydrin
  Methacrylic Acid-Esters
  Polystyrene Resin
  Polyvinyl Resin
  Polycrylic Esters
  Polymethacrylic Esters
  Phenol
  Formaldehyde
  Urea
  Novolak Intermediate Step
  Phenol Plastics
  Condensation Products

Cellulose
  Wood-Cotton
  Cellulose Nitrate
  Cellulose Acetate

Casein
  from Milk
  Casein Plastics

Polymerization Products
  Injection Molding
  Sheets
  Molding
  Lacquer
  Varnish
  Injection Molding
  Molding
  Laminating
  Casting
  Molding

Products from Cellulose Derivatives
  Tubes
  Rods
  Sheets
  Film
  Injection Molding
  Casein Plastics
Since the early development of plastic molding materials, greater importance has been assumed by the types of fillers employed in their manufacture. Variations provided by the choice of fillers are very important and a thorough understanding of these possibilities is a deciding factor in the selection of the correct molding material for a specific application. Nevertheless, the all-important ingredients are the resins which provide the plastics with their distinctive characteristics.

Fillers were first employed in an effort to lower costs of molding materials. This factor is still important, but it soon became evident that resin-filled molding materials possessed particular advantages. These advantages may be listed briefly as follows:

1. Greater speed of molding
2. Closer tolerances obtainable in the molded piece
3. More constant strength characteristics
4. Special characteristics of the fillers—electrical properties, heat resistance, chemical resistance, light resistance, anti-friction properties, etc.—allowing the development of molded parts possessing these special properties to a marked extent

Greater speed of molding is the prime reason for the rapid rise of the plastics industry. The comparatively short molding cycle has adapted itself readily to mass-production methods.
The lower shrinkage of the molded piece, together with the close tolerances that can be held both during and after the molding operation, makes possible the production of intricate pieces. In most cases, the addition of fillers gives a greater uniformity of strength characteristics and the variations caused by slight changes in molding technique are greatly decreased.

Fillers may be roughly divided into organic, carbon, and mineral types. This classification, of course, does not refer to pigments since they are used in relatively small amounts.

**ORGANIC FILLERS**

Cellulose derivatives, such as

1. Wood flour
2. Cotton
3. Paper or pulp
4. Textile by-products

**CARBON FILLERS**

1. Graphite
2. Carbon black

**MINERAL FILLERS**

1. Asbestos
2. Mica
3. Lead oxide
4. Miscellaneous, as barytes, silicates, aluminates, zinc oxide, etc.

Of all these fillers, wood flour has become the standard for large-volume production of phenolic molding materials. This is due not only to abundance at low cost, strength prop-
erties, good appearance, reasonably good electrical properties, and moisture resistance, but also to its low specific gravity.

The specific gravity is important from the standpoint of cost. The trade molder buys the molding compound on a price-per-pound basis and sells his finished article on a volume basis. In this respect, cellulose derivatives have a marked advantage over mineral fillers. This may be illustrated by the following figures which represent the specific gravity of a few common fillers:

Wood flour----1.36  
Cotton------1.36  
Asbestos-----2.0  
Mica--------1.90

Naturally, articles molded from materials containing high-gravity fillers are high in gravity. Thus, on a volume or piece basis, pieces molded from materials containing mineral fillers are at a definite disadvantage.

Within recent years, a variety of molded products, possessing a particular property or combination of properties, has appeared on the market. In this field, various fillers, other than wood flour, have justified their use.

For most purposes, the strength of molding materials, containing wood-flour fillers, is sufficient; but, where sudden shock loads occur, these materials are not practical. A standard test piece of this material will vary from 0.11 to
0.19 ft. lbs. energy to break.

A whole series of molding materials, having greater impact resistance than molding materials containing wood-flour fillers, have been developed within recent years. The range of such impact materials is from 0.20 to 2.0 ft. lbs. to break. Fabric materials, by-products of the textile industry--clippings, shearings, and the like--are used for high-impact fillers. They owe their strength, not only to the inherent strength of the fiber, but also to the interlacing or cross-locking of the woven clippings.

A somewhat lower range of impact molding materials is obtained by the use of a paper base. In this case, the pulp fibers, in the process of manufacture on the paper machine, acquire an interlocked structure, but this interlacing is not as complete as in the case of the woven textile products. The use of impact materials for articles which must withstand considerable abuse marks the successful entrance into a field in which plastics were considered impractical.

Fillers exert a marked effect on the electrical properties of a molded piece. Mica, as a filling material, has found increased favor for insulation and ignition parts. This material is well adapted to either high or low frequency uses and also maintains good electrical properties over a wide range of
temperatures. These properties have proved particularly attractive to the radio, scientific-instrument, and automotive fields. Recently, other mineral fillers of the silicate and aluminum type have been offered to the trade, but their uses have not yet been extended.

Asbestos, as a filler, is used for its heat-resistant property. This material is successfully employed in the manufacture of molded articles such as ash trays where resistance to cracking and blistering at high temperatures is required. It is also used in connectors for electric irons and other heat appliances which must retain their properties at high temperatures over extended periods of time.

In the molded article the resin exerts a marked protective effect on fillers; yet, the degree of attack of a chemical agent will depend to some extent upon the filler. Where moisture or water resistance is of prime importance, mineral fillers are usually employed.

For acid resistance, the cellulose fillers are generally good. Mineral fillers, as asbestos, are better than cellulose fillers for alkali resistance.

Light-colored and light-resistant molding materials, particularly of the urea type, require filling materials which are light in color and remain stable to light. Wood flour, as
a filling material, is satisfactory in the manufacture of opaque products, but in this country the vogue has been towards translucent molding materials. For this purpose, bleached pulps, which give the desired translucent effect, are used.

In the manufacture of articles requiring accurate dimensions and low initial shrinkage, mineral fillers are preferred. These fillers, properly chosen, retain dimensions to a higher degree, particularly under varying humidity conditions.

A variety of fillers bonded with phenolic resins to attain high friction are used in the manufacture of brake lining and clutch rings. Asbestos, carbon black, berytes, and zinc oxide may be used.

In contrast to the high-friction products, there is a variety of uses for low-friction purposes. Cellulose has satisfied the filler requirements in the case of bearings which are lubricated, but for non-lubricated surfaces the addition of graphite in the molding material has proved advantageous in many cases.

In conclusion, the use of a variety of fillers has not only increased the usefulness of resins for general purposes, but, by careful selection of the fillers, special properties may be stressed, thus fitting molded parts to a wide range of demands
not otherwise possible.

The set-up of the plastics industry contrasts somewhat with that of other industries in that not all the steps from the making of the raw materials to the molding of the finished products are done by one company. For example, in the rubber industry, raw rubber in sheet form is produced by planters, purchased by manufacturers who compound the rubber, and carry the process right through to the finished product.

In the plastics industry, the manufacturer may prepare only the resins; carry the process through the compounding state by adding pigments or fillers; or complete all the steps from the manufacture of the resin right through to the molding of the finished product, as in the case of American Cyanamid in the manufacture of Beetleware. Du Pont, Union Carbide, and Carbon companies are the largest producers of the resins as well as the raw materials. The molding operation is usually performed by concerns who specialize in that field although several large molders of plastics are in the business incidental to their main businesses, as in the case of the General Electric Company and the Westinghouse Electric and Manufacturing Company.

In the compression molding process, the molding is performed in hardened steel molds, which are subjected simultaneously to heat and pressure in hydraulic presses. As
regularly carried out, the molding powder, or a preformed tablet of compressed powder of suitable weight, is put into the lower half of a heated mold. The press is then closed slowly to allow the material to become sufficiently plastic to fill the cavity in the mold. The molding pressure varies from 2,000 to 3,000 lbs. per sq. in.

The mold is heated either directly by the circulation of steam through channels provided in it, or indirectly by heating the platens of the press. The molding temperature ranges from 285 deg. F. to 330 deg. F. depending upon the material used and the design of the object molded.

A short period later, the pressure is released; the mold is opened; and the finished article, formed to the exact shape of the mold, is complete and ready for use, except for the removal of the thin mold fin.

The molding time varies with temperature and pressure, character and excess of material used, and thickness of the molded object. The present-day practice of discharging the mold hot has greatly speeded up the molding process for thermo-setting materials, so that today the complete molding cycle for a thin-walled object (1/16 in. thick) may be as low as one minute. Increase of thickness calls for more than proportionate increase in molding time. If thermoplastic powder is
used, the mold must be chilled before the piece can be removed. This operation, obviously, increases the total molding cycle to about four minutes.

The use of injection molding is probably the most outstanding development in molding technique in recent years. This process, however, is only adaptable to thermoplastic materials, such as cellulose derivatives, vinyl resins, polystyrene resins, and cumaron resins. The entire mold charge is concentrated in one place, heated into a molded condition, and then forced through a small orifice into the cavities of a cold mold. As this process must be very rapid to insure complete filling of the cavities before the material starts to set through contact with the chilled mold, the molding cycle is consequently very short, approximately a few seconds. This process adapts itself very readily to mass production. However, only small pieces can be molded.

Injection permits the molding of articles which are impossible to make by the compression method. For instance, in making a long tube of small diameter with a thin wall by compression molding, the force which forms the tube core might easily flex under the pressure required to flow the plastic. Such an article can be very satisfactorily made by injection.

Injection molds are light and quickly and easily changed.
No chain hoists are required and storage space is reduced to a minimum. Furthermore, it is not essential that molds be hardened. Thus, contoured surfaces of delicate dies are not subject to the risk of warpage and distortion which so often attends heat treating.

Another great advantage of injection molding is the reuse of scrap. While in the ordinary compression mold there is considerable flash, the scrap in the case of injection-molded pieces is confined to the small amount in the extreme end of the orifice of the pressure cylinder and in the gates and runners of the mold. This scrap is mixed with new material and fed again into the hopper.

In the casting process, the resins are poured in a sirupy state into molds where they are hardened by slow baking. Inasmuch as a considerable period is required for the curing of such products, they are customarily produced in sheets, rods, or tubes, and the finished articles are made therefrom.

In the laminating process, either paper or cloth is saturated in a resinous solution. Then, a number of these sheets are placed in layers and subjected to pressure and heat to form a laminated plastic. This treatment converts the resin to the finished state and yields a hard, dense product which will not delaminate and which possesses mechanical or dielectric properties. This laminated sheet can easily be machined into the
finished product.

The accompanying diagram is a typical cross-section of the processes involved in the manufacture of plastic products of the phenolic type:

![Diagram of plastic product manufacturing process]

(Properties of Finished Products)
Now, one might wonder if plastics, in their various branches, are not universal materials capable of displacing all others? One cannot hope to answer this question while the industry is so young; but one may lay down some generalities.

While the properties of the materials of the plastics industry show considerable variations as between different types of plastics, certain of these plastics have properties more or less common to all. They have an unusual combination of desirable qualities: light weight, durability, resistance to chemicals, insulating qualities, and facility to molding. They need no protective coating and their color goes all the way through. They are not subject to rust, corrosion, chipping, or denting.

To quote:

"1. Simplification and improvement of apparatus design by using plastic products as both a structural and an insulating material."

"2. Availability of colors and surface designs permitting distinctive and decorative designs not readily obtainable with metals."

"3. Elimination of the necessity for surface treatment, such as plating, polishing, painting, varnishing, enameling, etc."

"4. Freedom from rusting or tarnishing."

"5. Resistance to weather, water, oils, solvents, salt air, washing soaps, cleaning fluids, most acids, etc."

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6. Low heat-conduction, which renders the products comfortable to the touch.

7. High ratio of strength to weight.

8. Resilience to absorb mechanical shocks.

9. Low density, as compared to other structural materials.

10. Versatility of form.

There is no doubt that certain natural materials surpass the plastics in one or more of these qualities, but they do not ordinarily possess, on the whole, such a combination of desirable properties. This does not imply that plastics are a universal material; for, in some applications, a single property may be desired above all others, as strength, and this is better supplied by the metals. To be sure, the plastics have very definite limitations in certain uses, but in an increasing number of applications they are superior to any other material.

The popularity of plastics in motor car construction has come swiftly. It is only within the last five years that plastics have become an important material in interior decorations and other construction of automobile design. With the development of certain molding materials—phenol formaldehyde, urea formaldehyde, and vinyl—and the improvement of molding technique, it has become possible to mold such complicated objects as the steering wheel, instrument dashboards, and timing gears, to say nothing of the gearshift knobs, cigar lighters, horn buttons, control knobs,
switch buttons, dome light bowls, etc.

The following statement is pertinent:

"Eliminate molded phenolics, bring back hard rubber in their place, and you would have a regression in automotive and electrical technology."

A recent development in molding material is cellulose acetate, of which Tennessee Eastman is the only important producer.

"Salesmen for this material, Tenite, have made a beeline for the automobile market, to compete with the colored resins such as Plaskon and Catalin; and they have gained an inside track on General Motors'..."5

In England and in Germany plastics are used to an even greater extent in automobile construction not only in interior decorations but in exterior parts as well.

Furthermore, the contribution of plastics to the comfort and safety of the community is most significant. Before the introduction of safety glass, in the motor car industry, two out of three injuries in automobile accidents resulted from breakage of glass. These accidents caused a large number of fatalities and permanent disfigurements. Therefore, as soon as a reasonably acceptable product—cellulose nitrate—was brought on the market, its adoption was widespread and today "state legislation requires the use of safety glass in the cars enjoyed by over seventy-five


5 Ibid. p. 144.
per cent of the United States."  

Indeed, the automobile is plastics' greatest outlet. Another wide market for modern plastic materials is the electrical field. They are used either for their purely insulating characteristic as impregnation material for electric coils and motor windings or for their structural and insulating properties in flat irons, toasters, switch boxes, current breakers, etc. The laminated plastic materials are used for instrument panels, electric ranges, and refrigerators. One of the most interesting uses of plastic resins is in sealing electric light bulbs in their metal bases.

The subject of plastics and their applications in artificial lighting is broad. The lighting fixture industry is receiving marked attention today because of the country-wide effort to preserve and aid eyesight and, at the same time to provide lighting fixtures that complement rather than detract from the scheme of interior decoration. The various plastics are equal and, in some instances, superior to contemporary materials for lighting transmission, diffusion, reflection, and strength, and they make a definite contribution towards improved lighting conditions. Their light weight, economical manufacture, and adaptability to decoration recommend them to interior designs.

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The remarkable qualities of molded urea plastics make them especially suitable for reflector bowls. With the increasing use of indirect lighting, their demand has been enormous. By proper pigmentation, any desired degree of opacity may be obtained and, in addition, the control of dimensions of the molded reflector gives the plastic material distinction not found in other materials.

In recent years, urea plastics have become more important for transportation lighting since higher speed of travel and more rigid safety codes demand non-fragile, lightweight illumination devices. These plastics are also used in aviation lighting for instrument dials and cabin reading lamps. Although not actually unbreakable, they are shatterproof. Should a fracture occur, it would more or less take the form of a crack in the material.

Schools, libraries, and hospitals, as well as many business establishments prefer reflectors of plastics because, besides being efficient lighting fixtures, they are sanitary, easy to keep clean and eliminate the danger of serious personal injury should they fall.

One of the latest developments in department store lighting is the replacing of the aluminum in fixtures by ivory-colored cellulose acetate. The old fixture weighed 58 lbs. as compared with a weight of 7 lbs. for the plastic type.
Then again, the acrylic resins, such as methyl methacrylate, indicate a new departure in clear transparency of organic plastics. "They are claimed to be the optical equivalent of quartz crystal and are reported to possess greater light transmission qualities than any glass."\(^7\)

In closing,

"We believe with Dr. Luckiesh that a tide of demand for more light and better lighting is rapidly rising and we believe, too, that decorators, lamp and lighting fixture manufacturers, architects, and others who in the future will meet the demand will find in plastics of one sort or another an exceedingly useful and efficient material."\(^8\)

The cellulose plastics were developed largely for the purpose of imitation, and, as a result, were associated in the minds of the public as cheap and inferior. The new plastics, on the contrary, were developed on their merits alone and, as such, have gained recognition in the costume jewelry and style goods trade. The brightly colored plastics, such as cellulose acetate, cast phenolics, casein, and urea formaldehyde, are used for their colorings in buttons, jewelry, novelties, and in a number of applications where appearance is important.

The entrance of plastics into the packaging field occurred only a few years ago. Since that time, a definite place for

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\(^8\) Ibid.
plastic packaging has been gained. Yet plastics have but begun to scratch the surface.

Formerly, the package designer was forced to consider some material other than plastics for large-size packages. Today, with the advent of large molding technique, he has a much wider range in using plastics for package design.

Package designers take full advantage of the plastic materials by planning their containers not only for display but for re-use purposes for cigarettes, jewelry, and knick-knacks. An excellent example is that announced by the Larsen Baking Company, Inc.9

"This consists of a circular tray molded of black phenol resin which serves as a base for the fruit cake, and a top or cover of molded white urea.... Besides being used for fruit cake, it is also adaptable for the serving or storage of various comestibles, cocktails, etc., and wins immediate acceptance."

New, too, is the use of a plastic box as a container for cutlery, as evidenced in the carving set put out recently by the Remington Arms Company, Inc.10

"Here, not only color and design form a pleasing background and bespeak the quality of the cutlery, but the durability and convenience of the box itself can be expected to win the approbation of many purchasers."


10Ibid.
Still again, plastics have been very widely adopted for the display and sale of cosmetics and toilet goods articles, jewelry, and watches.

"Gruen, Hamilton, Waltham, and others have turned to plastics as the ideal medium for the display of their products and the enhancement of their appearance in the store window and on the counter."\(^{11}\)

In the furniture industry plastic materials are used in a number of interesting ways. Cabinet housings offer manufacturers an excellent solution to certain of their sales problems. For example, the radio industry, after competing for years on the basis of mechanical perfection, had reached a point where competition resolved itself into variations of cabinet designs. As the urea materials offered unlimited and permanent colors, the manufacturer recognized the value inherent in the use of plastic cases.

Today radios and clocks are sold not only because of their greater display values in the retail market but because of greater consumer recognition and appreciation of color in the modern home. At present, some twenty different types of radio cabinets are made from plastic materials ranging in size from the tiny three-piece Emerson cabinet to the huge Pilot case, one of the largest housings yet produced in this country.

\(^{11}\)Ibid.
In addition, the problem of assembly is much more simple because the housings are molded into the complete product ready for mounting. Then, too, there is no danger of chipped paint or veneer or scratched surfaces. It is estimated that 10% to 40% of the cost of furniture is represented by sanding, painting, varnishing, etc., depending upon the type of the piece and the grade. As no finishing of the molded product is necessary, this saving in cost plus the light weight, strength, and permanence of finish should assure plastic materials a recognized place in the furniture industry.

Some interesting developments in the field of furniture were shown recently at the Paris International Exposition.  

"Tables, chairs, couches were all in green crystal cellulose acetate and chrome metal. Arm chairs, chairs, and tables of this same material, designed by Kohlman and J. & M. Andre, were shown in the Modern Artists' Pavilion and Louvre Pavilion. Dressing tables, consoles, chaise lounges, screens, seats, stools, and tables of plastics combined with metal or wood were shown at the Plastics Material Pavilion."

Another interesting application of plastic materials was shown in the design of school furniture at an exhibit of the Salon des Arts Menagers in Paris. This furniture is receiving favorable comment over wood because it is less likely to carry germs and it is easily cleaned. In addition, they are light-

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weight and easy to store away at times when the classroom is used for other purposes.

"Probably no other desks and chairs in any sort of service are required to withstand the abrasive attack given them by youngsters at this early age. Their resistance to wear makes them a permanent investment."[13]

Plastic products have found still another usage in the home. They are used in the handles of cutlery and kitchen utensils. Colored novelty tableware under the name of Beetleware has flooded the market within the last few years and the demand for these lightweight and durable dishes has been stimulated by the growth of airplane and trailer travel.

In the building and construction industry plastics play a very important part. The plastics taken together offer many of the desirable factors of a building material.

1. Ease of fabrication: with the increasing application of mass production methods to reduce the cost particularly of small homes, plastics fit very well into the picture since they can be prefabricated at the factory or finished on the job with very simple tools.

"The old method of sawing a tree into boards, employing carpenters to cut the boards into proper lengths and build them into a house, and then hiring painters to weatherproof it may become obsolete. Instead, a tree may be ground up

and molded into large light sheets of the proper size, which can be quickly and easily erected."

2. Superior properties: by selecting the proper types, plastics provide superior resistance to wear and to the corrosion of chemicals. They do not warp; are free from expansion and contraction; have a high electrical insulating value; and are practically fire and acid proof.

"It was estimated that more than $100,000 of American laminated plastics entered into the construction of the Queen Mary. The same amount is to go into the Library of Congress Annex for doors, table and cabinet tops, and wherever abrasion or wear is likely to occur."15

3. Decorative possibilities: the almost unlimited range of colors offers an endless choice of decorative effects.

4. Cost: since these synthetic materials are derived from raw materials, both common and abundant, there is not likely to be a scarcity, resulting in higher prices should the demand increase. While these plastics, at present, can only compete with the high-priced decorative materials, there is no doubt their reduction in cost will come with a large volume of manufacture.

In the construction industry, plastics are used in the form of laminated boards or panels of both the phenolic and urea type

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15 Ibid.
for store fronts, bathroom walls, and theater lobbies, etc. While the theaters were the first to use them extensively, the use of plastic materials has spread to the construction of many bank and office buildings. In fact, many of the older theaters have been made modern solely by the use of plastics. More recently, the hotels have used them as the principal material for redecorating their grill rooms. Many private homes and, perhaps, a large number of personally decorated apartments have also used laminated plastics for their decorative effects.

Since molded shingles of cement and asbestos belong in the plastics family, plastics are already represented as far as the roof and sides of the house are concerned. While plastics of the phenol laminated type make attractive fronts for many stores, restaurants, and theaters, they probably will not replace the present favored construction materials for the external walls of houses. 16

"Therefore, for the present, and even looking some years into the future, it seems that plastics' contribution to housing will be principally limited to internal decoration and to useful accessories."

Plastic materials have also entered the paint, varnish,

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and lacquer industry. The automobile introduced two new finishing problems: high-speed baking and long life on metal. It was found that synthetic resins, especially alkyds, had much merit in automotive lacquers because their durability was greater. They, in turn, quickly replaced a large amount of natural resins. In fact, some automobile manufacturers have replaced all other ingredients in lacquer with alkyd resins. Such an enamel naturally has great durability and luster retention and is lower in cost due to the cheaper solvents used. Thus, an established savings is made in the cost per car.

For the same reasons, enormous quantities of all-alkyd resin enamels are being used for exterior purposes today in such objects as farm implements, license plates, street cars, and buses.

One of the most interesting developments, which has taken place in recent years, has been the entrance of plastic materials into the textile industry. In the first place, phenol laminated plastics have replaced the standard construction of hard maple tenter rails in textile machinery. These rails formerly lasted about six weeks whereas the new plastic rails, after four years of continued use, are still in good condition. This replacement has not only reduced the maintenance cost but has permitted greater-production speed.
In the second place, the development of synthetic resins for impregnation and the finishing of fabrics is an important factor in present textile industry. With the earlier treatment of resin-coated fabrics, such as oilcloth and artificial leather, the final product was merely a sheet of resin and the fabric acted as a backing base. Today with the use of newer resins for impregnation, the finished fabric looks unchanged and possesses new and advantageous properties.

The most important development of synthetic resins for textiles is the anticrease fabrics, which were patented in Manchester, England. In this country a number of textile finishers are licensed under these patents to produce anticrease and crush-resistant cottons, rayons, and linens. Men's and women's rayon suitings are one of the most important developments in this field. They are particularly cool and attractive and retain their shape and appearance after continued use.

There has been increasing interest in the use of resins for the production of permanent finishes for all types of textile fabrics to replace the finishing oils, starches, and gums which are removed in a single washing. These resins, in addition to giving a finish with greater permanence, frequently add to the character of the fabric, reducing its shrinkage, increasing its
brightness, and giving it a more attractive tactile finish.

"By increasing elasticity, and by increasing luster; by decreasing shrinkage and by decreasing slippage; by increasing strength, and by decreasing wear, the use of textiles is amply justified and a new field for resin application is opening which promises to be one of its largest opportunities."17

Plastics will never replace all known materials; nor are they even equal to them for many jobs, but the point is they do provide industry with a new tool—a new opportunity for mass production. Molded parts eliminate expensive machinery and hand operations, since they are produced in one operation and require no additional finishing.

The importance of this simplified production may be made more evident by reference to typical examples. The case for a scientific instrument, formerly involving as many as fifteen machining and finishing operations, is now made from molding material with a single closing of the press, and within the period of a few minutes. Then, too, through the use of multiple-cavity molds, the output of each molding cycle can be increased; thus, from a single mold a gross of tooth paste tube closures can be produced and in a single operation.

Another factor of economic importance in the plastics

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industry is the abundance of raw materials. Take, for example, the urea resins. Due to their method of manufacture and the nature of the raw material required, they can be produced in enormous quantities. The first step in urea production is combining the nitrogen and hydrogen of the air to form ammonia, which, in turn, is reacted on by carbon dioxide to form urea.

Plastic materials offer splendid opportunities for sales demonstrations. In many instances, transparent materials have been used not only to mold an exact reproduction of the actual article but also to show the inside workings of its mechanism. Moreover, their light weight enables the salesman to carry the article around for demonstration. A striking example is the counter scale made of urea plastics by the Toledo Scale Company. This scale weighs only $55\frac{3}{8}$ lbs. as against 165 lbs. of their former model.

Reduction in weight necessarily results in savings in shipping and handling costs. To illustrate, reflectors made of plastics in the illuminating industry are practically unbreakable and require no expensive or bulky crating.

Modern product design has become an important part of today's selling technique. The addition of color and beauty to any product creates a definite plus value which every customer
appreciates. Color variations made possible by plastics have given a tremendous impetus to the sale of many of the most commonplace articles, such as tooth brushes, fountain pens, and combs.

Another phase of the plastics industry that is receiving much emphasis at the present time is its utilization of waste materials. An important ingredient in plastic raw material is wood flour, commonly known as sawdust.

Of major importance, however, is the use of chemurgic products as predicted by Henry Ford only six weeks ago.18

"The time is virtually here when almost an entire automobile—body, fenders, doors and paneling—may be constructed out of wheat chaff, soy beans, corn husks, or other farm by-products."

In conclusion, it naturally follows that through the extensive use of plastic materials there has been a tremendous saving of the basic raw materials, wood and metal, and that in the future "furfural and sawdust will eventually furnish the raw material for millions of feet of lumber substitute."19

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CHAPTER IV
PRESENT LIMITATIONS AND PROBLEMS OF THE MODERN PLASTICS INDUSTRY

No one material whether natural or man-made possesses the ideal physical or chemical properties necessary to meet all the complex requirements of modern industry.

The plastics, in general, have less strength than metals and are not used in applications where strength is of prime importance.

The capacity to simulate marble and other products may not be of great advantage in interior architecture, as tradition does not sanction such uses in the finer arts. Bright and varied colors are, in most cases, too gaudy.

One of the major problems of the industry is cost reduction to expand markets. First, prices must be lowered and, second, the latent demand for plastics stimulated. Plastic manufacturers, when asked what will lower the price of their products, invariably say, increased demand. Therefore, the public must be familiarized with the properties of plastics, their manufacture, and their uses.

"Even architects, by and large, have only a general knowledge, the builder knows even less, and the public practically nothing at all."¹

There are structural as well as economical limitations to the size of molded articles. In the first place, there is a definite relation between the size of the article and the strength of the article. In the second place, in order to produce large molded pieces expensive press molds and auxiliary equipments are required.

As an illustration, the Toledo Scale housing required the construction of a new press unit weighing 89,000 lbs. and nearly 2 stories high to develop a total pressure of 1,000 tons. No small factor in the success of the complete process was the provision of means for the proper machining of the mold. This part of the press weighs nearly 7 tons and has an over-all height, when closed, of 5 ft. A special method of heating had to be devised to prevent distortion and cracking.

There is a wealth of material from which the industrial designer can choose but, in order to choose widely, he must have a thorough understanding of the possibilities as well as the limitations of all these various materials. This means he must select materials which not only meet utilitarian requirements but which also carry a broad eye appeal. It is this fact which has led the designer to turn more and more to molded plastics.

Like all other materials plastics have their limitations,
which should be known to the designer responsible for the design of the part to be molded. The lack of this knowledge often complicates the design of the mold.

The price of the molded article depends, to a large extent, upon the proper type of mold. The capacity of the mold determines not only the price of the parts to be made but the rate of delivery of these parts as well. The number of cavities in a mold, that is, the number of parts made in each operation of the mold, controls the operator's time.

To illustrate: when running a mold with only 1 cavity, only 1 piece is made each time the mold operates and 10 pieces each hour from this mold. It therefore, takes 100 hours to make 1,000 pieces. If the mold had been designed with 10 cavities, making 10 pieces each time it was operated, 100 pieces could have been made each hour and only 10 hours would have been consumed making 1,000 pieces, thereby saving 90 hours of labor.

Naturally, a mold of 10 cavities costs considerably more than a mold of one cavity, and there is no object in making a 10-cavity mold unless the requirement for pieces warrants it. Therefore, it is advisable to determine as closely as possible what the yearly, monthly, and weekly requirements are.

The number of cavities to put into a mold is determined
not alone by the number of pieces to be delivered at a time but is also governed, to some extent, by the size and shape of the piece, the kind of material of which it is to be molded, and the size of the press in which the mold is intended to be operated. As the molding represents a material part of the ultimate cost, its design and construction should be entrusted only to those familiar with good molding practice.

Patents in this industry are in very much of a tangle and it is probable that trouble of this nature will continue for some time. The following example is characteristic:

In 1929, the American Cyanamid Company, chiefly engaged in the fertilizer business, decided to go into the chemical business. It bought nearly thirty companies and, among its purchases, were the American rights to patents from European companies for a synthetic resin made of urea, thiourea, and formaldehyde.

The new material, under the name of Beetle, produced by Cyanamid, was of the thiourea type. It had a great advantage over Bakelite because it could be produced in color; however, thiourea contains sulphur, which has a corrosive effect on molds. Moreover, the new plastic, requiring high pressure and a long cure for molding, was not cheap to manufacture.
About this time, a fellowship, established at the Mellon Institute of Industrial Research, Pittsburgh, succeeded in producing a urea-formaldehyde molding powder without the presence of the undesirable sulphur that was in Cyanamid's thiourea product. The Plaskon Company, a subsidiary of the Toledo Scale Company, acquired the patent for this plastic. This material, manufactured under the name of Plaskon, possessed many Bakelite qualities plus a color range and could undersell Cyanamid's thiourea.

With the onslaught of Plaskon, Cyanamid was forced to switch from its original thiourea formulae and to experiment in straight ureas under other European patents it had subsequently acquired. Thus, in one corner was Plaskon; in the other, Cyanamid.

Meanwhile, Carleton Ellis, of Montclair, New Jersey, lownwolf patentee and holder of the third largest number of patents in this country, was experimenting in pure urea-formaldehyde resins based on the results of European research. He turned these experiments into patents and from these patents sprang the Unyte Corporation.

As the foregoing indicates, all these patents may be traced to the original European experiments and Cyanamid, due to its purchase of the European rights, is claiming to hold
the basic patents.

"Beetle is suing Plaskon, Unyte is suing Beetle, while Plaskon has a cross-license agreement with Unyte under the Ellis patent."²

The industry, on the whole, is not well organized and there is a lack of trust among the manufacturers. Closer cooperation and exchange of ideas would benefit the industry in general.

The most outstanding characteristic of the industry is constant change. For any individual plastic, there is always the possibility that it will lose a substantial part of its market to a new material that is cheaper, or sells at the same price with better properties for important applications.

Changes are rapid. The cellulose acetate, for example, replaced the nitrate in safety glass almost overnight and now it is not unlikely that the acetate will be replaced by a newer plastic.

Despite the tremendous number of products made of plastics today, there is no question that their possibilities and advantages have only begun to be exploited. There is practically no industry which cannot use plastics to advantage somewhere—in some way, for the plastics field is constantly broadening, adding comfort, beauty, safety.....lowering cost of many articles.....making possible new products.

CHAPTER V

PRESENT-DAY TRENDS IN THE MODERN PLASTICS INDUSTRY

Certain plastics exist today in the industry which are a decided advance over the older plastics and there are certain trends in the development of plastics which in time will show themselves to be a marked improvement over those of the present day.

In recent years a number of large and important companies, such as Ford, Eastman, Union Carbide, General Electric, and Du Pont have entered the industry. With their ample research funds and with the continuing interest of the older companies, it is quite likely that research will be continued on an extensive and increased scale, for the story of the growth of the plastics industry is a story of industrial research chemistry. ¹

"In the Du Pont laboratories, the search continues on a broader and even more intensive scale for new plastics which are even better and more widely useful than those of today."

The Plastics Department of the General Electric Company at Pittsfield, Massachusetts, was recently formed in recognition of the rapidly increasing use and importance of products based on synthetic resins and other binders of various types.

When asked about the investment of nearly a million dollars in a new plant and equipment, Gerard Swope, President of General Electric Company, replied:

"I might say that we look forward with confidence in the immediate and ultimate future of the development of business, especially along new lines, in which category plastics come.

"Perhaps the general conception of plastics is the molding kind only, but when you consider laminated materials and plywood with a binder of plastics, the opportunities become so great that no one can safely predict their future. Industry needs these materials in increasing quantities and through improved facilities and more efficient performance we shall be in a better position to make our contribution to the progress of the plastics industry."

Today the prospective user of synthetic resins and plastics faces a real task in selecting from the scores of materials offered the one best suited to his purpose. As the plastics industry was built around the framework of the phenol-formaldehyde resins, the physical properties of all subsequent resins were based on those of the phenolic type.

"Phenolic plastics were referred to as king of plastics, and if we look back to see why it is considered in that light by a number of people I believe it is because the molding industry, the people who mold these plastics, have set up all their standards on phenolics; in other

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words, strength is referred to as how strong it is when compared with phenolics, what kind of insulator is it when compared with phenolics."

With the steady development of newer resins, differing through a wide range of properties by such small margins, the selection to meet any specified set of conditions has become a serious problem. Although the American Society for Testing Materials has standardized methods applicable to plastics for electric insulating, which are useful for other purposes, there has been no complete standardization of the physical and mechanical properties of all known resins.

The plastics industry is quite literally a creative contribution to the resources of civilization. The further development and expansion of the plastics industry is practically assured. The perfect plastic for each of many purposes is still to be discovered. As the chemist develops new substances and research develops new uses for the products of the laboratory, the plastics industry will certainly experience a marked increase in both the quantity and the value of the product.

The rapid growth of the industry may be shown by the

fact that a year ago the cellulose ether plastics had not been produced in this country whereas today we find that

"The introduction of ethylcellulose into the plastics and allied fields comes in answer to a demand for a material having new and different characteristics which will permit the enlargement of the industry into virgin fields, and will facilitate the manufacture of articles having novel properties and uses. This cellulose derivative is not new, but its development has awaited a demand for the characteristics which its properties provide."  

Before the plastics industry can possibly reach its destined economic position, the cost of plastics must be considerably reduced. That means they must be made from cheap raw materials, and the trend clearly points to this end as may be seen from the following quotation:  

"We know that here in Detroit there has been a great deal of work done on plastics from farm products, we know that other plastic manufacturers, established plastic manufacturers, are spending a great deal of money to develop some of those things, and we feel that the future is very bright, and that we may some time be able to materially reduce the cost of plastics which of course will enable expansion of the field."

Another method that may reduce the cost of plastics was developed by the Forest Products Laboratory whereby sawdust

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is hydrolyzed, subjected to high temperatures and pressures, and then treated with furfural and phenol; but, so far, the water resistance has not been as high as in the better established plastics.

Progressive management throughout all industry is on the alert for new means and methods to produce more and better goods at lower costs. In the plastics industry, in particular, rapid change is taking place. The conventional compression mold press of the past has been largely a heritage from the rubber goods industry where the simple hydraulic hot plate press has long been employed for vulcanizing. In plastic molding, this type has been used with hand molds. The so-called semi-automatic press for operating molds with knock-outs has been essentially an alteration of the basic press.

With the modernization of the molding press, a radical break with the past in methods of both generating and controlling the molding pressure has been brought about. This is of outstanding interest to the molder inasmuch as the press has been constructed with new and definite performance characteristics making possible numerous improvements in the economies of operation. With the uniform molding compounds now available, the use of automatic production methods for some of the simpler and well established processes of plastic
molding is now possible.

However, automatic molding cannot replace existing equipment in plants that are well adapted to mold complete lines of plastics including large and complex parts. It can be used by contract molders to add to plant capacity and lower costs on parts within its range. In the large molding plant, it may be profitably used for the preliminary work that precedes large production, to experiment with mold changes, to produce samples, and to make deliveries in smaller quantities prior to the time that large output is possible.

The next steps in the further development of fully automatic molding methods will doubtless be the perfection of equipment to utilize multiple-cavity molds and to mold simple parts in which inserts are incorporated.

The latest development in plastic molding technique is injection molding. In the United States it has only been used commercially for the last two and one-half years, but, in this short time, tremendous progress has been made. Until then, little attention had been given to this method of producing castings from thermoplastic materials due to the fact that suitable materials were not available.

Injection molding is a process of injecting a thermoplastic material in a soft, flowable condition from a heated
cylinder through a nozzle into a cold mold. It has many advantages over the usual compression molding, the most important of which are high-speed production and reduced mold costs, as smaller and lighter molds with fewer cavities are used.

For example, a 2-impression injection mold, operating at a normal rate of 4 cycles per minute, would produce 48 pieces in 6 minutes. For the same article molded by the compression method, a 6-minute cycle would be normal. Obviously, this would require 48 impressions—24 times the number of cavities to equal the production of the 2-impression injection mold—at a mold cost probably ten times as much.

As mentioned before, the injection method is suitable only for molding thermoplastic materials. Consequently, there is a definite trend to develop resins of thermoplastic nature suitable for injection molding. Cellulose plastics and such materials as vinyl resins, polystyrenes, and coumarone plastics are being increasingly used in this process.

The general opinion in informed circles is that laminating material has the most promising growth possibilities. Laminated material is usually employed for its strength and
ruggedness and its ability to do a better job in some applications than metal, wood, or some other material.

With the improvement of laminated materials, a wider market for their application is being opened. In fire tests conducted by the Government a few years ago on various materials, the performance of laminated materials was such that considerable interest has been aroused in it for the partitions of new ships that are now, or soon will be, under construction.

"The S. S. 'Catherine' of the Bull Steamship Co. has just been reconditioned by the Maryland Drydock Co. with an extensive use of plastics replacing wood for partitions, built-in furniture, table tops, walls and doors. The laminated plastics in this case were applied to asbestos composition sheets with the result that the ship comes well under the safety standards set up by the Department of Commerce. An additional advantage of plastics for marine use is their low labor maintenance because of their permanent, easily cleaned surface."^6

The railroad industry in building its new high-speed trains has made an almost universal use of laminated material for table tops in the lounges, etc.

One of the special developments of laminated materials resulted from the development of electrical refrigeration.

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Laminated materials usually carry a characteristic phenolic odor, which is especially objectionable where foods are concerned. The requirement for a moisture-resistant material of low thermal conductivity and decorative value produced the demand that laminated materials be manufactured without any odor.

The future development of laminated materials and their further extension with our industrial and social needs will depend, to a large extent, upon the further stabilization of these materials to mechanical and electrical stresses and to weather and light conditions.

Another important phase in the application of laminated materials is the growing demand for safety glass. At the present time, cellulose acetate, as an interlayer, is used for safety glass. However, as satisfactory as it has been, there are still numerous points in which it can be improved. It has been difficult to get a well-balanced plastic, that is, a plastic which would furnish safety glass of about the same breaking strength at 0 deg. F. and 120 deg. F. This type loses its plasticity and shockproof resistance at temperatures below 40 deg. F. and at extreme low temperatures has little or no utility as shatterproof glass.
There is now available a new thermoplastic polymer of an acrylic derivative which has the appearance of ordinary glass and, at the same time, retains the properties of synthetic organic resins called Plexiglass. Its transparency and light weight suggest its use for windows in all types of vehicles, particularly in streamlined vehicle bodies. This glass can be made in plane or curved sheets. Although still in the experimental stages in this country, both the acetate and acrylic resins hold great promise for the future of safety glass.

This resin has already been used abroad to a considerable extent for windows in airplanes and lighter-than-air craft. The windows of the ill-fated Hindenberg were made of Plexiglass. This modern resinous material gives equal visibility, and even greater light transmission, besides being more flexible and considerably lighter in weight, than ordinary window glass. It has the ability to "give" in high winds and is not likely to fracture under any normal circumstances. This material is to be used even more extensively in the new zeppelin now under construction in Germany.

Another promising use for the methyl-methacrylate resin in this country and abroad is its substitute for glass in eyeglasses, binoculars, cameras, and magnifying glasses. This resin can be molded into lenses. It is transparent to ultra-
violet light as well as to the whole spectrum. It is light-weight, slightly flexible, can endure pounding, resists acids, but it scratches easily. However, it can be refinished to its original brilliancy and translucency.

In this country, the resin is produced by Rohm and Haas Company, in Philadelphia, under the name of Acryloid; by Du Pont Viscaloid Company, at Kearny, New Jersey, under the name of Pontelite and Lucite. Abroad, the resin is produced by Rohm and Haas A-G, in Darmstadt, Germany, under the name of Acryloid; and by Imperial Chemical Industries, Ltd., in London, England, under the name of Perspex.

At a recent exhibit of the Olympic section of the British Industrial Fair, a series of optical lenses molded from Perspex was shown. The accuracy of molding these new plastic lenses is reported to be 1/500,000 of an inch. This accuracy is sufficient for any but the finest and most expensive of optical instruments. In fact, it is much better than the accuracy requirements of 1/50,000 of an inch for spectacle lenses.

These lenses are claimed to be as good as, or better than, glass and not affected by the ordinary temperature range. The pictures taken with the lenses showed unusual depth of focus.

This remarkable new molding process is credited to two co-inventors: Arthur W. Kingston, English research chemist,
and Peter Koch de Gooreynd, Anglo-Belgian industrialist.

Dr. W. E. Williams of Wheatstone Laboratory, King's College, University of London, has acted as consultant.

No detailed data are yet available on how the inventors hope to overcome the problem of correcting "chromatic aberration." This technical phrase means the ability of a lens to focus at a single point, all the different colors of the light ray spectrum. In the manufacture of glass lenses, this condition is overcome by a combination of two or more different kinds of glass cemented together to compensate for one another. If this problem can be solved by combinations of different resins, molded lenses will then enter the superior instrument field.

It is probably safe to predict that improvements in furfural resins and sales of furfural to resin manufacturers during the next ten years will far surpass improvements in and sales of phenol-formaldehyde resins. At present, oat hulls are the chief source of furfural, but, as the demand increases, other cellulosic materials like corncobs, rice hulls, peanut shells, cotton seed, bran, and bagasse fibers must be used. The increasing use of furfural will result in lower costs.

"The broad general demand for furfural requires the utilization of other furfural-yielding materials and the conservation program calls for the utilization of all this cellulosic waste."  

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Still another low-cost plastic is from lignin. Wood consists, in general, of about 25% lignin (the soluble substance of wood). In the manufacture of paper and cellulose derivatives, lignin is usually discarded as a waste product. Lignin is also abundant in other waste products, such as corn cobs, oat hulls, and sawdust. It has been estimated that the cost of plastics from this source is from one-fourth to one-tenth of the present lowest-priced plastic used. The tendency of plastics from lignin, however, to absorb moisture and warp will have to be overcome before they will find general application.

Speaking of plastics made from lignin, Mr. H. N. Dent, President of General Plastics, Inc., says: 8

"The lowest-priced article I have ever run across for a plastic is a wood mold.... That is wood that was very high in lignin.... That was the lowest-priced raw material we ever worked for a plastic."

Until recently, there had been no use made of plastic materials for containers of food products; but, with the development of vinyl resins, a definite trend is discernible. The fact that these resins are odorless, tasteless, and acid-resistant recommends their use specifically as linings of

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storage containers for food and beverages. A well-known example, in this country, is the beer can and its application is gradually gaining ground abroad.

"The consumption of beer in 1936 increased as did the proportion sold in individual packages. The sale of tin containers in this newest field was large. A continuation of these trends, together with anticipated expansion of the market through research, offers possibilities of increased sales of tin containers for a variety of beverages."§

Paints and varnishes encounter severe requirements for modern uses. Varnishes made with phenol resins give a new conception of varnish durability. In actual service on motor boats and sailing craft over a two-year period, these varnishes have demonstrated unequaled toughness and resistance to wear and weather. They retain their brilliant gloss for longer than the highest grade spar varnish made with natural gums. They truly represent a definite step forward in the improvement of protective coatings.

When unusual decorative effects and permanent quality were sought for the famous Rockefeller Center, synthetic resins for paints and varnishes were the natural selection.

"So from skyscraper to cottage, from the workshop of the artisan to the mammoth plants of industry, these materials will be found rendering enduring service in a million different ways."\(^{10}\)

CHAPTER VI

CONCLUSIONS

The history of the modern plastics industry shows that the industry is comparatively new. Although plastics have been known and used since 1868, the public has been conscious of a plastics industry only in the last five or six years. The story of the plastics industry tells us that it is one of industrial research chemistry and that it has been developed to replace such natural products as stone, wood, and the metals. Facts prove that the plastics industry has a recognized place in our national economy and that plastic production is on the upward trend in countries all over the world.

A brief synopsis of the plastics industry shows that the author tried to give a general description of a great variety of synthetic products of a resinous character, for the industry deals chiefly with moldable substances, together with coloring matter, and, in some cases, a filler, which are obtained by the chemical interaction of a wide range of materials—nitric and sulphuric acid on cotton linters, carbolic acid and formaldehyde, or other chemical transformations involving soy beans and casein from cow's milk.

It is hardly necessary to say that no one material, whether natural or man-made, possesses all the ideal physical or chemical properties necessary to meet the complex requirements of
modern industry. To be sure, the plastics have very definite limitations, in certain uses, but in an increasing number of applications they are superior to any other material.

The properties of the plastics show considerable variation as between different types but certain of the plastics have qualities more or less common to all. The materials are light, tough, and durable, possessing excellent dielectric properties. They are resistant to solvents, alkalies, greases, and, to some extent to water. The surfaces are smooth; they are not subject to rust, corrosion, chipping, or denting, and their color goes all the way through.

Notwithstanding the above-mentioned facts, in industry, in the home, in transportation, in all manner of personal belongings, plastics are supplementing materials for which there has, in the past, been no practical substitute. They are being more widely used in the manufacture of automobiles and electrical equipment. They form the laminating material in shatterproof windshields. The building industry is using them for wall panels; furniture makers employ them for modernistic furniture, and industry generally is using them in a score of different ways.

Nevertheless, plastics will never replace all known materials; nor are they even equal to them for many jobs; but they
do provide industry with new opportunities—for mass production, for sales demonstration, for utilization of waste materials, and for conservation of basic materials.

However, certain problems confront the industry. Like all other materials, they have their limitations. The plastics have less strength than metals and are not used where strength is of prime importance. One of the major problems of the industry is cost reduction to expand markets, and the most outstanding characteristic of the industry is constant change. For any individual plastic, there is always the possibility that it will lose a substantial part of its market to a new material that is cheaper, or sells at the same price with better properties for important applications.

So much for the problems of the industry. Plastics are not even potentially a universal material, and a Plastic Age, in the sense that we have had a Steel Age, is more or less of a myth. Yet, it is predicted that the plastics industry within ten years is destined to be one of the greatest industries. It is now doing a gross annual business of $200,000,000 and is still in its infancy.

The preceding paragraphs are really foregone conclusions whereas the following paragraphs are, more or less, just trends of the present day. With the research funds of such large
concerns as Ford, Eastman, and Union Carbide, it is quite likely that research will be continued on an extensive and increased scale.

With reference to the future possibilities of the plastics industry the subject is a broad one. The plastic limitations of three, five, or seven years ago are not comparable with those today. It was not many years ago when there were no really satisfactory light colors. Then, came the urea plastics, which range in colors from white to black, and undoubtedly in the phenolic field these light colors will also appear on the market before very long. The strength of the material has been improved. Today there is a material for containers in which liquid contents can be stored. All of these improvements break down old limitations.

Six or seven years ago, it would have been impossible to get an automobile manufacturer to use phenolic plastics for the dashboard of an automobile; yet this year practically all manufacturers are using plastic materials for this purpose. What the future will bring is difficult to predict.

The further development and expansion of the plastics industry is assured. As the chemist develops new substances and research develops new uses for the product of the laboratory, the industry will certainly experience a marked increase in both the quantity and the value of the product.
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Mr. James W. Ferguson
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