PLASTICS

in the world of tomorrow

by

Captain Burr W. Leyson

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PLASTICS

IN THE WORLD OF TOMORROW

Captain Leyson

HAS ALSO WRITTEN

AMERICAN WINGS

AERONAUTICAL OCCUPATIONS

FIGHTING FIRE

PHOTOGRAPHIC OCCUPATIONS

FLIGHT TRAINING FOR THE ARMY AND NAVY

AUTOMOTIVE OCCUPATIONS

THE AIR RAID SAFETY MANUAL

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IT WORKS LIKE THIS

THE ARMY ENGINEERS IN REVIEW

THE WAR PLANE AND HOW IT WORKS

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THIS MAN LA GUARDIA (with Lowell M. Limpus)

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PLASTICS

IN THE WORLD OF TOMORROW

By Captain Burr W. Leyson

ILLUSTRATED WITH PHOTOGRAPHS

NEW YORK • E. P. DUTTON & CO., INC. • 1944

FIRST EDITION

A WARTIME BOOK

THIS COMPLETE EDITION IS PRODUCED IN FULL COMPLIANCE WITH THE GOVERNMENT'S REGULATIONS FOR CONSERVING PAPER AND OTHER ESSENTIAL MATERIALS.

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BURR W. LEYSON

PREFACE

THAT plastics are to play a steadily increasing and more important part in our life is not to be denied. The technological advances in this field have brought this industry, within the brief period of the last decade, to the position where it bids to become one of our most important.

This is not to say that the field of plastics will supplant such established industries as steel or the use of various woods in manufacturing processes, any more than it can be expected that plastics will eliminate fabrics. Nylon and rayon have not done so in the fabrics field. Nor have the various plastics created any such displacement in the fields of the so-called heavy industries represented by steel. Plastics have augmented these fields. They have opened up entire new vistas of opportunity through their adaptability.

It follows that such an industry — one which has come to the front within the last decade and then, when one development followed close upon another, had its forward march in commercial fields abruptly terminated through the exigencies of war — cannot but offer a multitude of opportunities for highly interesting careers and also for ones which will be equally remunerative.

To those interested in this field for their career plastics present two main divisions. Covering the wider scope, by far, is the sales and promotion field. Second, and much more restricted through the requirements of the highly technical education required, is the chemical or engineering field.

While the first may be generally termed a sales or promotion field, it is more than might be implied by such a term, for there enters into this field the adaptation of plastics to innumerable other fields which are now established. The creation of new uses for these wonders of modern science is far from restricted. The field has been explored but not charted. Here, in this field, technical education is not so important. True enough, it is an advantage, although too much of it may be disadvantageous. This is more than any other a practical field, the finding of places where plastics can be utilized to the betterment of the product or project. There are innumerable opportunities for the man who knows what can be done with plastics and then can apply this knowledge to the practical problems of everyday life.

To cover the subject of plastics completely is beyond the scope of any single volume. An examination of the bibliography at the end of this volume will prove that at a glance. But an authentic and comprehensive general survey of the plastics field can be made in a single volume. That is the purpose of this book. It is designed to present the various plastics to the reader in a non-technical manner, to enumerate their present uses, to show the unlimited possibilities of a career in plastics, and finally, to present to the reader a sufficient over-all view of the industry so that this volume will be of assistance to him in his determination of the particular division of the industry which he considers the most attractive to him.

To simplify the presentation, the author has made no distinction between the advance of plastics before the advent of the war and those advances made since the outbreak of hostilities. Naturally, there have been certain advances which, at this time, military reasons forbid detailing. But the uses of the latest plastics can be mentioned and their eventual peacetime utilization suggested. And it must be kept in mind that plastics is not a static industry. It can be safely stated that the progress in this field since our preparation for, and eventual entry into, the war has surpassed that of all the previous decades when plastics were known.

In an endeavor to make reference to the various phases of the industry easier for the reader, the author has made what may seem to be rather arbitrary classifications of both plastics themselves and plastics in industry. Such was not his intent, and the classifications are made here only for the purposes of this volume.

Part One

Careers in the Plastics Industry

CHAPTER I

A GENERAL SURVEY OF THE USES OF PLASTICS IN INDUSTRY

The field for a career — plastics in architecture — building trades — office fixtures and supplies — light fixtures — musical instruments — phonograph-record field — automotive field — aviation — advertising — electrical field — household appliances — textiles — photography — packaging — sports — medical, surgical, dental and optical fields — ornaments — railways and steamship lines.

THE choosing of a field for a career is far too serious a matter to be undertaken lightly or without due consideration of all of the factors entering into the situation which will make for eventual success. It is germane, then, to consider first the progress of plastics and to give due thought to the future of plastics. No better way of presenting this is possible than to make a brief but fairly comprehensive survey of the advances plastics have made in industry and see if it is possible to determine the extent they are to play in industry in the future. The author wishes to emphasize that, although he possesses a great faith in the future of plastics, he is not making any deliberate attempt to "sell" plastics to the reader. This is hardly necessary. Surely anyone can realize that future when he scans the present position of plastics. But it must be borne in mind that one of the greatest factors in the forming of a successful career is an interest in one's work. If plastics as a subject is not appealing, it stands to reason that plastics will have little interest as a career. Let us then make a very brief survey of the present position of plastics in the industry of our country.

Taken alphabetically, the first field of plastics is probably architecture. In this field, more than any other, the plastics enthusiast has envisioned a roseate future. But as with all enthusiasts, it seems that he has covered the palette with colors of slightly too bright a hue. That plastics have exerted and will exert a tremendous influence in architecture is not to be denied. But that they will eventually replace other materials now used in architecture is open to serious debate. Obviously it is possible, but so highly improbable that such "reasoning," particularly at this time, seems absurd.

At the present time plastics are used chiefly as panels and decorations. The panels may take the form of surfacing. In addition, plastics are making great headway as floorings, tilings, and roofings. But in the heavy construction field, such as replacing girderwork and other construction where heavy stresses are present, they have not made any advances worthy of note.

Few of our modern buildings are constructed without a very considerable amount of plastics being incorporated into them. Plastic panels of the laminated types in particular find wide usage. Here the bright colors and water- and wear-resisting qualities of plastics make them valuable. Any surface can be duplicated in plastics, and in many cases this effects a great saving in the cost of the building. Tilings for the floors and corridors are commonly made from plastics. Modern roofing is practically all plastic-based. In connection with the roofing, it is interesting to note that full advantage is taken of the ability of a plastic to incorporate another substance into it and increase its own characteristics. For instance, asbestos is incorporated into a plastic roofing compound and a fireproof roofing results. Various other materials are used to create special characteristics.

There are two main divisions of decoration in interior work of all building. These are coatings, such as paints, varnishes, lacquers and enamels; and ornamental work of various kinds. Here we find a wide and varied use of plastics.

Plastics form the base of almost every one of the modern coatings, especially those of the so-called "quick-drying" kinds. They possess far greater resistance to wear than the types formerly used, which were not synthetic. They come in a full range of colors and their use is by no means confined to architectural work, as we shall see.

In the ornamental field plastics are used as panels, floorings, trim, elevator cages and casings. In addition, they form partitions and are used as facings for various sections. For strictly ornamental purposes they are used throughout the building. Because they are easily molded and their cost is low, they find special favor in this field. Stairways and bannisters are made of plastics. The drinking fountains, toilet facilities, and so on also are a field for plastics. Nearly all of the interior illuminated signs are now made of plastics. They are not as fragile as glass and do not shatter, so this hazard is eliminated through their use.

In the office-furniture and fixtures field, plastics appear on desk tops and drawer fronts; in the various items commonly on the desk, such as telephones, trays, pens and pencils; in coatings for metal files and typewriters, index cards, blotter holders, adhesives, waste baskets and other containers. Some of the most modern of the designers have used solely plastics in desks and chairs with excellent effect. Their expanded use is certain, for they possess great wearing ability coupled with unusual beauty.

Today the majority of the modern light fixtures are of plastic base. Certain plastics have the ability of transmitting light better than ordinary glass. In addition, other plastics diffuse light better with far less loss. Shades and reflectors of all kinds are likewise made of plastics.

In the arts, plastics find an increasing use in the manufacture of musical instruments. Because the lips do not tend to "freeze" to a mouthpiece of plastic as they do to one of metal, plastic bugles are now standard with the armed forces. While perspiration tends to discolor metal, it has no effect on certain of the plastics. As a result, keys and other parts which are subject to handling are now made of plastic or carry plastic shields. Reeds for instruments such as the oboe, clarinet and saxophone are of plastic. It gives a better tone than the bamboo formerly used, and has the additional advantage of not splitting or flawing as did bamboo. In the piano field, the keys and other parts are now made of plastics, because of the advantages of such material. The stringed instruments make use of plastic strings and picks, as well as plastic rests for the chin or hand.

The greatest use of plastics in music, however, is in the phonograph-record field. As we shall see in the chapter on the resins, this is the base of by far the greatest number of records. A few records are released which are made from vinyl resins. These are more costly and do have the advantage of being better recording mediums; but their cost does not justify the slight gain in tone for any general sale. Broadcasting companies make use of them for special recordings, where they wish to have the original reproduced as perfectly as possible.

In the automotive industry, plastics have been accepted far more than in any other industry. That we eventually will have a plastic car, except for the engine, is certain. As far back as 1940, the author viewed plastic bodies and fenders. These had been made experimentally, but automotive executives stated with assurance that they were the coming thing. They offer many advantages and effect a great saving in tooling. Furthermore, colors heretofore unavailable can be produced through plastics.

The acceptance of plastics in the automotive field is not new. Automobile men were the first to make use of them. For some reason this industry, far more than any other, seeks out innovations and eagerly accepted plastics. In the chapter on cellulose nitrate, we shall see that the automobiles of the early period of the industry used this material for windshields and for windows in the curtains of those days. Today cellulose nitrate is used only where it is well protected from the possibility of fire and where there is little chance it is will be touched by cigarette ashes. Its high flammability limits its use, as does its lack of resistance to the effects of ultraviolet rays, which turn it brownish. It is now used for such items as instrument faces, dials, pointers and so forth, which are well protected.

Another cellulose widely used is cellulose acetate, which is far less flammable than the nitrate. It is often molded over metal, the metal inserts being used to give it the required strength. It forms a large part of the handles, window cranks and so on, and in addition is used to a considerable extent for radio and instrument panels.

A third cellulose, cellulose acetate butyrate, is replacing to some extent the straight acetate. It does not weather as does the acetate, and it has far less shrinkage.

In some of the new radios and instrument panels in automobiles, advantage is taken of the edge-lighting effects that are possible with plastics. The methyl methacrylates are used here. They are perfectly clear and transmit light easily. The figures or other inscriptions are sunk into the surface of the plastic, and the light, passing edgewise through the plastic, is reflected in the recess.

The electrical systems make use of the molded phenolics because of their good resistance and insulating qualities. The bituminous plastics supply the battery case.

Laminated plastics are used for gears, and to reduce noise and increase the resistance to wear. In some of the new-type engines, plastics are replacing metal for the crankcases and the covers over the valve mechanisms. The waterpumps are being made of plastics, and most of the engine parts which are not directly stressed by the development of power can be made of plastics. A great saving in both weight and initial cost of tooling is made possible in this manner.

In tires we are due to see a tremendous use of plastics, for our synthetic tires are plastic. In addition, the cord used to make the fabric layers and reenforce the tire is a plastic, rayon being the best material found to date. Rayon is much superior to cotton of any quality. It has far greater strength per equal unit, and in addition it is not affected by the moisture as is cotton. Moreover, it is much more heat-resistant.

Briefly, then, we see that plastics in the automotive industry supply many parts to the car and are certain to form the greater part of the complete structure in a very short time after the war is over. There can be no doubt about this. Every manufacturer has plans for a so-called plastic car. In these, metal will be replaced throughout, except in the parts of the engine where the heat is too great and in certain parts of the car where the stresses are exceptionally high, as in the gears of the drive and parts of the rear end and the frame.

A new plastic which bonds practically anything is now in use, and by means of it the automotive industry has been attaching wood to metal, metal to metal, fabric to metal. It forms laminated materials which are lighter than steel, and stronger.

Summing up in regard to the automobile, in addition to the finishes used we find plastics in the following places: instrument panel; dashboard, overlay panel for decorative effect; glove compartment, door, handle, any ornamentation; speedometer, lens, dial, panel, pointer, cable washers, odometer lens, dial block; radio, push buttons, control, grille, grille ornament, dial, knobs, lens, scale; headlights, socket washers, terminal plates, insulators, terminal block, switch base; radiator ornament; parking light lenses; bonnet side-light lenses; water-pump parts; spark-plug caps; generator base; distributor, housing, rotor, cable caps, cable insulation, friction pad for points, etc.; voltage current regulator, insulating sheets and tabs, terminal block for ammeter; coil, top, terminal, base, resistor, cover, box; transmission washers; cigar lighter, housing, base, washer, insulating washer; knobs, throttle, choke, light signal switch, windshield wiper, ventilator, heater, hood latch, lighter, gearshift handle and cap, window regulator; steering wheel; battery box; lock switch body; accelerator pedal; antenna, insulator, bushing; clock, panel, dial, lens, hands; door locks; molding medallions; shank insert on handles; dome light, lens, switch, insulating block; upholstery, buttons, trim, fabric; ash tray, lid, bushings, lamp housing; interlayer for safety glass; signal light, lens, washer, contact switch, sleeve switch; direction indicator; trunk light lens; tail lens; license plate cover and lens; gas-tank top; gauge unit washers; escutcheons; door bumper shoes; horn parts; wire connectors; tires, and several others.

While the automotive industry has made wide use of plastics and is finding more and more uses for them, a newer industry is likewise making use of them and they are contributing materially to its progress. This is the aviation industry.

Plastics have proved to be invaluable in aviation and they are to be credited with much of the success of our air forces against the enemy. In the aircraft field they are used for three general purposes, which, in order of their importance, are as follows:

Construction of the airframe and wings and other major parts.

Construction of minor parts not necessary to the structural integrity of the airplane.

Accessories, such as control knobs and so on.

In the first category, great advances have been made. There has been a vast amount of loose talk, however, about the "plastic" airplane, and this should be corrected. There is no plastic airplane, and there is, at this time, no promise of any such airplane. What there is, and in quantity, is a *plastics-bonded* airplane. In this type of plane, plastics are used to bond together other materials which possess the required strength to withstand the stresses which are imposed upon an airplane in flight. Plywood is the chief material used. An excellent example of this type of airplane is the famed British deHaviland Mosquito fighter-bomber, which is constructed throughout of plastic-bonded plywood. Its success is outstanding, and it stands as one of the most efficient and fastest of all aircraft. Many of our trainers and some of our newest experimental models follow this same type of construction.

Plastics have a peculiar advantage in the aviation field. Typical of their use is the Duramold process which is described in the chapter covering that subject. The resulting finish of a plastics-impregnated plywood is far smoother than that of a metal surface, and there is an increased efficiency in the aircraft due to the lessened drag. Also, and of more importance, production is speeded up and the costs lowered. The fuselage is made in two whole sections and these are then set together and welded into one by plastics. The wing sections are made in somewhat the same manner, as is detailed in the chapter mentioned.

In the second category, plastics of the methyl-methacrylate type are now universally used to form the transparent nose and tail sections, windshields, windows, and enclosures for the guns in the gun turrets. Other plastics are used to form partitions, bulkheads, trim tabs, and a myriad of other smaller parts.

In the third category come the many instrument panels, faces, dials, knobs and so forth. In addition, laminated plywoods are used for the innumerable control pulleys each plane contains.

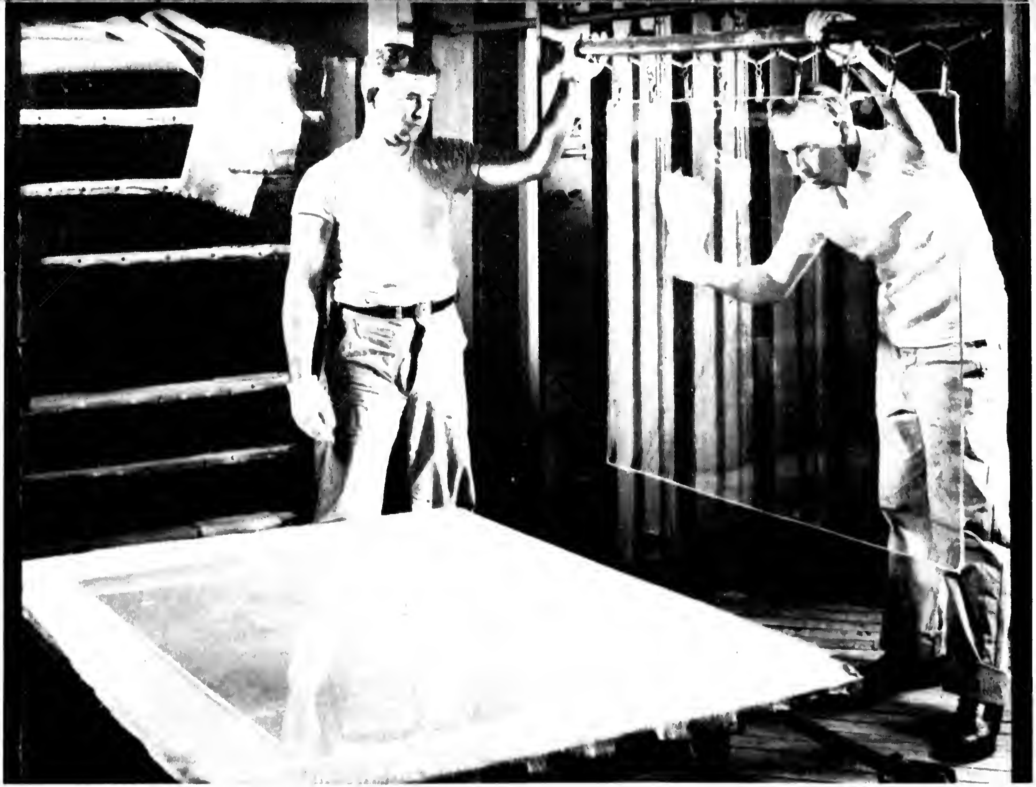
Earlier in this chapter we mentioned the use of plastics in buildings and office supplies. This field of interior decoration has been extended to the aviation industry.

Commercial airliners and private planes are finished in plastics. The furnishings likewise are of plastics. Here again plastics show themselves to be of advantage from both the economical standpoint and, in the case of airplanes where weight is of prime consideration, from the standpoint of lightness.

In the advertising field plastics are making great headway, especially in the displays. Cellulose acetate, phenolics, acrylics, the methyl methacrylates and vinyls are widely used.

Edge-lighted signs, where the letters are embossed or raised from the rest of the surface, are widely used. Ornaments of all kinds are in demand for window displays. Shelves made from acrylics are in general use. These resins are as clear as glass and much lighter; and in addition, they are not brittle. Acrylics have the peculiar ability to pipe light around sharp bends and center it wherever desired. As a result, light is often brought through an acrylic rod and centered on an object for display. No light shows around the rod, yet it projects from the end. Incidentally, this same characteristic is made use of in surgery and dental work. For signs, plastics can be used in color as well, and this brilliance of color renders them particularly useful.

Plastics of various shades are also used in molded forms to advertise various products. Miniature bottles and other objects are easily molded, and the cost is low. In sheet form, colored plastics make attractive back-



Inspecting a sheet of Lucite, a plastic used in the airplane industry. The sheet has just been heat treated.
(Courtesy Modern Plastics)

Insertion of a plastic called Butacite between two panes of glass reinforces this airplane windshield so that it will withstand the impact of a four-pound fowl projected into it at 300 miles per hour. *(Courtesy Modern Plastics)*

Plate glass table top rests on tubular legs of Lucite. Table was designed by Gilbert Rohde. *(Courtesy Modern Plastics)*

Plastics used for interior decoration on stair railing.
(Courtesy Modern Plastics)

grounds or serve to accentuate the object of display through contrast. More and more signs, as well as the letters and figures used in prices, are being made of plastics. Every day sees some new use in this field.

In the electrical field plastics, especially the phenolics, have a wide use as insulators. The fact that they possess excellent dielectric properties makes them ideal for the purpose. The ureas are employed as well, and in high-tension work the polystyrenes find wide use. As most of the uses of plastics in the electrical field appeared, in one form or another, earlier in this chapter in the detailed list of plastics in the automobile, there is no necessity for recapitulation here. It is sufficient to say that their use is general and the volume heavy.

To enumerate all the uses of plastics in the household would require a considerable part of this volume. Moreover, the uses would overlap with some already mentioned, as in the electrical system of the house, the paints and so on. But almost everywhere you turn you will see, with a little study, where plastics are around you in your home. They are in the better kinds of paints, varnishes, lacquers, enamels, coverings for tables, refrigerators, cabinets, toilets, containers of all kinds, games, toys, dishes, holders, coffee makers, coasters, flashlights, reflectors, garments, shoes, brooms — in short, everywhere!

In the field of textiles, plastics again are coming to the fore. It is not necessary to go into the progress of nylon and rayon. Their general use is well known. But there are now plastics on the horizon awaiting such time as the clouds of war are dispersed that will make the wonders of these fabrics seem drab. Strange as it may seem, glass fibers, as thin as thread and as flexible, can be woven into fabric, and when this fabric is bonded by a plastic the result is startling. Colors of every hue are possible and the sheen of the fabric is unmatched. In addition, it is spot-proof and possesses wearing qualities far beyond anything now in general use.

In upholsteries and artificial leathers and other coverings, plastics cover a wide field and find general use. The covering of modern furniture is seldom leather, but is usually some form of plastic. Even the soft fabrics which are used to upholster are made of plastics.

In photography, all of our film bases are plastics. The housings for cameras and lenses are plastic. Filters, developing tanks, containers and baths of all kinds – in all these, plastics are replacing metal. Even the bellows of the camera is a plastic.

In the packaging of various articles, plastics have absolutely revolutionized the field. We can remember when, but a very short time ago, "Cellophane" made its appearance. Now such plastics are in general use. Nearly everything we buy that is of a nature which demands protection from moisture, or is sold better in a wrapping that will permit it to show, is packaged in a plastic.

In the container field, this applies as well. Bottles, caps, boxes, closures of every kind are available in plastics. This field of use is tremendous and is expanding daily. Paper treated with plastic becomes liquid- and acid-proof and far stronger. Cloth can be treated in the same way. The possibilities are innumerable.

In sports, nylon replaces gut strings, plastics replace rubber, leather, wood, metal. Handles and grips for bats, golf clubs, tennis racquets, ping pong balls, soles and uppers for sports shoes, even fabric for uniforms — all these offer a field for plastics, and in turn the articles offer better service.

In the field of medicine and surgery the same applies, as it does also in dental work. Plastic dentures duplicate the real teeth so realistically that they are impossible to detect. In optics, contact lenses for the eyes have been replacing glasses. These plastic contact lenses are unbreakable and transmit light better than glass.

In personal and other ornaments of all kinds plastics have little competition. Their molding qualities, low cost and brilliant colorings make them *sine qua non.*

Because of their resistance to acids and the effects of salt water, as well as weather in general, plastics find a wide use in transportation. Railways and steamship lines use them in quantity, and every year finds more fields where they can be profitably employed.

Briefly as plastics in industry have been surveyed in this chapter, it must be obvious that their use is general and that the full extent of their application in industry has been far from attained. And it must be borne in mind that the field of plastics is not a static one, well established and developed. It is a new industry and scientific developments are constantly being made. The entire list of plastics is by no means completed. We have, however, approached a point where we now can make a plastic to fill a specific demand. Scientists juggle the atoms almost at will, forming this substance or that and knowing what the characteristics of each will be.

The possibilities of careers in the field of plastics are evident from the foregoing. But how can one enter the industry? What are the best fields of opportunity? Let us consider plastics now strictly from the standpoint of what they have to offer as a career.

To do this, we must bear in mind what plastics are, how they are made, how they are manufactured into various products and marketed. Having gone over these points, we can more or less fit the situation to our own personal likes and dislikes, as well as qualifications.

CHAPTER II

THE FIELDS AND OPPORTUNITIES FOR A CAREER IN THE PLASTICS INDUSTRY

The two general fields — the technical side of plastics — educational background necessary — emphasis on specialization — schooling — demand for trained men — the practical field — the application of plastics to any particular field — necessity of knowledge of product and the properties of plastics — technical knowledge not vital — wide range of opportunities — the direct sales field — comparison to present selling fields — returns from both general fields ample — assured future of the industry.

PLASTICS offer two general and widely different fields for a career. These are the technical and the practical. In one, advanced chemistry is essential, and even then the subject is so complex that the careerist must specialize. The other field possesses several sub-divisions, but in general it may be said to cover the practical applications of plastics to industry and the arts. Here the highly specialized training of the first field is not essential. But it must not be thought that knowledge of the particular branch being dealt with is not necessary. For instance, many an automobile executive who possessed little or no knowledge of plastics immediately saw their possibilities as applied to the particular problems of his factory and product.

Training for a career in the technical field of plastics is long and arduous, but intensely interesting. Moreover, it offers excellent opportunities and holds many substantial rewards. Such training should have its beginning in high school. From the first the future worker in the technical plastics field must concentrate on chemistry. In addition, he should have a thorough grounding in physics.

Naturally this will call for attendance at one of the technical high schools. From here the student should plan to attend one of the best advanced technical schools he can afford. Unfortunately the total costs for such an education are high, but they are not beyond the reach of anyone with moderate means if he possesses the will.

At the present time there is a demand for trained technicians in this field and there is no reason to believe that this demand will not be augmented in the years to come, for plastics are definitely going to play a greater part in our life as time passes and developments bring out additional plastics which will answer specific needs.

There is little necessity of going into detail about the educational steps. Any competent science teacher will be glad to advise a student, or if not familiar with the steps the teacher will certainly be able to direct the student to where the information can be secured. Inquiry to almost any one of the larger companies manufacturing plastics will bring a response on the subject.

In the practical field the situation is more complicated. Here the problem of technical education does not play such a major role. It is a problem of application. This necessitates a sound knowledge of two things. First, one must know what plastics will do, must understand their advantages as well as their limitations in the particular field under consideration. This does not mean that the knowledge of plastics must be highly technical. For instance, if one were going to plan to use plastics for the transparent nose of an airplane, cellulose nitrate certainly would not be the choice although it is a transparent plastic. The fact that it is highly flammable and turns brownish under the influence of ultra-violet light precludes its use in this field. We would probably use such a material as methyl-crylate.

From this it is readily seen that it is not necessary to have a technical knowledge of the plastic, that is to say, the *chemistry* of the plastic. One must be thoroughly familiar with its *characteristics*, its *properties*. It is this application of the proper use of the proper plastic that makes a person valuable.

Examples could be given almost endlessly of like situations in plastics. We have seen that they enter into practically every industry and that their use is not as yet fully determined. The bonding of different materials through plastics, a process recently developed, promises to open one of the widest fields for plastics. It is certain to make their use universal.

It might be briefly mentioned here that this new process makes it possible to bind together permanently and thoroughly different materials such as fabric and metal, one metal and another glass and metal, or in fact any material one can conceive. In addition, this process frees plastics from one of its greatest drawbacks for general use in industry where vibration is present. Heretofore there has been a tendency for the joint where the plastic is attached to another material to collapse under vibration. This new process eliminates this. One result will be seen immediately when we again produce automobiles. Plastic tops are possible, and the corners of the bodies will be far smaller. Visibility will be widened. Safety will remain unchanged, as far as resistance to turning over is concerned, and will be augmented through better vision. Now plastics can be inserted permanently between steel frames which will be used in the same manner as rods in reinforcing concrete or in the structure of our modern buildings.

Thus it is obvious that for the person who has the knowledge of where plastics can be used there is an excellent field of endeavor, even if he is not equipped with a technical knowledge of plastics. But he must be able to make practical applications of them.

The second field in the practical category is the direct sale of plastics as a material. In this, as in the previous field, the ability to see where they can be applied practically is of the greatest importance. But here a more detailed knowledge of plastics from the technical point is an asset. This knowledge is nothing that will require long technical training. Study is sufficient.

Naturally these two fields overlap to a very considerable extent, and it is difficult to draw any clear line of demarcation. The first field may be said to be "selling the idea" of plastics as a material to be used, showing where they can be used to advantage; while the second consists of the actual sale of the plastics.

Both of these fields offer ample returns. While there are no definite figures available at the present time, because of war conditions, it is certain that when peace returns plastics will again be marketed as they were before the war. But with the great advances due to the war the field is even wider, and before the war it was already an excellent field of endeavor.

Part Two

The Principal Plastics — Characteristics and Industrial Uses

CHAPTER III

CELLULOSE NITRATE OR PYROXYLIN – FIRST OF THE PLASTICS

Its discovery – first commercial applications not a success – introduction into the United States – the Hyatt patents – their successful application to industry – modest beginnings – rapid expansion – formation of the Celluloid Manufacturing Company – application to the automotive field – Celluloid becomes a household name – characteristics of pyroxylin plastics – their advantages – their disadvantages – their fabrication – applications in industry – trade names.

IN 1833, in the dingy confines of his laboratory, a French chemist named Braconnot completed the final phases of a long series of chemical researches. In a Florence flask he held a small quantity of liquid. It was a clear liquid of heavy body that flowed sluggishly and left a thick film when it receded from the walls of the flask. A few drops which had spilled on the stained surface of the workbench slowly dried in the air and formed small buttons of clear, hard material. Idly the researcher touched them with his finger. They adhered tightly to the surface. His eyes returned to the liquid in the flask. He had succeeded in forming cellulose nitrate. That was what he had set out to do, and there was a quiet satisfaction in the accomplished fact.

If, through some magic, Braconnot could have seen projected in the flask the miracles of modern science which were to come from his research, it is doubtful if he would have believed his eyes, for in that flask was the first of all the plastics — the plastic which has had a direct bearing upon the subsequent development of a great industry, one which has exerted and will exert a tremendous influence upon the life of the peoples of the earth.

But, typical of the scientist, the researcher of that time, Braconnot was not interested in any of the commercial possibilities of his work. These were the concern of a world beyond his narrow confines of the laboratory. His discovery of cellulose nitrate was to lay dormant commercially for nearly seventy years until an American, John Hyatt, was to make the first practical use of it.

John Wesley Hyatt and his brother, Isaiah Hyatt, succeeded in 1896 in patenting a process using pyroxylin as a true plastic, that is, not in a fluid form but rather in a mass which was semi-solid. This mass could be molded and formed with ease. The basis of the patent was founded on the process of using very small quantities of solvent to reduce the pyroxylin. This was accomplished by dissolving it under heavy pressure. As the solvent was an expensive item, their process materially reduced the cost of the product as well as making it practical.

It may be of help to the reader in classifying this form of plastic to bring to his attention the fact that cellulose nitrate, or pyroxlyin plastic, is used widely in medicine to seal small cuts. It appears under the name of collodion. In this form, the plastic is dissolved in ether or chloroform, both highly volatile liquids which evaporate rapidly and leave behind a thin and flexible film of plastic which covers the wound. Incidentally, in a pigmented form, colored by dyes, the plastic appears as a nail enamel for women.

The Hyatts at first made little headway with their patent, as the uses in industry for such a material were extremely limited at that time. Innovations were not accepted as readily as they are at the present.

But the Hyatts were not discouraged, and four years later another patent was issued to them for an improved type of this plastic. They had discovered that if they mixed small quantities of camphor with the cellulose nitrate the resulting plastic had better qualities.

Immediately after the appearance of this form there came into being the first company in the United States to use plastics as their chief item of manufacture. The

Albany Dental Plate Company was incorporated in 1870.

Because of the fact that this plastic could be molded at comparatively low temperatures and set quickly at ordinary room temperature, it was ideal for the forming of dentures. In addition, it possessed the characteristic of being easily colored, so that flesh tones could be reproduced and thus make the denture less noticeable — a distinct advance at that time.

The Hyatts attracted considerable attention with this use of their product, and other manufacturers became interested in the plastic in various forms and colors. Soon it was in demand for a number of items, and the demand became such that the Celluloid Manufacturing Company was formed. It was under the name of celluloid that the plastic first appeared. The Hyatts moved their factory to the city of Newark, New Jersey, where it still is in business.

At the turn of the century, when the automobile began to come into general favor, celluloid gained wide use. It was capable of being made in sheets which were not only clear but flexible. The cars of that time possessed neither windshields nor windows. A fabric top, after the style of the horse buggies of the day, was the only shelter afforded the passengers.

Early manufacturers saw that they would have to make some provision to protect the riders during inclement weather. They devised fabric curtains which attached to the car with brass fasteners. These curtains carried

Something new in spring hats: a plastic trim.
(Courtesy Modern Plastics)

Plastic shoe. *(Courtesy Modern Plastics)*

This plastic lunch case was originally designed for war workers to permit easy inspection at gate.
(Courtesy Modern Plastics)

windows of celluloid. The windshield was made in a like manner.

For this celluloid was an ideal material. The curtains and windshield, when not needed, were stowed away in a small compartment in the car. This necessitated rolling them, and the flexible material withstood such treatment with ease. Unless it was rolled very tightly it would not crack.

In this clear form, however, celluloid had one bad feature in particular. Ultra-violet rays have the effect of turning it gradually to a dark brown, which cuts out a great part of the visibility. Besides this, the material is highly flammable. Yet, despite these disadvantages, celluloid has continued to be used in vast quantities even to this day.

It was during this period of the development of the plastics industry that celluloid gained a foothold in the homes of the country, and opened the door for the entrance of all the plastics which were to follow.

The Hyatts found that their product was easily molded, as was shown by the success of the Albany Dental Plate Company. Soon other manufacturers were molding celluloid. It could be produced in any tone, as we have seen, and it so happened that at that time ivory was a favorite material for ladies' toilet articles. But ivory is expensive. Celluloid closely resembled ivory in appearance but was infinitely cheaper. As a result, molded combs, mirror handles and backs, powder boxes, trays, handles for various toilet articles and so on made their appearance. In no time at all there was hardly a home in the land that did not have some celluloid article in it somewhere. It appeared as picture frames, clock cases and faces, even as men's white collars, stiff and high, and, as advertised, easily cleaned with a damp cloth! No laundering necessary — no starching! But woe to the man who carelessly dropped a glowing cigar or pipe ash on his collar! There would be a flash of flame and the collarless victim ended with a badly burned neck.

But this pyroxylin plastic soon emerged from the swaddling-clothes state. It met with favor from the start and became widely used throughout industry. As progress was made in fabricating it, its uses spread. One of its greatest fields proved to be the automotive industry.

With the advent of closed cars and their plate-glass windows, serious injuries from broken glass resulted. Time and again what might have been a minor accident, one that caused but slight damage to the car, resulted in fatal or disfiguring injuries to the occupants. The sudden stopping of the car threw the passengers forward and they struck the fragile glass. Long splinters of glass cut and seriously injured them. The manufacturers saw that something had to be done about it.

At this time one of the glass manufacturers had the idea of using thin sheets of glass bonded together by some flexible material which would not obstruct the passage of light, but would retain the glass in a mass even upon impact. As a result what was erroneously named as "shatterproof" glass made its appearance.

This glass was formed from two thin sheets which were separated by a fairly substantial film of celluloid. They were brought together and then heated carefully. The plastic celluloid became almost fluid and immediately adhered firmly to both sheets of glass. The three were bonded together and could not be divided unless the material was worked back and forth under heavy force.

Upon impact this glass shattered easily, despite its name. But it did not break into the dangerous and lethal large splinters which were formed when ordinary glass was broken. Instead, this glass combination broke into minute pieces but still held together, the glass firmly adhered to the celluloid binder between the sheets. The danger of cuts and injuries was eliminated.

This shatterproof glass found instant favor with the automobilists of the period. They installed it in the windshields, as it was against these that the passengers were thrown in accidents. But the cost was high, since production was low. Then Ford made it standard equipment in his cars, and others in the industry followed immediately. Shatterproof glass became the general rule, and the price dropped with the greatly increased production. However, the old disadvantage of the effect of ultra-violet rays on celluloid remained. After a period, the glass became brownish and this discoloring increased with age until vision through the windows and windshields was restricted. However, as we shall see later, other plastics came into being, and to them we can give thanks for the safety we now enjoy in our cars, so far as shattered glass is concerned.

During the time that these developments were taking place other plastics made their appearance, and with them came a series of improvements in the fabrication of plastics. These methods are discussed in detail in Part Three.

Instead of using dyes to color the cellulose nitrate plastic, manufacturers began to mix in various pigments which were finely ground. Metallics also were used. Taking advantage of the ability of the plastic to be dissolved and to leave behind a thin, flexible film which adhered strongly to almost any material when the solvent had evaporated, the automotive industry produced lacquers which they used to cover the metal bodies of the cars.

These lacquers, at that time simply cellulose nitrate in liquid form and pigmented, had many advantages over the paints and varnishes formerly used. First, they were far more weather-resistant and they withstood the effects of mild acids and erosion, as well as the abrasive effects of road particles. In addition, they dried much faster and only a single coat was necessary to cover the surface after it had been prepared with a filler coating. And in this pigmented form, cellulose nitrate was not affected by ultra-violet rays, as was the clear plastic.

Other forms of the plastic, molded to shape, soon appeared in tail lights and interior lights, replacing the glass commonly used then. Colored and highly decorative gearshift handles and parts of the instrument board were likewise made of plastic.

Cellulose nitrate now moved into other fields as a coating and decorative. It was found that the plastic could be expanded by the addition of organic liquids. If it was applied to an article in this state as a thin covering and the article was then heated to drive out the organic liquid, the plastic shrank and formed a very tight-fitting covering.

By placing two sheets of the plastic together and heating them in a mold until hot and then introducing compressed air, the plastic was expanded until it filled the mold, and thus hollow forms were made. Containers of cellulose nitrate made their appearance, and light balls, such as those used in ping pong, came into being.

In addition, it was found that by using very thin sheets of variously colored cellulose nitrate and placing them one on another, a mottled effect such as is found in marble could be reproduced when the sheets were bonded together by the application of heat and pressure.

The plastic was easily cemented and it formed a firm joint. This permitted the fabrication of other items having complex curves and forms which were not easily molded. It also permitted the fabrication of larger items than are ordinarily molded.

However, cellulose nitrate, pyroxylin, celluloid or whatever name it appears under, widely used as it may be, is far from the ideal plastic and is greatly surpassed by others, as we shall see later in this volume.

Pyroxylin has one great disadvantage besides its high flammability. It cannot be compression-molded in the powder form, nor does it lend itself to injection molding. In the latter process (described in Part Three) it appears to form a perfect article in the mold, but under test this is found to break down. Compression molding is done with a plastic in a powder form and the substance is then heated. But pyroxylin simply refuses to form a solid mass. It adheres somewhat and takes shape, but force will break it into its component parts.

This progenitor of the plastics deserves all the credit possible for the establishment of the industry and for bringing about the developments in fabrication which have resulted through its first introduction. The chief characteristics of pyroxylin can be summarized as follows:

It lends itself readily to cementing, forms a firm joint; it can be easily fabricated; it colors readily; it is flexible to a great degree; it becomes plastic at a fairly low temperature – between 160° and 220° F.; it is tough and resists wear and the effects of moisture; in sheets and considerable thickness it is transparent. But as already mentioned, it is flammable and it soon discolors when the transparent material is exposed to the effects of ultra-violet rays.

In fabrication, it is readily formed by molding at the temperatures mentioned above; it can be "blown" somewhat after the manner of glass; it is easily sawed; mechanical fabrication, such as punching with dies, drawing, turning, embossing, printing, drilling and so forth are all feasible.

Pyroxylin finds a wide use in industry, and appears in the forms of piano keys, handles for various articles, ornaments of all kinds, frames for pictures and bags, trays, toilet articles, pencils, pens, clock cases and dials, instruments, toys, balls and, lastly, in great quantities, as a covering for women's high heels which are made of wood, these being encased by a thin film of pyroxylin in some color to match the leather.

In industry, this plastic can be bought for various uses in many forms. It is manufactured in sheets, tubes, rods, lacquers and chips.

Some of the trademark names for this plastic which may be familiar to the reader and may help him identify it in various manufactured forms are the following:

Celluloid, made by the Celluloid Manufacturing Company, which was mentioned earlier in this chapter; Pyralin, a duPont product that appears in many forms, among which are toilet articles; Nixonoid, made by the

Nixon Nitration Works; and Monsanto C. N. (abbreviation for cellulose nitrate), made by the Monsanto Chemical Co.

CHAPTER IV

SHELLAC PLASTICS

Early appearance in the plastic field — the pioneers — Berliner's use of shellac plastic — adaptability — use with the coming of the automotive industry — advantages at that time — disadvantages — use in the electrical field — present uses — general characteristics of this plastic — forms available in the industry — how fabricated — applications — trade names.

WITH the advent of cellulose nitrate and its use in industry, another plastic which had been known but was more or less dormant came to the fore. This was shellac plastic, a plastic which has as a base a substance known to people of ancient times and widely used by them.

Lac, the base of shellac, is a secretion exuded by tropical insects and is found in quantity in India and the Malay States. These small insects, which are known scientifically as Coccus lacca, cluster in swarms on the stalks and twigs of trees and bushes.

They exude a substance which when it dries in the air forms a hard cellular protection for themselves and their eggs. These "shells" formed by the insects are of a dark brown color. Natives collect the shells and bring them to central points, where the branches to which they adhere are beaten over tubs of boiling water. The shells collapse and the fragments soon melt at the temperature of the water. The lac is then poured into molds and allowed to harden, or it is poured over large cool surfaces where it cools and forms into a thin film known as sheet lac. The sheet lac is then shipped for further processing, this usually being little more than the clearing of the impurities which such crude methods cannot be expected to remove from the native product. It appears in the form of rods, sheets and flakes. Any of these forms is soluble in alcohol or water; in the flake form the water must be hot for the best results.

Because of the fact that this lac, dissolved in a solvent which is volatile, will leave behind it a thin film which adheres firmly to practically any surface if there is the slightest irregularity present, the ancients used it as a means of sealing documents and for gluing in general. This was the first known use of the substance. Added to wax, it gave the sealing compound added strength. As its surface took a high polish with rubbing, it came into use as a polish with the ancients, and they also found it convenient to cover materials, using it in a solution of alcohol.

At about the same time that Hyatt discovered the commercial possibilities of cellulose nitrate and secured his patents, others patented uses for shellac plastic. But the material did not come into any wide use, as did the celluloid of Hyatt, until the advent of the phonograph, or, as it was better known at that time, the talking machine.

Berliner, a pioneer in this field, had experimented with the registration of sounds on various substances. By using a metal diaphragm having a sharp needle attached to it, he succeeded in etching a track on surfaces which would record the vibrations of the sounds fed into the space behind the diaphragm. These sounds were recorded in the groove cut by the needle as a series of indentations in the sides of the groove. The sound, impacting on the metal diaphragm, caused the needle to waver in its course and so form the indentations. When another and somewhat different needle retraced the same path, this needle having a rounded point, the vibrations were carried back to the diaphragm and amplified by the use of a horn. The result was a reproduction of the original sounds, minus, of course, much of their original overtones which were lost in the crude recording and reproduction. But the sounds were recognizable, even above the scratching noise of the needle.

Berliner found that hard rubber, wax and other substances were not entirely suited to his purpose. All of these substances had some disadvantage. Some were too hard, so that only the major vibrations were recorded. Others were too soft, so that they would not withstand the effect of the reproducing needle and were rapidly worn away. He sought some happy medium which would record the vibrations and still be of sufficient hardness to submit to prolonged use in reproduction of the original sounds.

In the year 1895 Berliner formed a compound which had shellac as its binder. This proved ideal for his use. He used a specially geared recording machine which cut the sound grooves in a spiral on a flat surface, and patented these plates of plastic as "Berliner records." They soon found world-wide use and "Berliner records" became a household word, since each recording carried a credit to his name. There was an announcement of the subject of the record and then the credit, "a Berliner record," to distinguish it from some of the other types which were on the market and were of inferior quality to the shellac-plastic forms. Even today, with all of our advances in this field, phonograph records still are made from shellac plastic and provide the greatest use for the material.

At the turn of the century the automotive industry was rapidly coming to the front in popularity. Cars were at a point where they possessed considerable reliability and public confidence was being won. With the development of the cars came a like improvement in their ignition and electrical systems, which had been one of the greatest sources of trouble previously. The main reason for this improvement was shellac plastic.

It was found that this plastic could be molded into the shapes required for the ignition and other electrical parts. The plastic possessed several characteristics which made it ideal at the time for such use. First of all, it was an excellent dielectric, one of the best insulators. Unlike glass, it did not shatter with abrupt changes of temperature from one extreme to another. This, in the presence of the heat from the engines, was of great importance. Nor did this plastic break down with moisture. It was thoroughly water resistant. Oil had no effect on it either, nor did gasoline. Best of all, it could be easily molded.

Its chief disadvantage was that it required a considerable period of aging after fabrication in order to prevent distortion, and even this aging did not prove entirely effective, as it still tended to warp. This made its fabrication into anything like precision parts an impossibility. It could only be formed into what might be termed rough tolerances, but the tolerances were sufficiently close so that it did permit the formation of certain necessary parts for the automotive industry.

In the high tension field, where the currents carried were of thousands of volts, the plastic showed to advantage. It did not tend to form tracks on its surface which would cause current leakage. If an excessive current did cause an arcing across its surface, there was no trace of the arc left afterward and the insulating property of the plastic was not destroyed.

Since the purified form lost its original brownish tone, the plastic could take any color desired, and it soon found favor in other uses. It made its appearance in the dental-plate field in competition with cellulose nitrate. Soon it entered the ornament field and others where celluloid had been supreme.

But in these various fields, its advance was soon checked by the appearance of other and better materials in the plastics. For a time it enjoyed a wide use as a binder for emery and other abrasives in grinding wheels and abrasive cloths. However, here again it was in time displaced and at the present its chief use, as mentioned before, is in the phonograph-record field.

Its low cost, its ability to reproduce the vibrations accurately, so that full tone is reached with improved recording and reproducing apparatus, its flexibility, the ease of molding, and finally the fact that when of no further use it can be broken up and remolded without additional processing all make it supreme for records.

To sum up this plastic, we find that it possesses certain outstanding characteristics which make it worthy of note and account for its importance as a pioneer in the field.

First, it is easily molded. In addition, it is an excellent dielectric, is hard and wear-resistant, will not break down under normal arcing of an electric current, is both water-and oil-resistant, can be used in solution to impregnate fibrous materials and, finally, has very good adhesive properties.

The fabrication of this material is, in general, entirely by molding. It can be molded by both the pressure and injection methods, which are described in detail in the Section Three. The molding is done under pressure of about 1000 to 4000 pounds to the square inch and at a temperature of some 250° F.

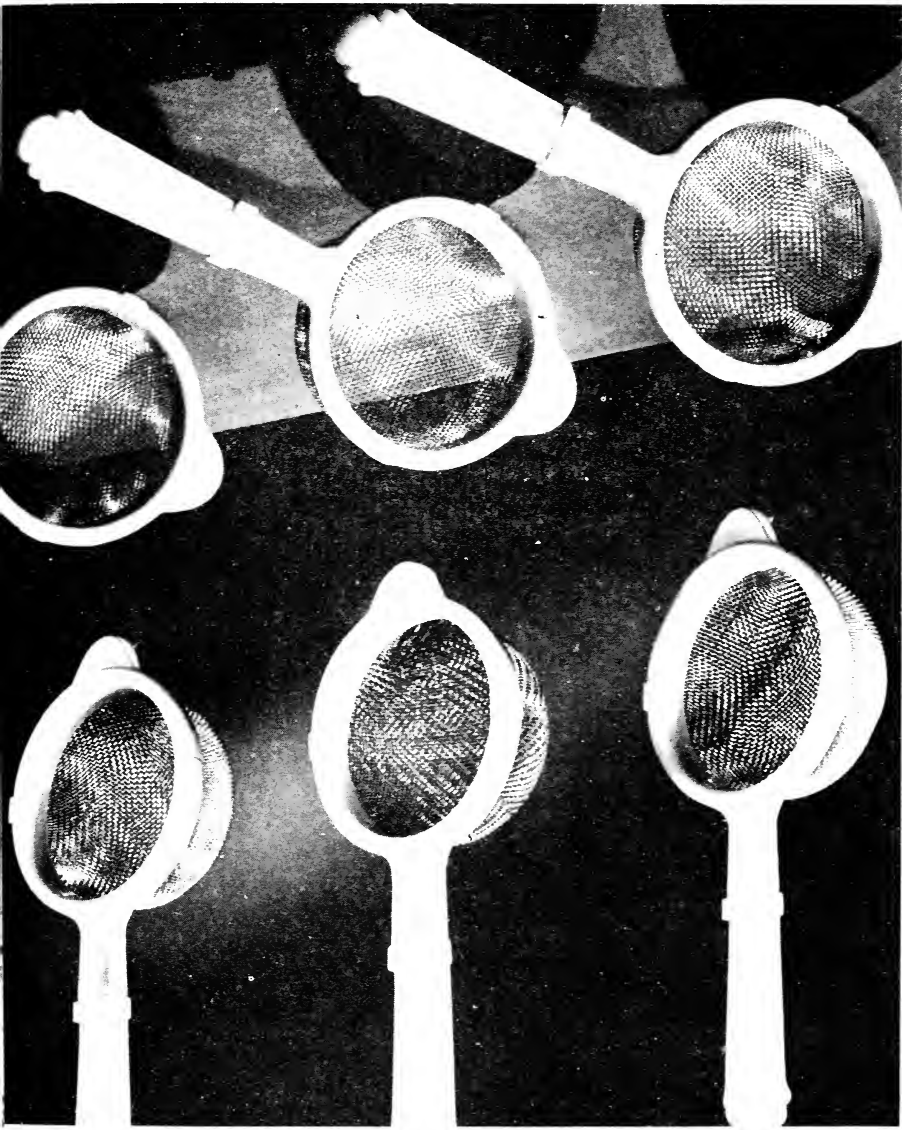
Reviewing the uses it finds in industry, we see that at the present time shellac plastic is employed mainly in the manufacture of phonograph records. But it also has been used and is being used in limited quantities in the fabrication of dental plates, electrical equipment, abrasives, novelties such as decorations of all kinds, game counters, adhesives and so forth.

It is available in the industry in various forms, in rods, sheets, flakes, chips, alcoholic solutions and aqueous solutions, where it appears as an emulsion in alkalines.

Some of the chief manufacturers of shellac plastic at the present time are listed below, with the trade name under which the product appears:

Harvite —	Siemon Company of Bridgeport, Conn.
Compo-Site —	The Compo-Site Company, Newark, N.J.
Electrose —	Electric Insulation Company, Brooklyn, N. Y.
Lacanite —	Consolidated Molded Products Company, Scranton, Pa.

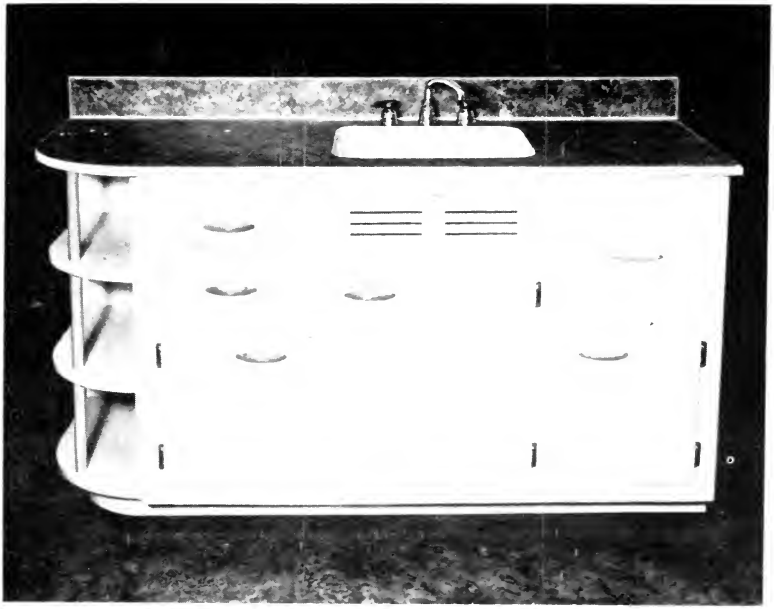
As is to be seen from the foregoing, shellac plastic is a limited field, and one which owes its importance at the present time to the production of phonograph records. But it is important in the over-all picture of the industry, for it pioneered in the field and through this helped to make possible subsequent advances. It is included here for that reason, as is the next plastic to be considered.



Plastic strainers. *(Courtesy Modern Plastics)*

Plastic handles on tableware. *(Courtesy Modern Plastics)*

Plastic grater. *(Courtesy Modern Plastics)*

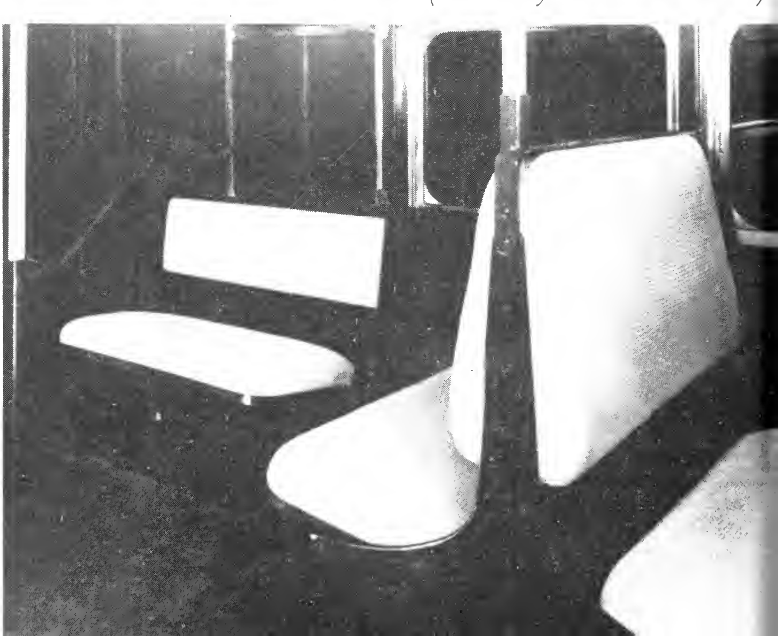


Postwar kitchen units will be made of plastic.
(Courtesy Modern Plastics)

Doors and telephone booths made of plastics.
(Courtesy Modern Plastics)

Office interior displays use of plastics.
(Courtesy Modern Plastics)

Long wearing, readily cleaned plastic rattan provides a colorful fabric for bus and streetcar seats.
(Courtesy Modern Plastics)



CHAPTER V

BITUMEN PLASTICS

Their development — field of use — special characteristics — materials entering into bitumen plastics — method of fabrication — curing — advantages and disadvantages — gradual replacement — present uses — characteristics cause limitations — résumé of bitumen plastic — forms available — trade names.

IN the year 1909 the first commercially successful plastic designed for a particular field was introduced into the United States. This was a bitumen plastic invented by Emile Hemming. As we have seen in the previous chapter, shellac plastic had a tendency to warp under the the effects of heat. This caused it to be unsatisfactory to some extent, but no better material was available on a commercial scale, particularly in the automotive and electrical fields. With the appearance of Hemming's plastic this drawback was eliminated. Moreover, his had the advantage of being a plastic which could be molded at ordinary room temperature, and without excessive pressures.

Notwithstanding these qualities the bitumen plastic was far from perfect, and possessed disadvantages which limited its field. But as it was deliberately designed for this specific field, it is not fair to compare it with the more recent developments which have in a large part replaced it.

In making his plastic, Hemming used a bitumen such as asphalt, coal tar, various pitches and even natural and synthetic resins and oils. These he employed merely as a binder. Fully three-quarters of his product was in the form of a finely shredded asbestos wool, which had the ability to resist heat.

Hemming made this substance plastic by the use of various volatiles. As these were subject to more or less rapid evaporation, the material had to be made in the same factory which produced the finished parts, for the plastic in this stage was not stable and required careful preparation and handling. This was one of its disadvantages, for it could not be shipped to other fabricators.

The substance was molded under pressure and then the product was removed from the mold and placed in an oven where the heat was carefully controlled. This heating was necessary to eliminate thoroughly the volatiles in the plastic.

After the product reached the ovens it was brought slowly to a heat of some 125° F, and this temperature was maintained for some time. Gradually the heat was increased until it finally reached as high as 425° F. This curing of the product after molding took from twenty-four to seventy-two hours or more, depending upon the volume of the material in the item molded.

By the time the heat had reached 425° F., the volatile materials were driven off and the bitumen had been changed through oxidization, or polymerization, into an infusible material.

The product, because of the evaporation of the volatiles and the alteration of the bitumen content, tended to shrink during this process, so that the molding of the plastic to close dimensional tolerances was impossible. But as such close measurements are not demanded in insulators and the other products it was designed for, the shrinkage was of no great importance.

The time factor in the curing had an effect on the costs, as was to be expected. In addition to this, the inclusion of asbestos had a distinct abrasive effect on the molds and cut down the life of them materially. The advent of other plastics has now driven this type from the automotive field, with one possible exception. It is still used considerably in making battery boxes, as it resists the effects of acids.

Reviewing this plastic, which is important mainly through the fact that it showed the way to the production of plastics to meet specific requirements, we find that it possessed the following characteristics:

It resisted heat to a marked degree, it was made from inexpensive materials, necessitated a curing period, had poor qualities for precision molding and could be used only at the point where it was manufactured.

In industry it was made into various handles and similar forms; was used widely as an insulator where heat was present to a marked degree; and was formed into wheels for steam and hot-water valves, battery boxes and so forth.

At the present time it appears under various trade names which may be familiar to the reader, and are listed for purposes of identification. They are, in part, as follows:

Cetec—	General Electric Co., Pittsfield, Mass.
Gummon —	Garfield Manufacturing Co., Garfield, N. J.
Aico —	American Insulator Corporation, New Freedom, Pa.
Okon —	American Hard Rubber Company, New York City.

CHAPTER VI

PHENOL-FORMALDEHYDE PLASTICS

The phenol-formaldehyde resins — Bakelite — the origin of this plastic — its early development — an American development — instant success commercially — composition — wide use in industry — fabrication — forms available — laminated products — trade names.

TO the United States goes the credit for the development of one of the most widely used of all plastics. This is the phenol-formaldehyde resin. It is the original of the thermosetting plastics and is still one of the most widely used, although it was first patented in 1909.

Phenol-formaldehyde resin owes its inception to the research work of Baeyer as far back as the year 1872. He discovered that there was a reaction between the phenols and the aldehydes which resulted in a resin. However, the combining of the chemicals was difficult to control and the reaction often took place so rapidly that the results were varying. Baeyer noted the reaction and went on to research in other fields. The resin was more or less of a scientific curiosity, one of many such which at the time had no particular interest or bearing on the work being done.

But nearly forty years later, in 1909, an American by the name of Baekeland was experimenting with this same reaction. He found that if there was present a catalyst which was alkaline, the reaction produced a resin which, upon being heat treated, became hard and very durable. He determined the exact quantities of this catalyst which were required to produce the resin, and secured a patent on the process. Baekeland saw the commercial possibilities in the product, for by now plastics were well in their first stages of development.

Going still further in his researches, he discovered that if he applied both pressure and heat to the resin so formed, he could mold it into any desired shape and the result was a firm, hard product of lasting qualities. In addition, it was a splendid dielectric, acid-resistant, oil-resistant, water- and weatherproof. Moreover, it was not changed by heat, unless of a high degree. It appeared to be exactly what it has since proved to be — an ideal plastic.

The first products, more or less in the nature of experiments, were made in a small laboratory in Yonkers, New York, in 1907. Baekeland trademarked his product Bakelite, a name which was to become a household word in the United States and even throughout the world.

In 1910 the Bakelite Company was organized, and the product was put on the market in a serious way. Baekeland's patent covered the manufacturing of laminated materials by using porous sheets and impregnating them with the plastic, then molding and heat treating as we have seen.

By this time there were several companies in the automotive field which specialized in electrical equipment. Bakelite was an ideal material for this purpose, and soon the various parts were more or less standardized. Bakelite could be molded to close dimensions and the costs of these parts were lessened. It became almost a universal material for this type of equipment.

This plastic gives us an excellent example of what plastics can do in industry if there is intelligent application to the various problems. We have mentioned that Bakelite was used to form manufactured articles by impregnating porous materials with it and then processing the result to produce solidified plastic to close dimensions.

In internal-combustion engines there is a chain of gears which drive off the crankshaft and operate the cams which actuate the valves. These gears are the source of considerable noise, giving forth a whining note which may vary in tone from a low growl to a high pitch. The early manufacturers sought to solve this trouble by introducing chains to drive the gears. These did have the effect of lessening the noise, but if the engine back-fired, which was a common occurrence at that time, the chain often jumped the teeth of the gears and the mechanism was placed out of the proper timing so that the engine did not function properly. This meant that the engine had to be taken apart and the timing of the cam gearing and chain readjusted.

Heavy canvas was impregnated with Bakelite and then formed into gears. As Bakelite could be formed to very close tolerances, these gears were quite suitable for an engine. They were placed in timing gears and the effect of the new-type gears was immediate. The whine and noise ceased. Bakelite became universal for this purpose.

Going still further, the automotive industry found that Bakelite, because of its resistance to heat and its ability to withstand a high degree of it, made an ideal material for bonding together the brake materials. Asbestos supplied a good gripping material, and bonded in Bakelite made a brake shoe which was entirely satisfactory.

When the radio industry came into prominence the use of this plastic was immediately widened, for here again it was superior to any other material available for the industry's needs. It not only could be formed into the various parts and proved an excellent dielectric, but it also made attractive cases. By now – the period of the early 1920's – it was so generally used throughout industry that to detail its various uses would require several pages.

With the coming of the airplane and its development, the plastic again proved its worth. In this field it is used in the electrical systems, for various panels, for the radio installations and, most important, for the various control pulleys in the planes. It is even used for propellers. The writer flew a plane with one of the first propellers made of this material, testing it under service conditions on the night airmail in the 1920's. It was constructed of laminations of fabric bonded by the plastic, and proved highly satisfactory. The control pulleys mentioned above were made in a somewhat similar manner, being fabric impregnations molded to shape and size.

In 1926 the original Bakelite patent expired, and as a result many companies began to use this plastic under their own trade names. These will be found at the end of this chapter and will help the reader to identify the plastic in many of its common forms.

Naturally, during all of the time that the plastic has been on the market there have been some advances in its production. The original chemical formula has been slightly changed and the original method of its production has been altered. Now the plastic is made with several different catalyzers.

We have seen that phenol-formaldehyde resins or phenolic plastics are used in two distinct ways. They are either molded as a solid plastic or they are used to impregnate porous fabrics so that articles can be formed from them. Let us at this point summarize the uses of the plastic as a simple molding material. We find that its chief characteristics are the following:

It can be molded to close tolerances, will withstand the effects of heat without warping, is easily worked, is not affected by either moisture, oil or acids of the kind usually formed by the atmosphere, is an excellent dielectric, and hardens under the influence of heat.

Its fabrication is not difficult, and is done by placing the plastic in steel molds at a pressure of some 2000 pounds to the square inch. While being molded at this pressure, the temperature is brought up from 280° to 350° F. Depending on the volume of the material in the mold, this heat is held for periods of from twenty or thirty seconds to several minutes, until the mass is solidified and becomes homogeneous. It is then cooled below the critical temperature and taken from the mold.

This molding is done from the powder form of the plastic. There are numerous forms on the market and each has a special purpose. For instance, some of the forms are particularly acid-resisting, while others are better for different types of molding, as we shall see in the chapter on fabrication.

Typical uses of the plastic in industry are, in part, as follows:

> Containers of all types, camera boxes and parts, ignition parts, parts subject to corrosion, telephones, handles, insulators, or almost any use where limited strength can be applied.

It is known to the public under various trade names, the following being the better-known ones:

Bakelite – Bakelite Corp., New York City.
Durite – Durite Plastics, Philadelphia, Pa.
Durez – Durite Plastics and Chemicals, North Tonowanda, N. Y.
Indur – Reilly Tar and Chemical Co., New York City.
Makalot – Makalot Corp., Boston, Mass.
Resinox – Monsanto Chemical Co., Springfield, Mass.
Texolite – General Electric Co., Pittsfield, Mass.

In the laminated forms this plastic has a multitude of applications in industry. One encounters it almost everywhere. We have mentioned that gears and even propellers for airplanes are made from it. In addition, it is used for bearings, radio parts, panels, trays, tables, walls and doors, cabinets, containers and so forth.

Because of the fact that, like all the plastics, it adheres tightly to almost any surface, this plastic is widely used as a decorative and protective coating. We find it on our refrigerators, the tops of kitchen and other tables, desks, counters and bars, signs; as a translucent sign with indirect lighting from either side; as covering for heels on women's shoes, as frames for bags and containers, as ornaments.

In addition, thin sheets of the plastic are used in varying colors, and when these sheets are cemented together a mottled effect like marble is obtained.

The plastic is sold for use in the laminated field in the form of sheets, tubes, rods and fabricated parts.

Some of the outstanding trade names under which it appears in this form are:

Dilecto — Continental Diamond Fiber Co., Newark, Del.
Formica — Formica Insulation Co., Cincinnati, Ohio.
Insurok — Richardson Co., Chicago, Ill.
Micarta — Westinghouse Electric, Trafford, Del.

CHAPTER VII

CASEIN PLASTICS

Casein plastic a European discovery — early uses limited — first appearance in the United States — limitations — search for other casein sources — soy bean — corn — present uses — fabrication — forms available — trade names.

IT may seem odd that one can wear buttons and other ornaments which are made from milk, but such is the case. Moreover, milk gives us one of our strongest glues. The explanation is, of course, that milk is the source of the plastic called casein plastic.

Casein plastic was discovered in Europe, where it was found that formaldehyde and milk products would form a hard, bonelike substance when properly chemically treated. But there was very little commercial use made of the discovery for a considerable period of time. As with other plastics — cellulose nitrate for instance — work in the laboratory and consideration of commercial possibilities did not coincide, as is the case now in modern research work. Then the researcher was intent upon purely scientific study, and was not directing his thoughts to the development of a substance for commercial use as is done now in the majority of cases. The system of research which we now employ has at times been termed too commercial, but those who criticize it forget that from this type of work, sponsored by our large corporations, has come most of our modern improvements, and the entire human race has benefited from it.

It was in 1900 that two Germans, Krische and Spitteler, received a patent for casein plastic. They discovered that if a mass of casein from milk was subjected to the action of formaldehyde the result gave a hornlike substance which became hard and insoluble. But it was not until 1919 that this plastic came into use in the United States. Then the Aladdinite Company began to manufacture ornaments and buttons and similar products from casein plastic.

This plastic has found no wide use, except for such products, and it is detailed here merely so that the reader will be familiar with it. From a strictly commercial standpoint it is not of very great importance, when one considers the volume of business done in the other plastic fields.

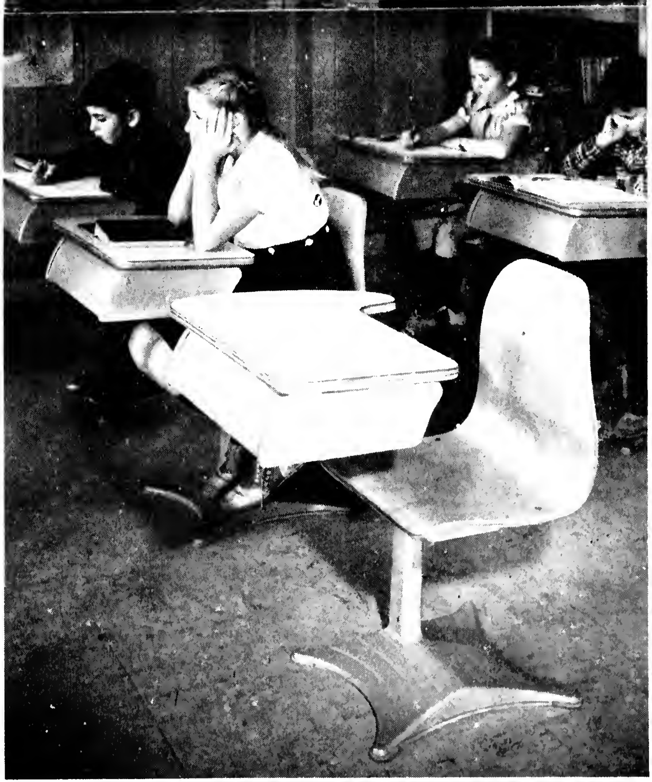
Casein plastic has one very bad feature. It will not withstand moisture, being hygroscopic. It warps and often it cracks. Research has not brought forth any means of preventing this. The addition of a certain amount of phenolic resin will prevent this characteristic from taking effect, but the quantity required is so considerable that the product really becomes a phenolic one.

The protein is present in other sources than milk, and some research and experimental work has been done with soy beans as well as corn. Henry Ford has shown a great interest in this type of plastic and has in cultivation over 10,000 acres of farm land near Detroit, Michigan, which produce soy beans. These are treated in a plant at Rouge River, and the protein and meal from the beans is used to make parts for his cars. Most of the plastic goes into accessories. Ford has, however, pioneered an experimental body made of plastic which shows great possibilities. He is of the opinion that a great majority of the farm products which are now in excess at times can be utilized in industry through the development of plastics. It is to be noted that Ford, like many other industrialists, has shown an uncanny ability to sense coming industrial events and his interest in plastics is noteworthy for that reason.

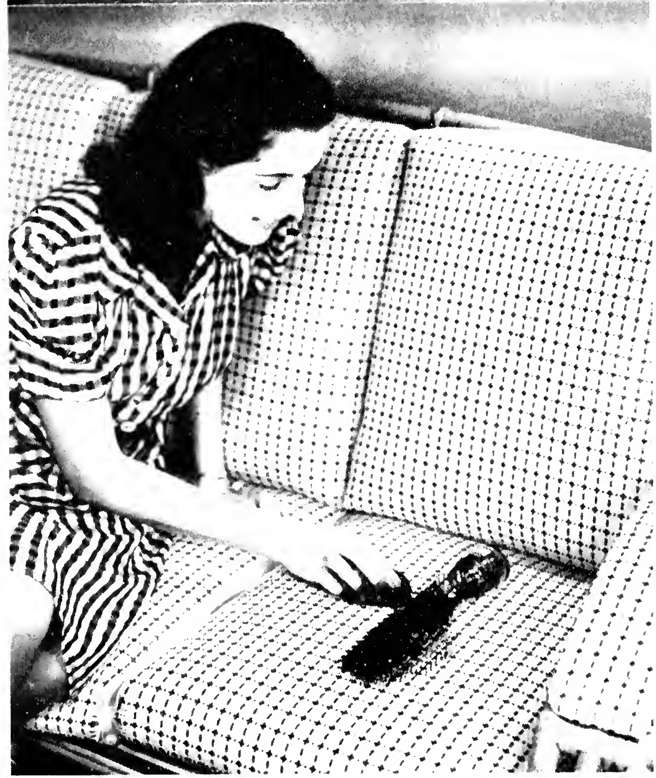
To summarize casein plastic, we find that its use in industry is more or less restricted because of its disadvantageous characteristic of warping and cracking. But it does find some use as ornaments, buttons, buckles, and so on.

Its fabrication differs from that of the plastics we have considered so far, in that this plastic is molded under pressure and then immersed in a chemical solution to harden. The usual chemical is formaldehyde.

It appears under the trade names of Ameroid, a product of American Plastics, New York City; and as Galorn, a product of the Morrell Corporation, Muskegon, Mich.

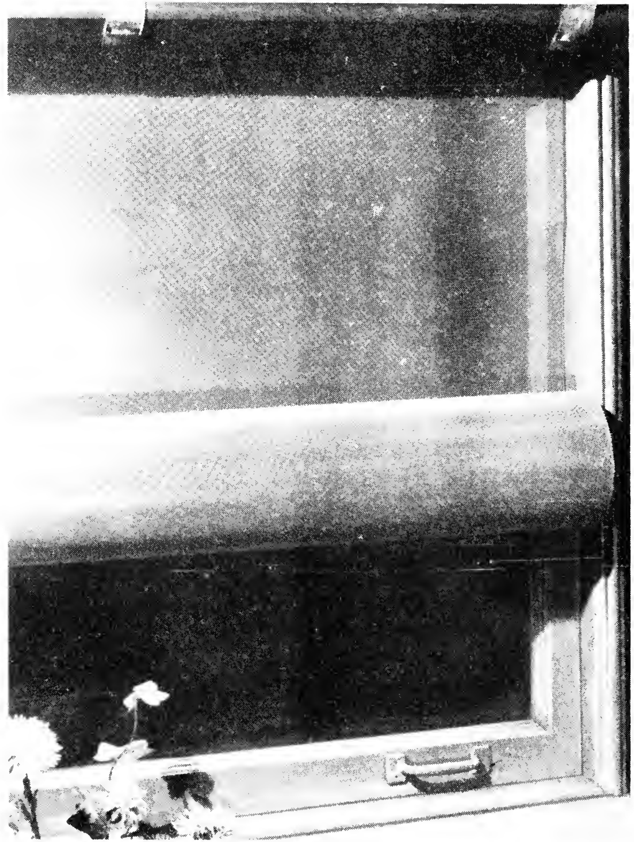


Students of Crow Island School, Winnetka, Illinois, use these plastic seats. *(Courtesy Modern Plastics)*

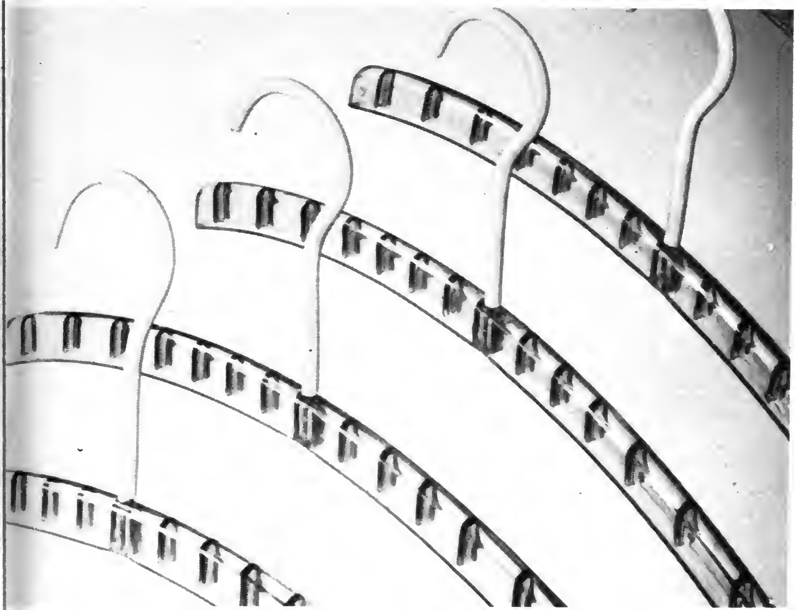


Stains are readily washed off plastic furniture coverings. *(Courtesy Modern Plastics)*

Plastic chair. *(Courtesy Modern Plastics)*



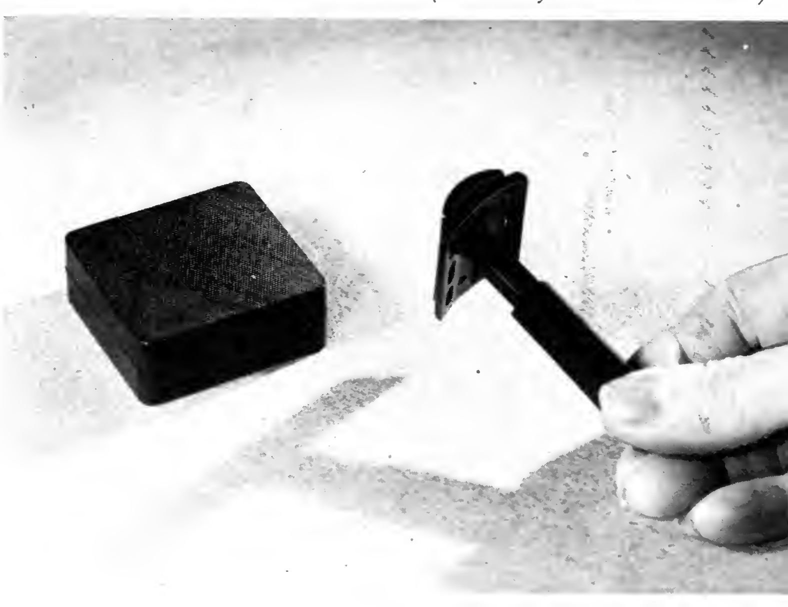
Plastic window shade.
(Courtesy Modern Plastics)

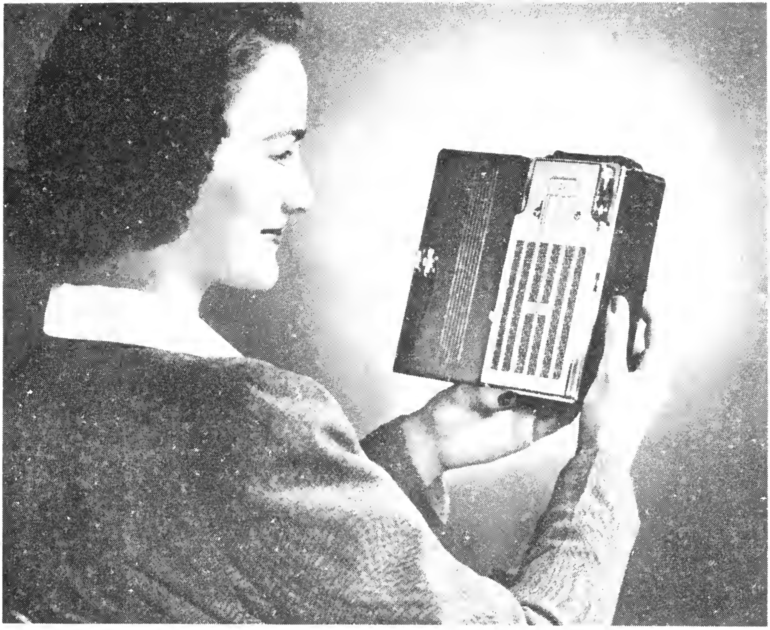


Plastic coat hangers. *(Courtesy Modern Plastics)*

Razor molded in two sections of cellulose acetate withstands severe boiling water test, has good mechanical strength and wear resistance. Box is also plastic.

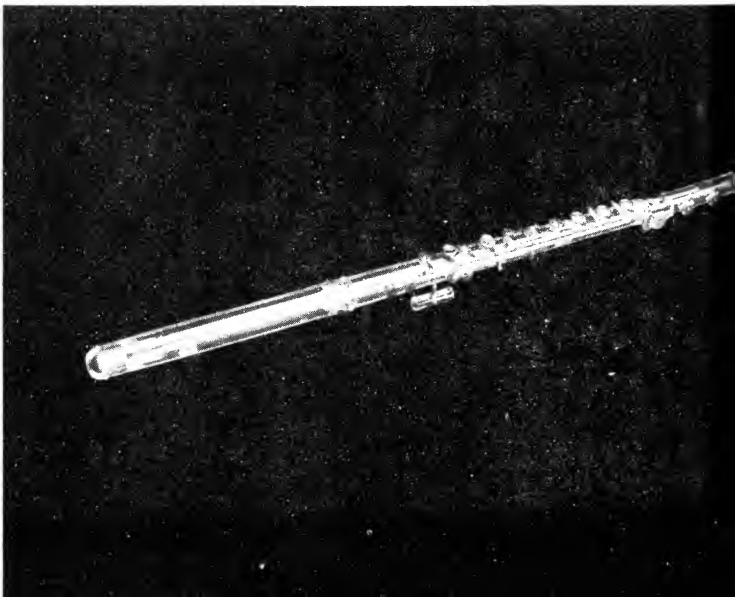
(Courtesy Modern Plastics)





Plastic portable radio. *(Courtesy Modern Plastics)*

Plastic flute. *(Courtesy Modern Plastics)*



CHAPTER VIII

CELLULOSE ACETATE PLASTICS

Plastics before the advent of cellulose acetate — this marks the beginning of a period of great advances in the industry — — the automotive field and plastics at that time — cellulose acetate supplies new fields — its advantages — wide use — still expanding uses — properties — fabrication — forms available — applications in industry — trade names.

WHILE the advance of plastics had been steady, it was not spectacular until the period which began with the ushering in of the cellulose acetate plastics. This was in the year 1927.

At that time, *Plastics,* a magazine devoted exclusively to plastics in industry, reviewed the plastics used in the automobiles on display at the annual New York Automobile Show. *Plastics* found that gearshift handles, door handles, instrument frames, cigar-lighter handles, steering wheels, windowframes, battery cases, artificial leather upholstery, safety glass and many other items in the cars were made of plastic or had plastic in their construction. One of the youngest and most progressive of our industries, the automotive industry, had taken to plastics, and with reason. They supplied a demand for low cost, durability and "eye appeal." All of these items are of immense importance to the automotive industry.

Yet, speaking late in 1939, Warburton-Brown, a well-known technician, is quoted by Doctor Gordon Kline, the technical editor of *Plastics,* as stating that the use of plastics in the automotive industry had but begun. He said that there was yet the field of tappet covers, sump covers, rocker covers, chain wheels, bushings, connecting rod bearings, oil seals, king pin bushings, camshaft bearings, fan blades, thrust washers, steering joint brake cross-shaft bearings, gear-box and rear-axle covers, cable conduits, filler caps, spring interleaves and covers, and a multitude of other parts which could be plastic formed. This does not include the body and fenders, where plastics definitely are coming. Thus in one field alone, we catch a glimpse of the tremendous future for plastics.

The cellulose acetate plastics did not appear until 1927 in this country, as we have mentioned, but they were originated as far back as 1869 when Schutzenberger, a German, produced them in a laboratory. They were patented here as early as 1903, having been made from cellulose acetate. But the first commercial uses were developed by the same firm which introduced plastics to American industry, the Celluloid Company, which had been combined with the Celanese Corporation in 1927 under the name, Celluloid Corporation. They produced the plastic in the form of sheets, rods and tubes. It was not at first available in powdered form.

With the coming of the powder form, the new injection-molding processes available through improved machines greatly speeded up the production of articles. The plastic can be molded in any color or combinations of color and this has brought it into wide use, especially in the automotive field, as we have seen. At the present time there are, on the average, over 200 cellulose acetate plastic parts in our cars.

Unlike cellulose nitrate, which is highly flammable, cellulose acetate burns very slowly. As a result, it has largely replaced the cellulose nitrate plastic as a base for photographic film. Readers may recall that in the past fires occurred in motion-picture projection booths with great frequency. So great was this hazard that the various insurance companies insisted upon fireproof booths. Today this hazard is practically eliminated by the "safety" film which is cellulose acetate plastic.

Being transparent and readily transmitting light, the plastic has come into wide use in the optics field. The lenses of many of the cheaper grades of cameras are cast of this plastic, as are the crystals of watches, lenses for headlights, eyeglasses, even the new contact lenses for the eye. In these uses the plastic, being shatterproof, has a great advantage over glass. It also finds a wide use in the goggles now standard equipment for the safety of workers' sight in various industrial operations. Its resistance to shock makes it ideal for bowling pins and the handles of various articles such as screwdrivers, and it is even made into special hammers, replacing the older lead and copper hammers. In the so-called shatterproof-glass field it reigns supreme. It is the bonding agent between the layers of glass which form this type of window and windshield in cars and other vehicles. In the aeronautical field it is widely used as a cover for cockpits and gun turrets, for transparent noses for bombers and astral domes for the navigators and on the various instruments. The fact that it is flexible and does not shatter into jagged fragments makes it ideal.

To summarize this plastic, we find that it possesses several outstanding characteristics. It is a good insulator and so finds use in the electric field; it will withstand impact, so is a good material for windows and other coverings in aircraft; it forms good eyeglasses, contact lenses, goggle lenses; the ease with which it is colored makes it ideal for ornaments, automobile accessories, costume jewelry, toilet articles, lights and shades, various household fixtures, toilet seats, radio cabinets and parts, containers of all kinds, and so on almost without end. Daily more uses are added.

It is fabricated by compression molding at a pressure of anything from 2,000 to 5,000 pounds to the square inch, and a temperature of from 290° to 350° F. It requires cooling to the critical temperature under pressure before it is removed from the mold. In addition, it can be formed into many articles from sheets which are heat swaged and so rendered flexible for fabrication. Also it can be injection-molded (see Chapter XXI). The usual mechanical methods of punching, pressing, sawing and turning are also used.

Cellulose acetate is available to the industry in the form of powder for compression and injection molding, sheets, rods, tubes, films and thin foils.

Some of the better trade names under which it appears are the following:

Bakelite —	Bakelite Corp., New York City.
Lumarith —	Celluloid Corp., Newark, N. J.
Masuron —	Masury and Son, Brooklyn, N. Y.
Monsano —	Monsanto Chemical Co., Springfield Mass.
Nixonite —	Nixon Nitration Works, Nixon, N. J.
Plastacele —	DuPont de Nemours, Inc., Arlington, N. J.
Tenite —	Eastman Co. (Tennessee), Kingsport, Tenn.

CHAPTER IX

UREA-FORMALDEHYDE PLASTICS

First appearance in the United States in 1929 — the importance of this plastic — compression molding at first limited its uses — injection-molding methods — high colorability — automotive uses — field widened recently — characteristics — forms available — fabrication — chief uses in industry — trade names.

WHILE the plastics we have discussed so far have had to some extent good colorability, they lacked much that was to be desired in this field. There was still room for a plastic which would color more readily and through a wider range. In 1929 such a plastic appeared on the American market. Like cellulose acetate plastic, this plastic originated in Europe. Typical of the plastics industry, it was developed to meet a specific demand for a specified material.

Made by the action of formaldehyde on synthetic urea, the plastic was first known as synthetic organic glass. It was transparent and readily molded by the compression method. But it developed a tendency to crack after it has been molded, and this retarded its use.

This characteristic was soon overcome, for it was found that the addition of a small percentage of filler of a hygroscopic nature eliminated the cracking. Finely ground wood, known as woodflour, or small amounts of pulp which had been bleached were added.

Two companies immediately placed the plastic on the market under different trade names. One was Beetle, and this soon became well known as Beetleware, in the form of very light dishes and other containers. It was used on our navy dirigibles at that time, as the weight of the dishes was almost negligible. In addition, it was widely used in different colors as ornaments and novelties.

The automotive industry, searching for a material which would color to any desired tone or combination of tones, quickly picked up the plastic and used it for the instrument panels and accessories, such as dome lights and so forth.

The plastic has the property of diffusing light to a marked degree, and this characteristic was noticed by the illuminating industry. As a result, there immediately appeared many light fixtures for stores, offices and homes which were equipped with both reflectors and lenses or shades made of urea-formaldehyde plastic. The fact that it colored so readily added to its appeal in this field.

In this plastic we again encounter one which lends itself to lamination. The colors in this plastic are highly stable; they do not fade. Sheets of the plastic are bonded to other materials to form panels which decorate such places as the lobbies of theaters, hotels and other public buildings, and for doors, walls, bathrooms and so forth.

At first, the plastic was handicapped through the fact that it could be molded only by compression. This type of molding, where the plastic is required to set in the mold, is not suitable to rapid mass-production methods as we know them, but injection molding is. The development of this later type of molding brought urea-formaldehyde to the front. Through the speeded-up production the costs were lowered, so that it became a competitor of the other types in the field.

To summarize this plastic, we find that it has an extremely wide range of color possibilities, it is an excellent diffuser of light, it does not readily break, it withstands the effects of weather, it is a good insulator, food acids do not affect it and it has neither taste nor odor.

It can be compression-molded at a pressure of about two thousand pounds to the square inch, or it can be injection-molded under the new processes. Its molding temperature is from about 300° to 350° F.

In industry it finds a use in ornaments, buttons, closures of different types (bottles, etc.), light reflectors, shades, lenses, electrical appliances, laminated materials, as a decorative coating, handles of all sorts, piano keys, dishes, toys and so forth.

It is produced in the form of powders; as resins which have been dissolved in chemicals so that the plastic can be applied in liquid form to fabrics and so forth; and, finally, in cement forms as an adhesive.

Some of the better-known trade names under which it appears on the market are the following:

Bakelite Urea —	Bakelite Corp., New York City.
Beetle —	Beetle Products Co., New York City.
Plaskon —	Plaskon Co., Toledo, Ohio.
Uformite —	Resinous Products and Chemical Co., Philadelphia, Pa.

CHAPTER X

VINYL RESIN PLASTICS

Their origin — most important resins of group — their industrial application — highly technical field — vast field of possibilities — properties of various resins in this group — typical applications in industry of these resins — trade names.

FACETIOUSLY, the American male is prone to state that his wife "cooks out of a can." This is a statement founded on fact, for a great portion of the nation's food comes from these containers. And, unless the can is punctured or the food contaminated before it enters the container, it is safe to state that when opened it will be as fresh as when it entered. We unhesitatingly trust canned foods. They are a staple item in our diet. The fact that food can be kept in metal containers unaffected by the reaction of the acids in the food with the metal is a triumph of modern plastics for all of our modern canned foods are packed in cans which have their interiors protected by a plastic. This plastic is usually of the vinyl-resin type.

Strangely enough, these plastics have been known to science for over a hundred years, yet they have been brought to the front commercially only in the last few years. They are now used in a large section of the industry.

To the non-technician, their names will at first be more or less of a mystery. Detailed information on the chemistry of plastics, covering the chemical components and reactions of the various plastics in their making, will be found in a technical text book.

The plastics of this group are composed of resins which are known as polyvinyl acetates, polyvinyl chlorides, copolymers of vinyl acetate and chloride, and the polyvinyl acetals.

That these names are formidable cannot be denied but it may be emphasized, again that there are *two* distinct fields for a career in plastics. One, as already mentioned, is the technical, and this simplifies these terms. The other and far wider field is the non-technical, with which the vast majority are concerned. In the final analysis it is not so much *what the plastic is* as *what it* *can be used for* that counts in industry. And it is industry that makes the successful career.

We shall not concern ourselves particularly here with the chemical development of these plastics, but concentrate upon their uses and applications to industry.

Thus we find that in this group we have the polyvinyl acetates, giving us a plastic which is clear, possesses great adhesive powers, is not toxic, has no taste or odor, and is not acidic.

The polyvinyl chloride group resists chemical action, is not affected by the weather, is not toxic, is very tough, and it likewise has neither taste nor odor.

The polyvinyl acetate-chloride copolymer group is also resistant to acids, is easily colored, can be molded to close tolerances, is non-toxic, resists weathering, has no taste or odor, and is tough.

Polyvinyl chloride possesses similar characteristics.

Polyvinyl butyral is an adhesive plastic, resists moisture, is tough regardless of temperature, and closely resembles the above in many respects.

All of these plastics of this group are available to industry in several forms — powders, molding compounds, sheets, laminations for glass, and extruded tubing. (For the last mentioned, see Chapter XXII.)

In fabrication, these plastics respond to either ordinary compression molding or the injection type. They are fabricated at about 250° to 300° F. As they are thermosetting, they must be cooled in the mold in which they are made before they can be removed. In the modern injection molds this cooling is rapid and the production is speeded up considerably. Where they are used to bond glass to form safety glass, the process consists of placing them between the sheets of glass, immersing the whole in a hot-oil bath and then applying pressure. The glass is firmly and permanently bonded together in this manner.

Typical uses of these plastics in industry are as follows:

Polyvinyl acetate.— This plastic is used widely as an adhesive, often termed a "cement." In this form it is a clear thick liquid, and transparent. It also goes into inks, and is used as a binder for metallic powders to form paints, much in the same manner as cellulose nitrate was used. The so-called plastic wood fillers we use for repairs and for filling cracks are made with this material, wood in finely ground form being mixed into a paste with the plastic. In addition, the plastic is formed into innumerable molded articles in the usual manner.

Polyvinyl chloride.— This plastic has received a great deal of advertising by the Goodrich Rubber Company, which uses it to coat fabrics and make them waterproof. They call the product Koroseal and make it into aprons, shower curtains, and so on. In addition, it is used to make impregnated tapes and molded articles, and to line the interior of tanks to prevent corrosion from various liquids.

Polyvinyl acetate-chloride copolymer.— This is used to coat cements to prevent their erosion from weather;

to make floor tiles which are extremely durable; to coat metals such as can interiors; to coat wallboards to make them waterproof; to line the interior of tanks to prevent corrosion; as a base for photographic films, and for sound records, radio parts and storage-battery cases.

Polyvinyl butyral.—This is the plastic which has displaced others in the fabrication of safety glass. It is strongly adherent, does not show any effects from ultraviolet rays, and is not affected by the weather where it is exposed to the air around the edges of the glass. Other plastics had a tendency to erode here, and the edges of the glass had to be sealed against this. This plastic requires no such sealing.

The principal trade names under which these plastics appear are the following:

POLYVINYL ACETATE

Gelva — Shawinigan Products Corp., New York City.
Vinylite A — Carbide and Carbon Chemicals Corp, New York City.

POLYVINYL CHLORIDE

Koroseal — Goodrich Rubber Co., Akron, Ohio.
Vinylite Q — Carbide and Carbon Chemicals Corp., New York City.

POLYVINYL ACETATE-CHLORIDE POLYMER

Vinylite V — Carbide and Carbon Chemicals Corp., New York City.

POLYVINYL BUTYRAL

Butacite –	DuPont Co., Arlington, N. J.
Butvar –	Monsanto Chemical Co., Springfield, Mass.
Vinylite X –	Carbide and Carbon Chemicals Corp., New York City.

CHAPTER XI

STYRENE PLASTICS

Styrene plastic one of the oldest known — its origin — difficulties of manufacturing — new developments — high cost retarded development — peculiar light-transmitting qualities — one of best dielectrics — extremely moisture-resistant — limited uses — chief characteristics — forms available — how fabricated — uses in industry — trade names.

STYRENE plastic, known as far back as 1839 as polystyrene, a synthetic resin, when it was discovered by Simon, is a result of the researches of Wohler, who had succeeded in making synthetic urea in his laboratory. In so doing, Wohler laid the foundations of the urea-resins plastics.

Styrene has had a slow development in the plastics field, because of two major difficulties. First, it was very expensive to produce in the pure form, and if it was not in this form it failed to have the transparency needed for many of the uses found for it. Also, in the impure state it was by no means as durable as the pure product. It could not compete with the more modern plastics in either price or quality. Yet it has outstanding properties which make it of great value in a limited field.

It was not until 1937 that styrene came into the market in a form which could meet the competition of the other plastics in its field. At that time the Dow Chemical Company brought out a styrene plastic, and shortly afterward the Bakelite Corporation produced another. Dow called theirs Styron, and Bakelite termed their product Bakelite Polystyrene. Both were crystal clear and the costs were reduced to normal in their production.

When styrene first came out it received considerable publicity and was regarded as a novelty because of the peculiar property it has of being able to transmit light around corners and wide curves. A solid rod of this plastic with a light source at one end can be bent into almost any shape and the light will be transmitted through it and be projected from the other end. Surgeons and dentists found this of great value. By using a rod of the plastic it is possible to bring light to bear wherever desired, and this has greatly facilitated surgical work.

As an insulator, styrene plastic is among the very best.

It is equal to fused quartz, a very expensive type. As a result, it is used in radio work where in certain places an almost perfect insulator is required.

Other uses of its "light-bending" properties include closures for refrigerators and other places where the light source is placed at a distance from the opening. The light travels through the plastic and illuminates the desired points. This same characteristic is used in signs, as well as for the instrument panels of airplanes and automobiles.

As was mentioned before, the general use of this plastic is more or less limited, but it does fill an important if small, field. To summarize this plastic, we find that it has the following characteristics:

It is easily molded, is stable, can be precision-made, has excellent insulating qualities, carries light "around the corner," does not absorb moisture, resists the action of the milder acids, is clear as crystal and can be used where this material is used as in lenses and so forth.

Though its uses in industry are limited, it finds a wide use in specialized insulations and specialized lighting, in the making of certain types of containers, for certain accessories for automobiles and for decorative parts for refrigerators.

It is available to the industry in the form of a powder, which is molded under pressures of from 3,000 to 30,000 pounds to the square inch and at a temperature of from 300° to 450° F.

The various trade names under which it is best known are as follows:

Bakelite polystyrene –	The Bakelite Corp., New York City.
Monsanto polystyrene –	Monsanto Chemical Co., Springfield, Mass.
Styron –	Dow Chemical Company, Midland, Mich.

CHAPTER XII

ACRYLIC RESIN PLASTICS

Their origin — early development — recent developments — general uses — special advantages — wide field as yet not fully developed — methods of fabrication — forms in which available — use in industry — properties — trade names.

THE acrylic resin plastics, like the styrene plastics, were known for a long period yet were not commercially developed until a comparatively recent date. They made their first appearance in the commercial field in this country in 1931, when they were marketed under the trade names of Acryloid and Plexigum. But the latest type of these plastics is a derivative of the first.

It has the somewhat formidable name of polymethyl methacrylate—a methacrylic acid derivative. It came into use during 1936 and has found a very wide market. It is of special value in the airplane and automotive fields at the present time.

These acrylic resin plastics are the polymers of acrylic and methacrylic acids, and have the particular characteristics of being transparent, odorless, elastic, very adhesive, and able to withstand weathering. Naturally, this makes them ideal for use as cockpit and other enclosures for airplanes, and for lenses and other items for automobiles. As a matter of fact, they have such a wide range of possibilities that the field has by no means been completely explored.

In these plastics we again encounter a typical case of what this industry has to offer for a career. Although not the preeminent plastic by any means, this material does offer many possibilities. Checking through the more familiar uses, we find that in addition to the airplane and automotive fields it is also widely employed in dentistry. It is an excellent adhesive and finds a wide use in this way. Any type of decorative article can be made from it, since it is highly colorable. The roadside signs which are self-illuminating in the beams of headlights make use of this plastic. Lenses are made from it for both planes and automobiles. In addition, it finds use as a protective coating for many materials.

With all of these present uses, it is not yet fully utilized.

There are still innumerable places where it can be used to the advantage of the product and of the manufacturer as well as of the consumer. In this field there is a great opportunity for the practical man who knows what can be done with plastics and can apply this knowledge to industry. It is not necessary that he be a technician. He can specify the specific use he wants to make of the plastic and the industry will supply him with it.

To summarize the uses of this plastic and its properties, we find that it is light transmitting, stable, transparent and moisture resistant; possesses good rigidity, weathers well, and is optically suited for lenses and so on.

It is one of the best plastics for fabrication, for it can be cast into almost any shape and molded; the sheets can be bent and worked into shape; the rods, bars and tubes, when heated to around 180° to 250° F., can be formed into any shape.

It is supplied to the industry in many forms. Sheets, rods, bars, tubes, granules, powders and solutions are all available for different purposes.

Some of its uses are the following: airplane enclosures, all manner of decorations, dentures, various display signs and backgrounds, other signs, lenses, as protective coating for various materials, as a reflector, and so forth.

The better-known trade names, which may help the reader to identify this plastic in the articles around him, are:

PLASTICS

Acryloid —	Resinous Products Co., Philadelphia, Pa.
Crystalite —	Rohm and Haas Co., Philadelphia, Pa.
Plexiglas —	Rohm and Haas Co.
Lucite —	DuPont, Arlington, N. J.

CHAPTER XIII

CELLULOSE MIXED ESTER PLASTICS

Plastics based upon fatty acids and acetic acid — esters — their origin — development — weathering properties — chief uses — limited field — summary of properties — forms available to industry — methods of fabrication — trade names.

IT IS perhaps best at this time to explain the nature of an ester, for from now on we are to encounter esters frequently. If one can, through chemical reaction, replace an acid hydrogen in an acid with a hydro-carbon radical the result is an ester. For those who are familiar with chemistry this will be self-explanatory. For those who are not, it is best simply to state that the result of such a chemical reaction is the formation of a plastic. As this volume is not concerned with the highly technical chemistry of plastics an explanation in detail, which might be given in a chemistry textbook, would be out of place. However, certain of the fatty acids present in all fats react with cellulose and the result gives us a plastic. These acids are chiefly propionic acid and butyric acid. When they are mixed with cellulose, the product is either cellulose acetate propionate or cellulose acetate butyrate. Both of these products are plastics.

The chief advantage of these plastics is that they have the property of withstanding weathering to a very marked degree. We have mentioned that cellulose acetate was considered a good plastic to use where weathering is important. But cellulose acetate butyrate is far better. If it is completely immersed in water for a long period it will be found that the absorption of water is less than one-half of the absorption of cellulose acetate. In addition, this plastic is soluble in many more chemicals than cellulose acetate is. This makes it cheaper to produce in the finished form.

However, the economic value of cellulose acetate butyrate is not of sufficient importance to devote a great deal of space to it here. It is a typical example of the highly specialized plastic. Where exposure to weather or water is considerable, this plastic is made use of. For this reason automobile tail-lights, fishermen's equipment, trim for outdoor use, and handles of utensils constantly exposed to water are made from it.

It is supplied to the industry in several forms, chief of which are sheets, flakes, granules and molding compounds.

Its fabrication is by molding under pressure, either by the compression or injection methods.

The following are the trade names by which it is known:

Hercose C — Hercules Powder Co., Wilmington, Del.
Tenite 2 — Tennessee Eastman Co., Kingsport, Tenn.

CHAPTER XIV

ETHYLCELLULOSE PLASTICS

First of the cellulose ethers made in this country — developed abroad — possibilities — chief uses — limited field — properties — forms available in industry — methods of fabrication — detailed uses — trade names.

WHILE ethylcellulose was first developed in Germany in 1912, it did not make its appearance in this country until 1916 and 1917, when patents were issued. Its manufacture remained static, however, until as late as 1935, when the Hercules Powder Company began working with it.

Two years later the Dow Chemical Company began manufacturing ethylcellulose under the trade name of Ethocel. Later they brought out another form under the name of Methocel.

Previous to the present war this plastic was very limited in its uses. At first, ethylcellulose was marketed for use in the automotive field and made a strong bid for use in the aeronautical field as well. It was employed as a coating for various materials. However, its greatest use seemed to point to a combination with other plastics, for it forms a plastic combination which has many desirable characteristics, among them hardness, water resistance and non-toxicity, and it is also a dielectric. In addition, it is easily fabricated.

Methylcellulose, another cellulose ether, shows promise of wide use. It is soluble in water, tasteless, has no odor, is non-toxic and resists grease and oil. In sheet form it is highly flexible.

The outstanding properties of ethylcellulose plastics are as follows:

They are good dielectrics, work easily at low temperatures, are tough and flexible, and readily combine with other plastics to form combinations which possess very desirable characteristics.

In the industry this material is supplied in the form of coarse powder for fabrication, which is done by compression molding, injection molding or extrusion molding.

The pre-war period saw it used chiefly as a coating for cables, as an adhesive, as covering for paper and other materials and as a protective coating which was colored with ground pigments. In addition, it had a limited use in injection molding.

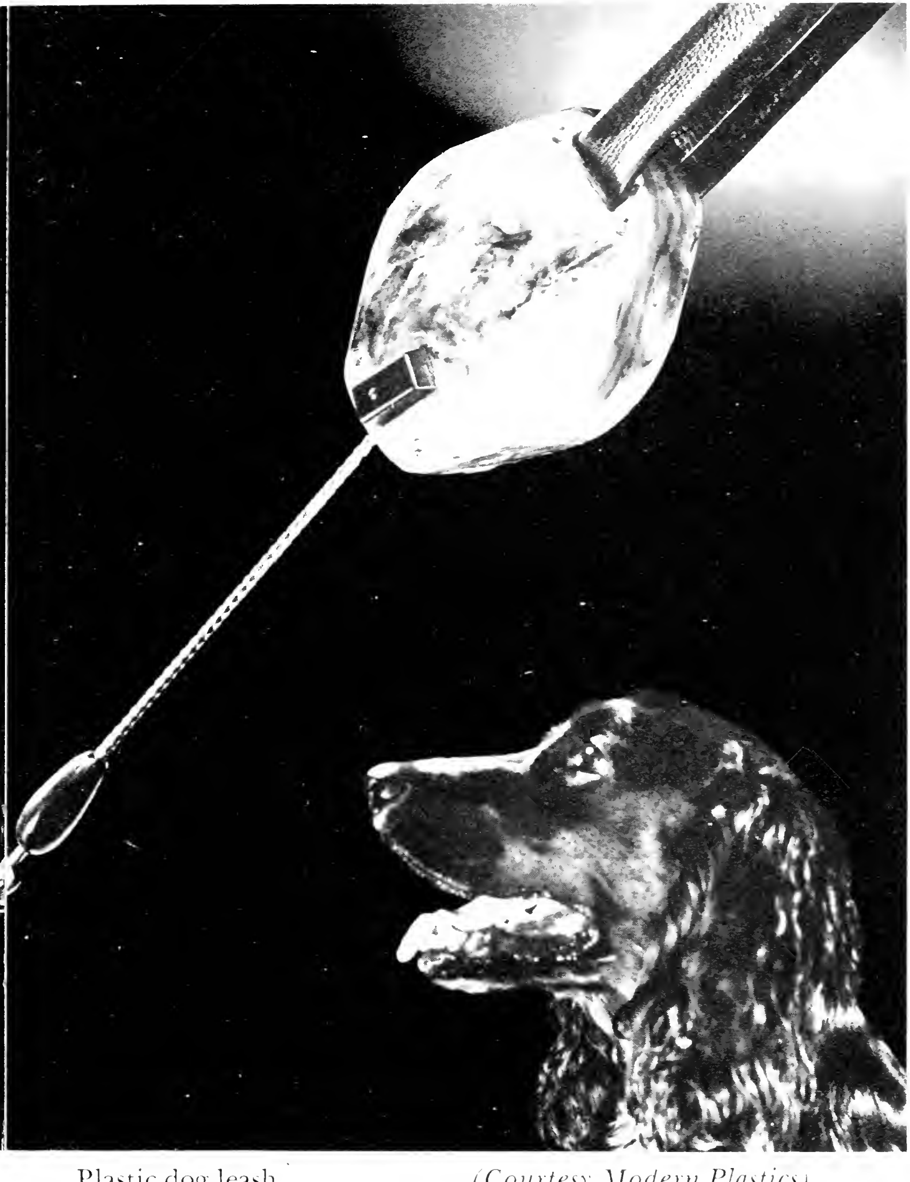
It was manufactured by the Dow Chemical Company under the trade name of Ethocel; and by the Hercules Powder Company as Hercules Ethylcellulose.

Plastic oil can. *(Courtesy Modern Plastics)*

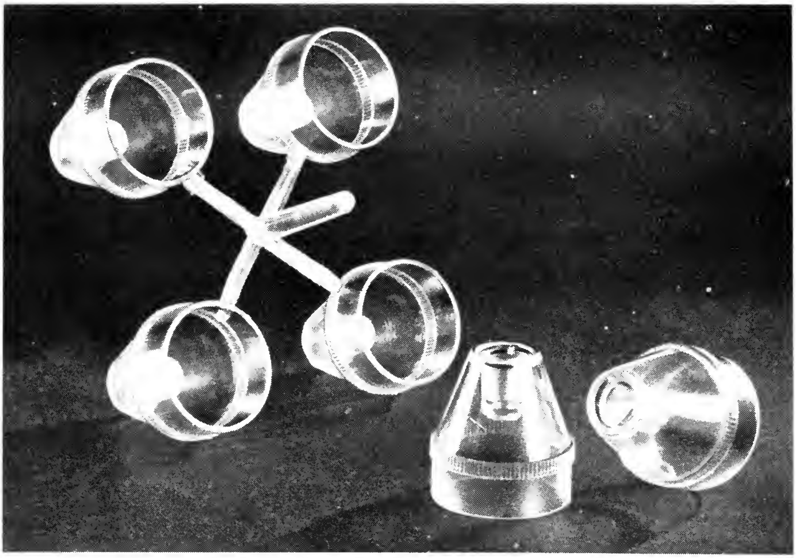
Plastic jar tops. *(Courtesy Modern Plastics)*

Worker wearing plastic industrial safety device. *(Courtesy Modern Plastics)*

Ray Dumont designed this Plexiglas window display figure for Saks Fifth Avenue. It is sturdy, shatterproof, washes easily with soap and water. *(Courtesy Modern Plastics)*

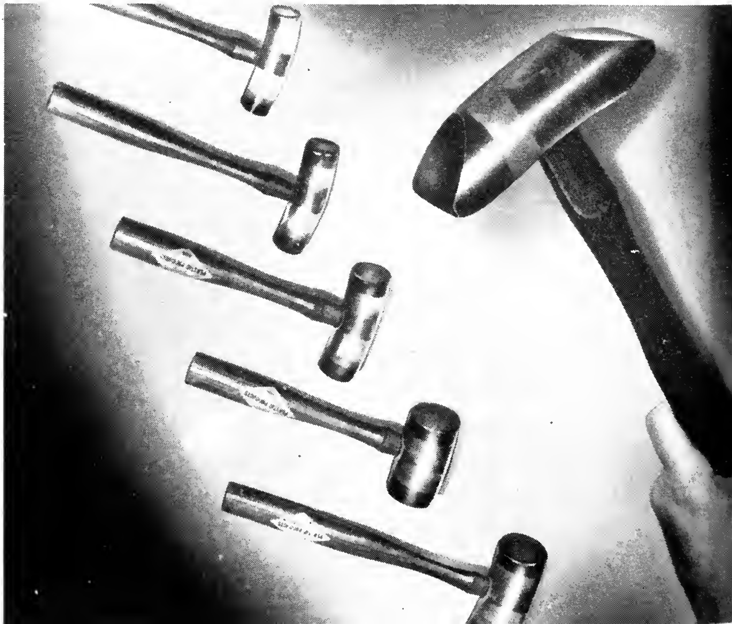


Plastic dog leash. *(Courtesy Modern Plastics)*



Plastic bottle tops, showing how they are cast.
(Courtesy Modern Plastics)

Plastic hammer heads. *(Courtesy Modern Plastics)*



CHAPTER XV

LIGNIN PLASTICS

Their early development — many investigators — low cost of basic material — wide field for use — pre-war limitations — fabrication — general uses — coating.

FOR a great many years a commercial use for the vast amounts of waste wood and sawdust produced in this country has been sought. To some extent certain uses have been developed, but it was not until 1937 that the possibilities of these materials as a source of plastics were realized. Woods in general contain some 25 per cent lignin, which is a very complex organic compound. When it is combined with aldehydes, phenols and so forth in the presence of heat it forms resinous substances — plastics.

The first lignin plastics were in the form of very thin sheets which were bonded together to form laminated panels. These panels possessed great strength for their weight, and found considerable use in construction.

In 1939 more lignin compositions were brought out. These were of such a nature that they could be fabricated by either injection molding or impact molding. Later a thermosetting type made its appearance.

The sheets of this plastic are usually coated with some other plastic if color is desired, for in their original state they appear only as black. They find use in panels as a construction material and as an insulator. Later developments brought them into use for furniture, and in a limited way for use in the aircraft industry and the automotive industry, as well as for some other uses. It remained for the war period to bring them to a fuller use, and this is described in the section of this book dealing with the so-called war plastics.

CHAPTER XVI

ALKYD RESIN PLASTICS

Wide use in the automotive industry — their base — development — properties.

ONE of the widest uses of plastics to date in the automotive industry is for the finish of the car, the protective coating over the metal body and fenders. In the earlier period of the industry the body of the car was hand-finished. This was a laborious process. First the metal was thoroughly sanded down to a smooth finish and then a coating of primer was laid on. This in turn was rubbed and sanded down and then the basic color was applied in two or more coats, usually with hand-finishing between these coats. After this, numerous coats of varnish were applied, each in turn being rubbed down until a fine, glossy finish was achieved.

The advent of the alkyd resins altered all this. Now a priming coat is applied and then the color is sprayed onto the body or other part. This coating of alkyd plastic dries in a few minutes as the coated part travels through an oven where it is subjected to the heat of banks of infra-red lamps. This form of heat dries the plastic from the bottom up, the top being the last to dry. Nearly 50,000,000 pounds of this plastic are used annually by the automotive industry.

The alkyds are formed by the action of phthalic anhydride and glycerol. They are mixed with phenols, oils or natural resins to form the protective coatings.

The properties of this plastic are the following: high gloss, it is quick-drying, and has flexibility, fine adhesion, ease of coloring, and excellent resistance to weathering.

CHAPTER XVII

COUMARONE-INDENE RESIN PLASTICS

A late development — limited use — adjuncts — outstanding properties — types available — properties which make them valuable — typical applications of these plastics.

PREVIOUS to the present war coumarone-indene resin plastics were not in general use except as a compounding agent with others. In this way they were fairly widely used. It is estimated that before the war the annual production of coumarone-indene resins amounted to some 8,000,000 pounds.

The plastic was first brought to the attention of industry in 1919, when the Barrett Company began its manufacture under the trade name of Cumar. It is derived from coal tar, light oil distillations, and polymerizing with sulphuric acid, which results in the formation of a resin.

This resin had the characteristic of being somewhat brittle and will melt at a very low temperature. As a result, its use was naturally limited. However, it was soon discovered that the plastic would mix well with others, and the resulting product was ideally suited to many uses.

Coumarone-indene has a high resistance to electricity; it is fluid in solution; and it dissolves readily in many liquids. It is delivered to the industry in liquid form.

It finds use in floors, tiles, paper impregnations, coatings to protect various materials, as a compounding agent for rubber and in the making of records.

Part Three

Plastics in the Aircraft Industry

CHAPTER XVIII

AIRCRAFT PLASTICS

PLASTICS have assumed an important position in the aircraft industry in the present conflict, which has created an unprecedented demand for suitable materials to supplant those which, through scarcity, are on the critical list. The acceptance of plastics has been general, and already they have effected radical changes in both the design and the construction of aircraft. That they are destined to exert an even greater influence on the aircraft of the immediate future is certain.

As a result of this influx of new and unfamiliar materials, there is a great deal of confusion of thought regarding them. This is evinced in press reports of flight tests of new planes. One reads such headings as "Plastic Plane Passes Flight Tests" or "Plastic Planes Now Being Built."

The fact of the matter is that plastic planes are not being built, nor is it probable that they will be for a very considerable period of time to come. These "plastic" planes are planes built of *plastic-bonded materials,* usually plywood.

This misconception of the proper function of plastics in the aircraft industry is not confined to the press. Because of the fact that the plastics industry is comparatively young — its importance having been established only during the last fifteen years — the general public likewise has more or less vague conceptions regarding them. To paraphrase Mark Twain, everyone is talking about plastics but few know what they are. Furthermore, and unfortunately, because of statements made by persons who were either overly enthusiastic or not sufficiently informed, an impression has been established that plastics are the universal answer to any fabrication problem, a sort of *sine qua non* of the industrial world. This they are not. They possess certain very definite advantages and equally definite limitations.

Plastics in general may be defined as synthetic organic compounds whose principal component is either a cellulose or resinous binder. These materials are either semi-fluid or fluid. If they are semi-fluid, that is, plastic, they are fabricated by molding. If fluid, they are cast. In industry they are often processed at the point of manufacture and delivered to consumers in either flake or powder form. These forms are then reprocessed for molding or casting. Other forms available are sheets of various thicknesses, and rods as well as tubing.

After proper processing and fabrication the plastic assumes a solid form. Some plastics, when solidified, are highly flexible; others are inflexible and easily shattered; while still others, although inflexible, possess a considerable resistance to fracture.

Certain of the plastics solidify through the application of heat, and cannot be remelted for subsequent use. This type of plastic is known as thermosetting, and among its many uses we find it as a bonding agent in the construction of plywood airframes and wing sections. Other plastics can be melted down after fabrication and used repeatedly. These are known as thermoplastic types. In addition, we find numerous substances which closely resemble plastics but which, in the strict sense of the word, cannot be classified as such. These include synthetic rubbers, elastomers and a series of natural resins.

The manufacture of plastics is a highly technical process and the chemistry of their formation is so involved and complicated as to be understandable only to the technician. An excellent example of this is the manufacturing of phenol-formaldehyde plastics, one of the more widely used types which is thermosetting.

As its name implies, this plastic is formed through the chemical reaction of phenol and formaldehyde. The phenol may be prepared in one or more ways. It is a product of the distillation of coal. It can be prepared synthetically by oxidizing benzine at high temperatures. Formaldehyde, familiar to many as a very pungent preserving liquid, is prepared by a reaction between hydrogen and carbon monoxide.

These two materials are then brought together in specially lined kettles. To speed the reaction, a substance termed a catalyst is introduced. Usually this is either sulphuric acid or ammonia. The resulting product of the reaction is a clear sirup which hardens into a synthetic resin. This resin, after being broken up and ground, is then ready for fabrication. By slightly altering the original chemical processes, another form of phenol-formaldehyde resin is secured which is soluble and consequently capable of being cast. After casting, the product is treated in huge ovens where the controlled heat causes it to harden. In the aircraft industry we find this plastic in the form of handles, control knobs, panels and radio cabinets, and as a bonding agent for plywood.

It is impossible within the scope of this work to describe the formation of the various plastics. Their origin is fantastic to the layman. One large group, the ureas, comes from a mixture of air, water and coal. Others have their genesis in the reaction of cotton lint, nitric acid, sulphuric acid and camphor. Sufficient for our purposes is the fact that plastics are materials which have proved of the greatest importance in the fabrication of aircraft and their accessories. It is their utilization with which we are chiefly concerned.

In no phase of the aircraft industry have plastics proved their worth more than in the bonding of plywood and thus making possible speedier mass production of more efficient aircraft at greatly reduced costs.

During World War I plywood began to be used more or less extensively in the frames and other component parts of the plane. Fokker, the Dutch designer, used it for wing spars and leading edges. It was used generally for certain compression members and engine bearers. In the post-war period Fokker and others constructed entire wings of plywood. Lockheed became world-famous through their plywood series of monoplanes.

However, because of the fact that the bonding agent of that period was usually casein glue, the life of the plywood was limited. Casein glue, a milk derivative, is subject to bacteriological action as well as to moisture. It did not form a permanent bond between the various layers of wood, and this led to rapid deterioration and often structural failure. As a result, plywood was discarded in favor of metal, except in a few light planes. Even in these the use of plywood was confined to leading edges, panels, and minor compression members.

With the appearance of plastics, in particular the urea-formaldehyde cold-press glues, plywood became of importance in the industry. In the construction of aircraft it offers many advantages. It possesses greater strength per unit of weight than the metals now used; lighter construction is made possible; and it has a smoother surface than the alloys and so produces less drag. Consequently greater speed per horsepower is obtained. In addition, tests have shown that it is better able than metal to withstand the effects of gunfire. Metal tends to rip and tear, particularly where the missile emerges, while plywood shows a clean aperture where the missile enters and no extensive shattering upon emergence.

In the urea-formaldehyde cold-press process of bonding, the plywood is used in long narrow strips. These are laid diagonally over male molds of the part being fabricated. A coating of the plastic glue is then applied to the upper surface of the strips and a second layer of plywood laid over the first. This second layer has its grain at an angle to the first. The plastic bond is then applied. This procedure is continued until the desired thickness is obtained. Then the layers are pressed firmly together, either by air pressure or by metal straps. Upon the setting of the plastic glue — a matter of hours — the various layers are permanently bonded together and are impervious to the effects of moisture or bacteria. The most notable example of this type of construction is the deHaviland Mosquito fighter-bomber.

In the tradition of mass production, American manufacturers were not satisfied with the somewhat slow process of bonding plywood by the use of plastic glues. As a result, two new processes have been developed. These are the Vidal and the Duramold, the latter used with great success by the Fairchild Aviation Corporation in the manufacture of trainers for the Army Air Forces.

In these methods the plywood is formed in the same manner as before, that is, successive layers of wood with the grain at an angle. But the cold-press urea-formaldehyde glue is replaced by a thermosetting plastic. After the parts are formed around a mold or in a jig, heat is applied and the thermosetting resin is set, "cured" by the heat. It solidifies and the bond is permanent. Gasoline, oil, moisture — all fail to alter the bond.

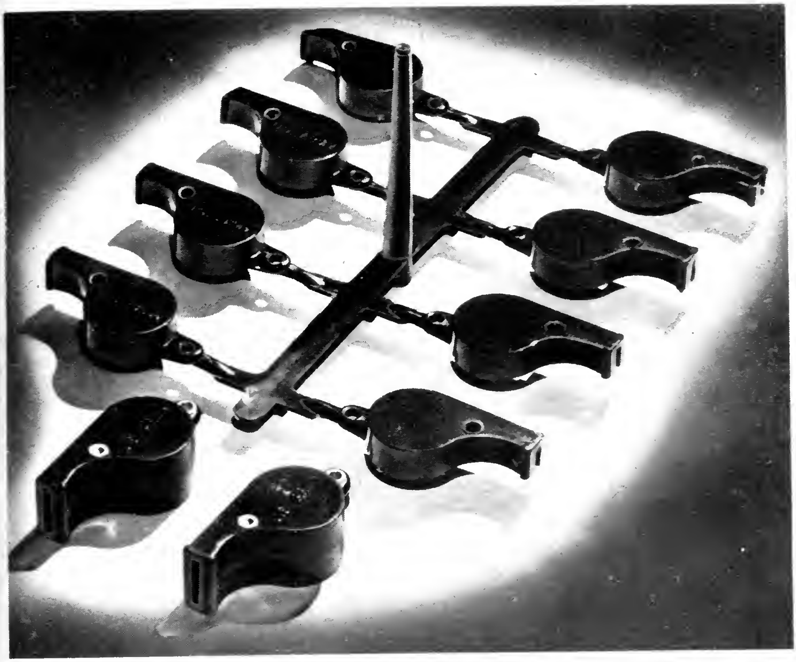
The application of heat in the Duramold process is through the use of ultra-high frequency electric current, somewhat in the same manner as a diathermy machine is operated. The plywood offers resistance to the passage of the current and this results in the generation of heat. By carefully controlling the amount of current flowing through the part being fabricated, the heat is controlled, and in this manner the wood fibers are not weakened through being subjected to too great a degree of heat. In the Vidal process autoclaves are used. The parts, with the mold, are placed in the autoclave and steam and air or water pressure applied.

The outstanding method of plastic bonding is still on the military restricted list, and so cannot be detailed here. This is the Cycleweld process developed by the Chrysler Corporation. It utilizes a thermosetting plastic, but its scope is so far in advance of other methods as to be almost unbelievable.

Through Cycleweld, it is possible to bond together permanently metals, wood and metal, fabrics, rubber, other plastics — in short, practically any material can be bonded to any other, even metal to glass.

The use of this plastic-bonding method has effected startling changes in our production of aircraft for the war. Wing flaps which formerly required some 1200 rivets and four and a half hours labor are now assembled in twenty minutes with only 300 rivets and the plastic bond. And they are stronger than the previous types. Tail planes, that is, stabilizers, which were fabricated in jigs with some 6000 rivets are now made using only thirty-some rivets and the bond. The procedure is very simple. The bond is sprayed on the inner surface of the joint and this part is then placed in a heated press. The plastic sets, and the bond is permanent. Tests show that it possesses equal and in some instances greater strength than like parts which are riveted.

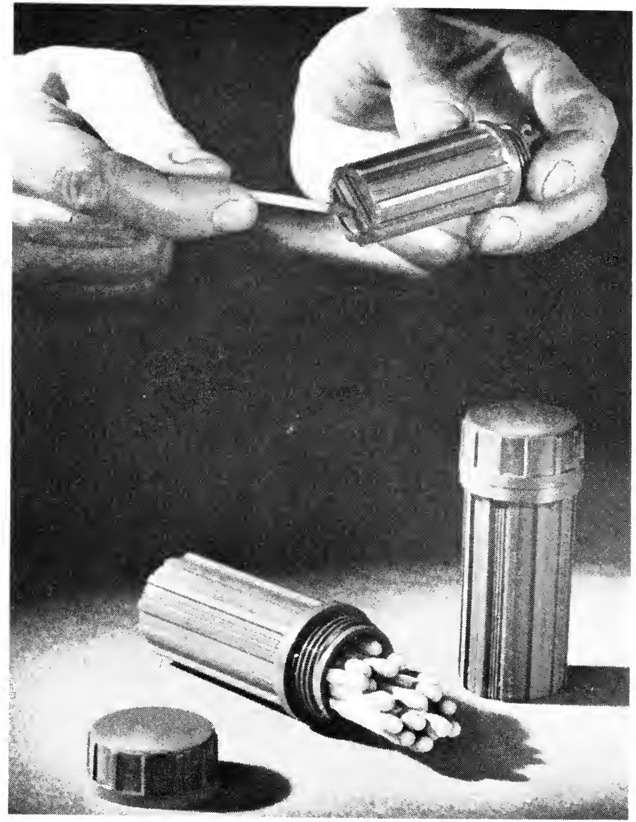
It is estimated that the new plastic-bonding method



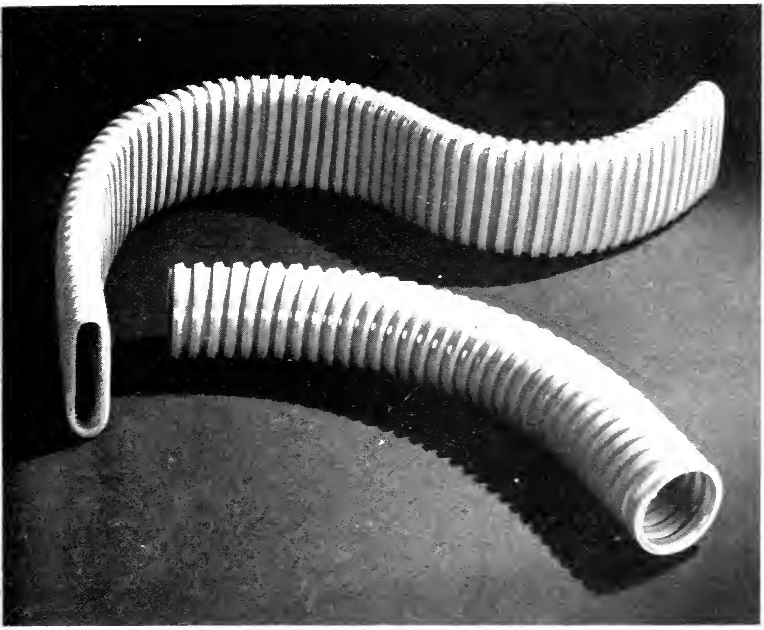
Plastic police whistles, as cast. *(Courtesy Modern Plastics)*

This plastic faucet, light in weight, was developed for wartime housing projects, may well find postwar acceptance. *(Courtesy Modern Plastics)*

Plastic luggage grips.
(Courtesy Modern Plastics)

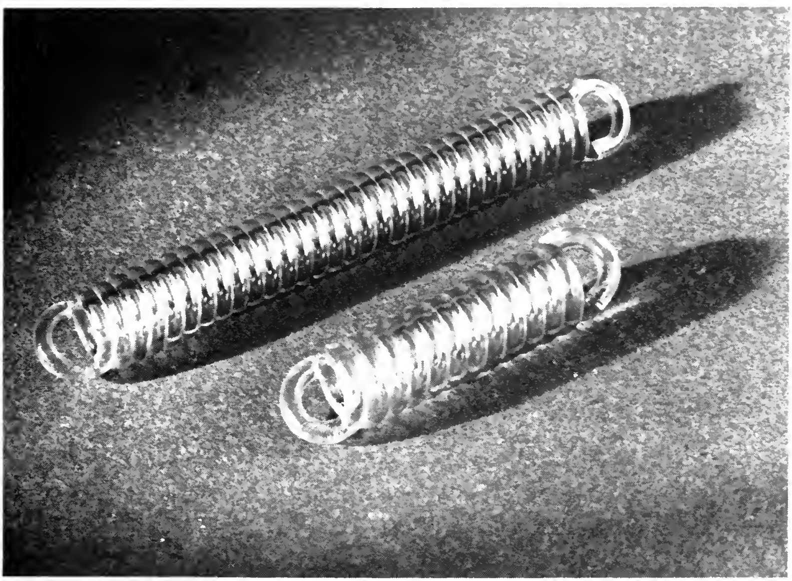


These plastic match holders have been popular with servicemen.
(Courtesy Modern Plastics)

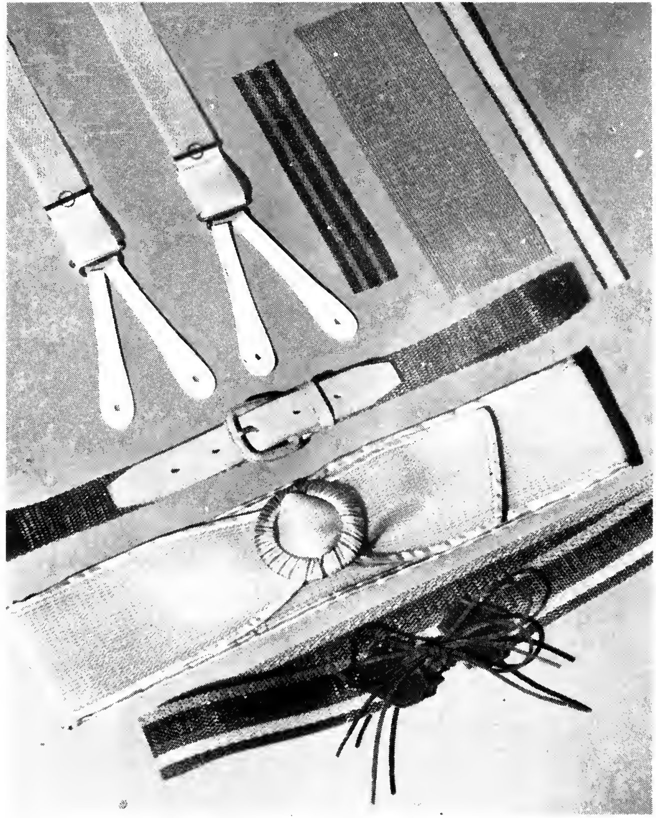


Flexible plastic tubing. *(Courtesy Modern Plastics)*

Plastic springs. *(Courtesy Modern Plastics)*



Plastic flashlight.
(Courtesy Modern Plastics)



Plastic clothing accessories.
(Courtesy Modern Plastics)

will produce a fighter plane identical to the present types, and this plastic-bonded plane will weigh only a third of what the present fighters weigh; will be produced four times as fast; will cost from 25 to 30 per cent less; and will have far superior performance.

Vibration has heretofore been the great difficulty to overcome in the formation of permanent joints where plastics meet other materials. And in planes vibration is pronounced, because of the powerful engines now in use. Cycleweld makes it possible to form complete transparent canopies over the cockpits and eliminate the metal supporting strips which have interfered with vision. Simply by Cyclewelding a narrow strip of rubber between the metal of the fuselage and the plastic canopy the vibration is dampened, and the failure of the joints eliminated. This same method can be used where metal meets metal, and the vibration further reduced. The method is of particular value in the mounting of instrument panels and radio installations.

Coupled with Cycleweld is a new process developed by duPont for plasticizing wood. In combination, these processes are certain to revolutionize aircraft construction. In the new duPont process, ordinary soft woods such as pine and others of the quick-growing varieties can be made as hard as steel. The natural strength of the wood is increased many times. It becomes thoroughly resistant to oil, gasoline, moisture, even fire. The oxyacetylene torch requires nearly twice the time to burn through the plasticized wood as it does through an equal thickness of steel.

In this process the wood is immersed under pressure in a solution of methylolurea, which is a urea-formaldehyde plastic. The wood is impregnated by the plastic and there is also present a chemical reaction with the natural resins in the wood. In the first stages the plastic formed is pliable, but upon setting it becomes solidified. In this state it is resistant to heat, moisture, gasoline, oil, and many acids and other chemicals.

Further startling prospects for this process point to the possible utilization of such materials as sawdust, shavings, wood scrap, cotton, paper, fabrics and even bamboo as an aircraft construction material. It bonds them into the same hard and strong material as it does the soft woods.

But plywoods are by no means the only plastic-bonded laminates used in aircraft. One of the other major uses of plastics is in the bonding of fabrics in laminations to form pulleys for the various control cables. Disks of fabric are cut to size and then impregnated with plastic. Molded to shape, they emerge as the amber-tinted pulleys with which we are familiar. The same process has been used successfully to mold propeller blades. Canvas impregnated with plastics is molded into the blades, which give excellent service.

In the interior of the airplane we find the innumerable knobs, handles, instrument panels, radio cabinets, crystals for the instrument faces, the dials and pointers, light reflectors, seats, navigation instruments — practically a universal use of plastics to form either a part or the whole. In the latest airliners, the interiors have plastic panels and trim; the furnishings, even the fabrics, are plastic. Also the various guides for controls, the grommets, conduits for electric lines, ventilators, toilet fittings — the list is endless. Wherever you look, you will find plastics.

From the foregoing it is readily seen that because of their light weight and efficiency plastics have found high favor with the designers as well as with the engineering staffs. The use of plastics in the electrical systems of the engines dates as far back as the first successful internal-combustion engines for aircraft. Here the stresses imposed upon the material are of secondary nature. The same thing applies to the plastics used for windows, noses, and the closures for the gun turrets. Water-clear synthetic resins have proved more efficient than glass, and effect a very considerable saving in weight. Glass has a specific gravity of 2.6 against the average specific gravity of 1.18 for the transparent plastics used to replace it. These plastics have the additional advantage of not shattering as does glass.

At the present time the most important use of plastics is the structural, where it is used as a bonding agent in plywood. The advances made have effected radical changes, as we have seen. But the plastics industry is far from static. In the aircraft industry we can look forward to still more spectacular developments. While it is true that at this moment the plastic airplane is yet to be built, that is not to say that it will not be built. It is not beyond the realm of probability that fuselages and wings will be molded of plastic in the future. When that time comes we shall have true mass production of aircraft, with the concomitant low cost and high efficiency of plastics.

CHAPTER XIX

ELECTRONIC BONDING OF PLASTICS

AUTHOR'S NOTE: *One of the greatest advances in the aviation industry from the construction point was the development by the Fairchild Engine and Airplane Corporation of an electronic bonding method called Duramold. Because of its importance and because of the fact that this method is not confined alone to the aircraft industry, the official Fairchild description of the process is included here verbatim.*

IT WOULD be burdensome to attempt to describe all the developments which have been under way with the object of improving the use of wood as an aircraft material. A review of these would show that the trend of most of the work has been along lines of improving the durability of the bonds between laminations or assemblies, and of improving finishes.

To see why new bonding techniques, like the electronic one, have been so important to develop, it is desirable to know something of the classes of bonding materials, or glues, as they are commonly called, which are available. There are three classes in general use, with many modifications of each type: casein glue, urea-formaldehyde resins and phenol-formaldehyde resins. The first two classes will set at room temperature, 70° F. to 90° F., in about six to eight hours, although this time can be reduced by the application of heat. The last class, and the most durable, requires either room temperature, 75° F. to 100° F., coupled with a long setting time (measured in hours), or high heat, 200° F. to 280° F., for the rapid setting (measured in minutes) necessary for production.

Casein glue, unless fortified with strong preservatives, loses its strength and molds when exposed to moisture. Although there are many airplanes with parts fastened together with casein glue — such as the Fairchild 71, many of which are flying after fourteen years of continuous and satisfactory service under unfavorable climatic conditions — this glue has been practically given up because of the difficulty found in modern monocoque structures of providing drainage and surface protection over the glue joint to such an extent that there is no possibility of the joint being subjected to accumulated moisture. Failure of casein glue, because the joints were allowed to be exposed to moisture, is one of the main causes for lack of confidence in wood airplanes.

Urea-formaldehyde resins are moisture-resistant, and thereby overcome the main objection to wood structures bonded with casein glues. It is important to avoid the possibility of thick glue lines with ureas, because thick urea glue lines "craze" with time. The small cracks in the crazed glue line, and the internal stresses set up by the crazing, weaken the glue line.

To avoid thick glue lines in making assemblies, a process called Durassembly has been developed. This process uses fluid pressure to push parts, even thick ones with uneven surfaces, into such close contact that thin glue lines are assured. Heat is usually applied in using this process by equipping the jigs with external heating strips. This reduces the time in the jig from 6-8 hours to 15-40 minutes. By so doing, the expense of building duplicate jigs, which would otherwise be necessary in order to meet a production schedule and still permit time for loading and unloading plus 6-8 hours in the jig, is avoided.

The phenol-formaldehyde resins are the most durable and do not require extreme care in avoiding thick glue lines. They meet every requirement of an ideal bonding material except that they require either very long setting times at room temperatures, or the necessity — for short setting times — of heat higher than that required for quick-setting ureas. Great progress is being made in reducing the maximum setting temperatures required for quick setting of phenol-formaldehyde resins and modifications of this type, such as the resorcin-base resins. These new bonding agents, now under life tests, give hope that in the near future some of these types can be substituted for the ureas.

However, whether the problem be to use either the present phenol-formaldehyde resins or the new types now under test, heat is required. Also, if the long setting times of the ureas are to be reduced in order to eliminate the cost and time required to make duplicate jigs to meet a production schedule, heat is required.

There are two methods of applying heat to a glue line. The first is to apply a heated platen to the surface of the wood, depending upon conduction to bring heat to the innermost glue line. The second, the electronic process, is to cause a current to flow through the wood and by electrical agitation cause the wood to heat uniformly throughout its thickness. The first heating method is used in the Duramold process. Here the heat, provided by steam in a tank or autoclave, is conducted through a steel platen and rubber blanket to the layers of wood compressed between the platen and blanket. The first method is also used in the Durassembly process. Here the heat is conducted through the wood to the glue line from hot metal strips pressed against the surface of the wood. These strips are heated by the resistance which they offer to the flow of a low-voltage current. Where the glue line is not over ½ inch from a surface to which heat can be applied, the first heating method works perfectly.

However, wood is a poor conductor of heat, and as the thickness is increased the time for conduction of heat, with the hottest platen or strip which can be applied against the surface of the wood without burning, becomes excessive. Even if the time required were not a factor, attempts to heat thick pieces from the surface would result in drying out the surface layers much more than the center. When, in time, the surface layers stabilized themselves and reached the same moisture content as the center, these layers would have expanded with resulting stresses in the wood itself and in the glue lines.

Therefore, when a problem such as the manufacture of the laminated spar flange of the Fairchild AT-21 Gunner arises, which problem is to heat the innermost part of a piece 25 feet long and 7 by 5 inches in cross section to a sufficient temperature either to set a phenolic glue line, or to set a urea glue line quickly without excessively drying out the outer layer, it is evident that any attempt to heat the center by conduction from the surface would be impractical. As part of its design data, Duramold has extensive curves showing the time, with any surface temperature and any platen material, to reach a given temperature at the center of a piece of material of any given thickness. For a piece five inches thick, this time is many hours.

Therefore, until electronic processing was proved, such spars had to be made with cold urea glue by being left in numerous presses for eight hours. With electronic processing, this large piece can be brought to 210°-230° F. in twenty minutes with practically uniform temperature. With this process the most durable phenol-formaldehyde resin bonds can be made, production speeded up, and the number of costly jigs reduced.

What is this electronic processing, and how and when was it developed? For a number of years home diathermy has been used for arthritis and many other medical uses where it was desirable to heat the inside of the body without overheating the surface.

Some years ago diathermy apparatus was used to heat up wood, and it was known that the wood heated uniformly. However, the commercially available apparatus was too low-powered, because there was no medical use which envisioned heating a body the weight of one of the AT-21 spars. Moreover, human bodies could not be safely heated to temperatures approaching those for setting glue lines. In the diathermy apparatus there was, nevertheless, the nucleus of a method.

In going from diathermy apparatus with average powers of 100 to 500 watts and maximum temperatures of 110° F., to powers of 1000 to 30,000 watts and temperatures up to 280° F., many problems were encountered. Numerous tests were required before results were obtained which were sufficiently uniform and reliable to permit using the electronic processing as a production tool.

In starting on electronic processing, the first problem was to obtain equipment. Small high-frequency generators, which had been used for test or other purposes, were converted and rebuilt. Later, a converted 15-kilowatt frequency-modulated radio station, built before the war, was obtained and modified by both its manufacturer and Duramold's electronic engineers. Additional equipment could not be obtained on a delivery schedule to meet Duramold's production requirements. Therefore Duramold decided to design and build its own equipment, aimed specifically at electronic processing of woods and plastics. By doing this the limitations of equipment designed for diathermy or broadcasting were removed. Improvements already incorporated have resulted in equipment less critical in adjustment, and less subject to service interruptions.

Three sizes of apparatus have been designed and built with conservative ratings of 1 kw.; 5 kw. for scarfing, edge-gluing and small assemblies; and 30 kw. for the Fairchild-Burlington plant's spar flange operation. The first two sizes are portable; that is, they can be brought to the jig where rapid uniform heating is desired. These smaller units can be used with old-type jigs, and even jigs with screw clamps, to speed the setting of cold-setting ureas. Therefore their use does not have to await the construction of newer fluid-pressure-type jigs. The large-size apparatus is stationary, with the jigs surrounding it like spokes around a hub.

Unfortunately, the design and satisfactory operation of the electronic apparatus and the availability of parts to be processed were not the only requirements necessary to start production operations. In fact, the applications of high frequency to the work provided more problems than the design of the apparatus.

There is no great mystery about electronic processing. The passage of an electric current through any material causes it to heat up. For materials of medium resistance, such as nichrome used in toasters and electric irons, and the strip heaters in Durassembly jigs, a direct or 60-cycle, 110-volt alternating house current is satisfactory.

Wood, sometimes thought of as a non-conductor, is really a very poor conductor. Its resistance to the passage of direct or 110-volt alternating current is very high. It would require tremendous electrical pressure, on the order of millions of volts, to cause enough current to flow through wood of appreciable thickness to make it heat up. Fortunately, as the frequency is increased from the 60 cycles per second found in most factories, to the 3,000,000-8,000,000 cycles per second used in electronic processing, the effective resistance drops. Therefore, at these high frequencies, sufficient heating currents can be obtained with available voltages.

In electronic processing the heating can be obtained either by a combination of low frequencies, that is, low in the electronic range, on the order of 3,000,000 cycles per second in combination with high voltages of 15,000 to 18,000 volts, or by higher frequencies of from 15,000,000 to 20,000,000 cycles per second in combination with lower voltages of 3000 to 4000 volts. In either case, it is evident that the voltages are such that the apparatus and guards must be carefully designed from a safety standpoint. The selection of the proper combination of voltage and frequency is a complicated one. As the thickness of the piece being processed is reduced, the voltage must be reduced below a value which would result in arcing between the electrodes.

Uniform power distribution or its resultant — uniform temperature distribution — is much more difficult to obtain in a large piece such as the 25-foot AT-21 spar flange, than in the PT-19 spar flange or smaller pieces. The reason for this is that when the dimensions of the work become comparable to a wave length corresponding to that of the frequency used, standing wave effects appear. These cause non-uniform power distribution. This non-uniformity can be minimized to a satisfactory degree by introducing the current to the electrodes at a number of points, which results, in effect, in breaking the large piece into a number of smaller pieces. The necessity for doing this is reduced, obviously, by lowering the frequency, which increases the wave length.

Naturally the frequency cannot be reduced below the point where the voltage required would arc between electrodes. With small pieces, such as cap strips for ribs and bulkheads, there is no problem of uniform heating.

Another item which must be considered in any application of high frequency is called the power factor. The power factor of a given material, in simple language, might be said to be the measure of the heat which will be generated in that material by a given current. Materials containing water, such as wood at high moisture content or wet urea-formaldehyde glues, generate more heat from the passage of a high-frequency current than dry materials. For this reason, with a given power, the time required is less with wet glues than with dry glues. If a wet glue line can be placed at right angles to the electrodes, there is a concentration of current in the glue line and the relative heating effect in the glue line as compared to that in the wood is further increased. With this arrangement, voltages as low as 200 volts at 5,000,000 cycles are used with glue lines one inch wide.

From the standpoint of cracks due to explosions in the wood from steam or pitch pockets, there is a practical top limit of around 230° F., unless the part is entirely under fluid pressure as it is in the Duramold process, in which case temperatures around 290° F. can be used.

The ideal bonding material would be one which could be applied to the work and then set at any convenient time. Most bonding agents, like casein glues or cold or warm setting adhesives, have a fairly short allowable time between applying the glue and getting the glued parts under pressure. This time is called the open assembly time. As the temperature required for setting the bonding agent is increased, the permissible open assembly time is lengthened. Duramold, in cooperation with resin manufacturers, has had developed and production-tested one bonding agent which has an open assembly time of days, yet it can be set at 205°-230° F. With an upper limit of 230° F., from the standpoint of wood not completely under fluid pressure, it can be seen that uniform current through the wood must be obtained to give uniform heating, because the heating effect varies as the square of the current.

Good joints result only from sufficient and even pressure, and this can be obtained only with fluid pressure. It goes without saying that it is desired to heat the work and not the jig or fluid-pressure container, because heating the fluid-pressure container has caused it to break. Methods have been worked out to confine effectively the heating effect where it is wanted, and these methods are working on a production basis.

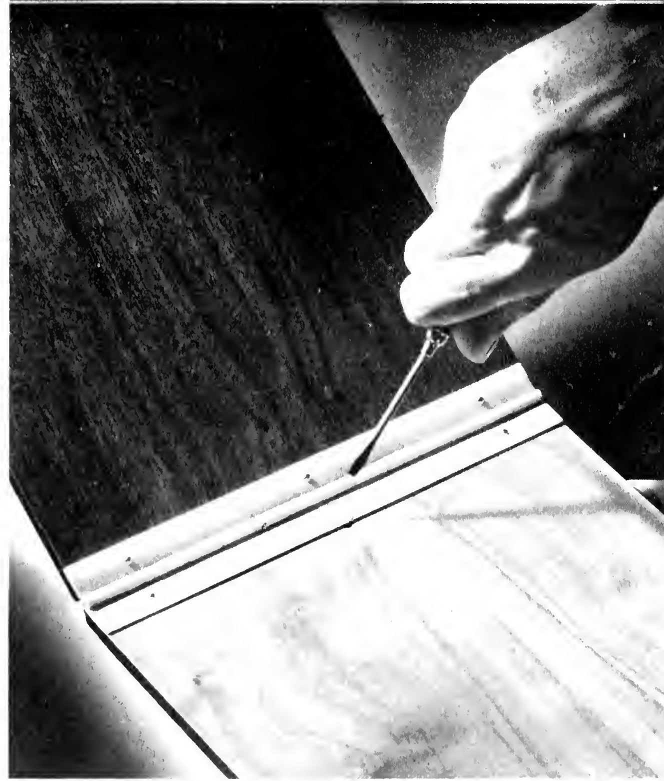
The installation at the Burlington plant, used to cure the flanges of the center section spars of the AT-21, consists of a powerful high-frequency generator and, beside it, a large jig which holds the laminated assembly while it is being "set." In the bed of the jig is a long channel, shaped to the flange's form. One side, and the blocks on which the flange rests, are movable. Thin laminations of wood, smeared with a phenolic resin which has dried, are assembled on their edges, to the proper thickness. The flexible blocks on which the laminations rest are made of two pieces joined by a rubber hinge. Since the rubber is under tension, it holds each support open to the full width of the open jig, yet allows for compression as the jig is closed.

When the sides of the jig are clamped together, the thin laminations are pressed into the proper shape. Each side of the jig is lined with a copper plate, or electrode. The two electrodes extend from end to end along opposite sides of the spar and the high-frequency current completes a circuit through the laminations of wood and plastic.

Along one side of the jig, behind the copper plate and its support, is a high-pressure air hose. The use of air pressure not only achieves accurate control, but provides the required uniformity of pressure. The thickness of wood laminations cannot be controlled with the accuracy possible, for example, in the machining of metal. Consequently, if extremely rigid platens were used to apply pressure it would result in crushed fibers or either open or thick glue joints.

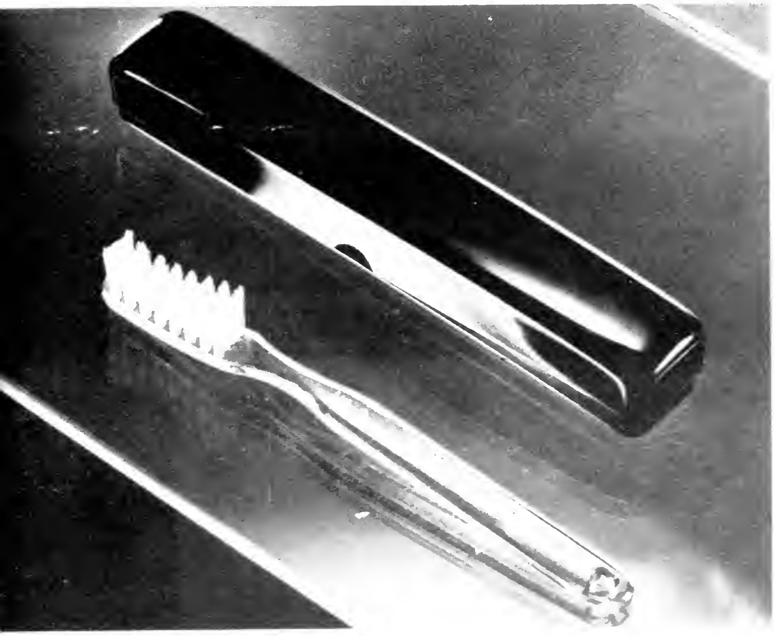
This process brings the internal heat of the flange up

Plastic fire-hose nozzle.
(Courtesy Modern Plastics)



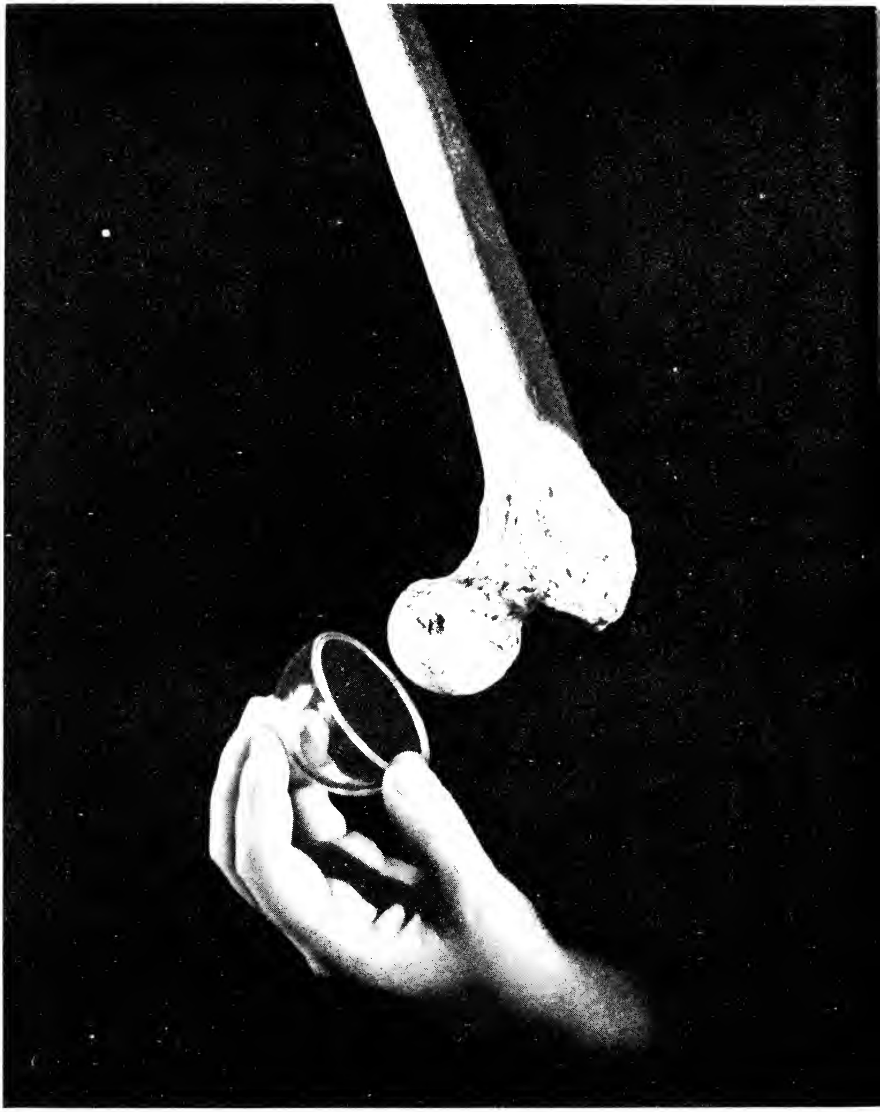
Piano type plastic hinges.
(Courtesy Modern Plastics)

Plastic ice bag. *(Courtesy Modern Plastics)*



Plastic toothbrush handle is moisture-proof and weather-resistant. Toothbrush boxes are also plastic.
(Courtesy Modern Plastics)

Plastic desk set. *(Courtesy Modern Plastics)*



Insertion of Plexiglas cups in joints affected by arthritis is part of new method for treating the ailment.

(Courtesy Modern Plastics)

to the desired temperature in approximately twenty minutes, with remarkably uniform heat throughout the adhesive lines. The whole heating operation is done in approximately 30 minutes. Compare this to the 6- or 8-hour curing period under the cold-glue method.

Here is another example employing a variation of the principle. Curved reenforcing cap strips for the perforated bulkhead used for dividing a dropable gas tank into separate cells are themselves cured by high-frequency heating of the laminated assembly. But when it comes to bonding the flanges to the web the problem is quite different. Of course, the cold-glue method could be used. But here again, faced with quantity orders, it would have meant duplicate jigs, clamps, precious floor space and the use of less satisfactory adhesives. Furthermore, in the case of assemblies having sharply curved members, heating the entire assembly sets up undesirable inequalities in expansion, resulting in out-of-balance stresses in the finished part.

Earlier in this article it was brought out that a wet glue line is more responsive to the high-frequency impulses than dry wood, and so it was decided to produce the heating effect directly in the glue lines. This was accomplished by applying just enough glue, so that when pressure was applied to the joint a slight excess squeezed out all along either side. Strips of metal foil were placed along opposite edges of the glue lines and held in contact. Suitable jigs were made to accommodate two sets at a time of each of the three sections of the bulkhead. Pneumatic pressure pads are arranged to provide exactly the right amount of pressure as the glue is heated. In a few moments, the glue is brought up to the right temperature for creating a permanent strong bond between the flanges and the web. The process results in only a slight warming of the wood adjacent to the joints, although the adhesive becomes hot enough to set (or polymerize).

The operation described goes into the construction of expendable gas tanks tucked under the bellies of the Navy's Jap-blasting Corsair fighters. The Duramold tanks require a minimum of critical materials, and they weigh less than metal tanks of like capacity for the same planes. Larger expendable tanks, with a capacity of hundreds of gallons, are being made for the Douglas A-20. In addition to conserving metals, the use of the Duramold tanks can result in adding precious miles to the range of our warplanes, because the savings in weight are translated directly into increased load capacity – in this case equivalent to adding another member of the crew to the plane or an equivalent weight of gasoline or explosives.

There is no great mystery in applying electronic processing to speed up and produce more durable wood airplanes. However, the successful application requires the services of an experienced engineer who not only understands high-power radio equipment, but who has a thorough understanding of basic electrical engineering.

In addition, he must understand the theory and application of bonding agents, wood technology and the application of fluid pressure. However, once the operation is set up and the proper safety interlocks provided, it can be operated by a locally trained technician.

The Duramold process is not confined to plastic-bonded wood. The process has been applied to paper, fabrics and other fillers. The possibilities of plastic-bonded glass cloth have been barely touched. All shapes and contours can be made by this process and still other materials hold limitless possibilities.

High-frequency heating will play its part in the future of Duramold. It will be applied where it is the most efficient means of curing the cement-like, waterproof bonds between wood or any other low-density material. And the Duramold engineers have just begun to explore the possibilities of this basic technique. It will be possible, for example, to imbed fine wires or foil deep in a complicated assembly, and then weld the whole into an integral unit with the snap of a switch.

At present, Duramold is one-fifth the density of aluminum. The future, says Arthur W. Loerke, chief engineer for the Duramold Division, holds promise for Duramolded materials that may be one twenty-fifth the density of that metal.

Part Four

The Fabrication of Plastics

CHAPTER XX

COMPRESSION MOLDING

Compression molding made possible through development of hydraulic press — simple type — rod press — hand-operated — limited use today — newer types developed — automatic ejection of the molded piece — the fully automatic press.

THE origin of the hydraulic press dates back as far as the middle of the seventeenth century. It is generally credited to the researches of Pascal. He developed a small model using the hydraulic principle and used it in his work. The press was of the simplest construction yet it embodied every chief working part of the latest designs today except the automatic features.

Most of us recall that pressure in fluids is transmitted in all directions with equal force. So it follows that if we fill one chamber with a fluid and then connect it with another in which we develop high pressures this pressure will be transmitted to the first chamber and it will bear on every part of that chamber with equal force.

Pascal took a simple cylinder and inserted a piston in it. This piston he coupled to a flat plate which bore against another. By raising the piston the plates were brought apart and material could be placed between them. Then the chamber was filled with fluid.

This chamber containing the piston was connected to a very small chamber having a strong force pump attached to it. By operating the force pump the pressure was raised and transmitted to the second chamber. At the same time a quantity of the fluid was forced into the second chamber so that the piston was forced down. In this manner the material between the plates was compressed. Naturally, as the contents of the pumping chamber were small, the amount of movement in the piston was small with each stroke of the pump. But very high pressure could be built up and thus a great degree of compression was secured. Exactly the same method is used in our modern hydraulic presses.

In the modern press both chambers are connected to a common water supply at normal pressure of the water main. This supply of water can be caused to act on either side of the piston in the chamber through valves, so that the piston and the plate it carries can be raised or lowered at will and facilitate the changing of the materials to be compressed.

Once the plate is raised and the material to be compressed is set in position, the normal water pressure drives down the plate until it rests against the material. At this time the normal pressure supply is cut off. Both chambers, the piston chamber and the high-pressure chamber, are completely filled with water. Then the high-pressure pump is set in motion.

The piston of the high-pressure pump is small compared to the other one, and its stroke is short. As it makes its stroke and forces a portion of the water into the other chamber, this water is replaced in the pressure chamber through valve action on the return stroke. This is exactly what Pascal did, though not with the same speed or at the pressures we now operate. Gradually the larger piston is forced down and the material compressed. When the required pressure is attained, the press is stopped and the pressure released through a valve which permits some of the water to flow from the chamber.

In the compression molding of plastics the two plates of the normal hydraulic press are replaced by dies. These dies are cut from specially hardened steel. They are the exact duplicate of the original article which is to be molded in quantity. The cutting of the dies is a precision operation and usually expensive. Where the article is small it is usual for the dies to be duplicated, so that more than one impression can be made at a time.

To follow the operation of compression molding let us consider a simple article such as an ordinary tablespoon.

In one of the dies the material is cut away so that the lower profile of the spoon is duplicated. The other die is carefully cut so that it carries on its face the upper, or inner, profile of the spoon. The two dies are so cut as to leave the depth of the material in the spoon as a space when the two die faces are brought together. This is done by leaving a flat surface around the point where the dies are cut.

In operation a measured quantity of the plastic is placed in the lower or hollow die and then the press set in motion. The upper die descends and forces the material into every part of the lower. Usually there is left a very small quantity in excess of that needed so as to insure complete filling of the mold. This excess, or flashing, as it is termed, forms a very thin edge along the center of the molded piece when the dies meet.

Various plastics require different pressures as well as different temperatures when molded, so each press is equipped with measuring devices to permit pressure and temperature to be controlled.

Where the molds are filled by hand and the finished product removed in the same manner the process is naturally slow. To speed this up and increase production, American designers have perfected molds which automatically eject the finished product. This is done by small pins which are operated by a mechanism that causes them to be raised when the mold is opened after an article has been formed. At this time the plastic has set and there is no danger of the pin making a mark on the material, which is now well hardened.

To speed up production further, the form of the original hydraulic press has been altered. In the newer types the head of the press is no longer placed at right angles to the base of the machine. Instead, it is set at an angle. The head tilts and opens, exposing the upper die. The lower die is more accessible and the plastic inserts can be readily placed in position. Coupled with the automatic ejection, this greatly speeds production. In addition, it exposes the lower die so that the operator can more readily clean it of any particles and have it ready more quickly for the next impression.

Going still further in the compression field, our technicians have developed a press which is fully automatic. It places the inserts in position, closes and presses the material, opens and ejects the finished article, and then repeats the process. These machines even clean the lower die after every operation. Usually a jet of compressed air is used for this.

Until very recently compression molding was the slowest of the molding processes. But these latest developments have again brought it to the fore, although it is not the most rapid process, as we shall see. But where production is low, it is of great importance.

Some of the typical automatic compression molding machines in use today are the Lauterbach, the Watson-Stillman and the Stokes. In the Watson-Stillman, there are two sets of rams. This permits the use of split molds without any extra handling. One ram operates the die cavity and the other exerts the compression. Heating units control the curing time of the plastic.

In the Lauterbach the press is rotary. Die after die is presented to a common feed, and by the time one revolution of the press has been made the articles are cured. The power to the rams is supplied from a central reservoir, and this press likewise is equipped with curing mechanisms so that the plastic is heated to the proper temperature before the cycle is completed.

These automatic presses reduce the time of the operation and eliminate the human element. They are strongly built and serve over a long period. They can be adapted to almost any article if it will fit within the limitations of the press. All that is necessary is to change the dies.

CHAPTER XXI

INJECTION MOLDING

Recent development — high-speed production — originated in Germany — perfected here — early attempts to injection-mold — difficulties of early experimenters — 1931 sees first success — limited capacities — present development.

MOST authorities agree that injection molding was first attempted by Eugene Pelouze in 1856. Pelouze experimented with a machine to force molten metal into dies and so cast it. He used both hydraulic and mechanical means of power, but there is very little record of his attempts and his success was limited. This is shown by the fact that injection molding did not come to general attention until 1872, when the Hyatt brothers, who have already been mentioned in the discussion of Celluloid, patented a machine which injected a charge of plastic into the die and so molded the final article.

Injection molding means exactly what the name implies. A measured quantity of the material is injected into the die by mechanical means to form the product. The material is contained in a reservoir and drawn from it as required. Some of the latest machines, as we shall see, are marvels of mechanical ingenuity.

Hyatt's early machine possessed some of the features of the present-day apparatus. In this machine celluloid was held in a reservoir under fairly high temperature. This heat and the pressure under which the cellulose was held caused it to deteriorate. In addition, there was always the possibility of an explosion.

Buchholz, a German, made the next advance. He patented a machine in which the plastic was held in a reservoir and heated until it was in a fluid state. It then flowed down to an opening where the quantity admitted to the mold was measured by a mechanical device. These early machines, however, were all of very limited capacity. They could not inject any great quantity of plastic into the mold. As a result, they were able to produce only such small articles as combs, rulers, buttons, decorations and so forth.

It is interesting to note the advance in the amount of material these machines could handle as they were perfected. Writing in *Plastics Magazine* in 1940, Doctor Gordon M. Kline, one of our outstanding authorities on plastics, stated that in the first machines the capacity was about ½ to 1½ ounces of material. In 1936 it had mounted to 2 to 4 ounces; in 1937 to 6 ounces; in 1938 to 9; and in 1939 to 12, with a total of 100 square inches projected area. Multiple cylinders brought the capacity of single machines to 36 ounces. Dr. Kline stated that presses were being developed capable of making the entire side of an automobile body. Today this is a fact.

Modern injection presses can make panels for walls, the steering wheels for cars, dashboards, instrument panels and many other large parts. In addition, they turn out innumerable parts for airplanes.

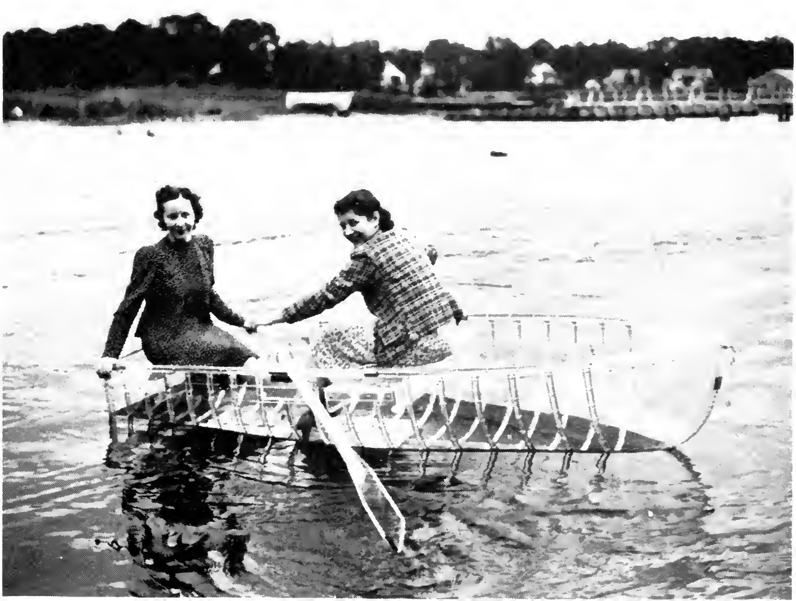
We have mentioned that American engineers have developed molding machines which automatically perform their function, measuring out the exact quantity of material necessary to make the object and forcing it into the mold. The molds were heated so that the plastic was cured in them and after a proper time the molded objects were automatically ejected, the mold was cleaned by a jet of compressed air, and the process repeated.

But in this type of molding it is sometimes hard to secure an even mold. There is a tendency for the plastic, if in a liquid state, to carry a small portion of air with it and then enclose this as an air bubble in the completed object. In order to insure an even flow of material into the mold there has been developed a system called transfer molding. This system is, basically, injection molding with an added feature.

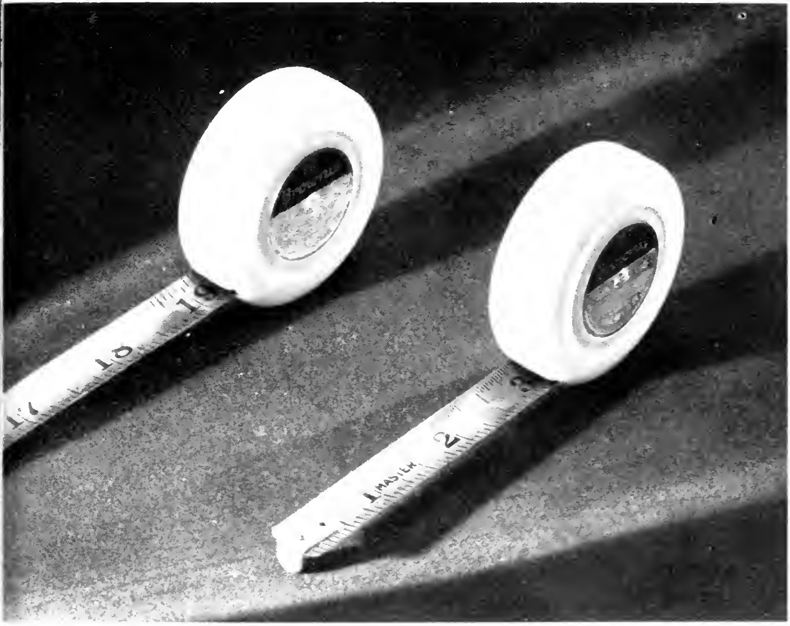
In transfer molding, the mold is maintained at a constant temperature which is the required degree for curing the plastic, and the plastic itself is allowed to enter the machine first as a powder and is then led into a chamber where the heat renders it liquid. As a result, when the opening to the mold is in position the plastic flows smoothly and evenly into the cavity and fills it without carrying with it any air bubbles. The mold opening is closed and the required pressure exerted. The heat of the mold cures the plastic and the product emerges. By pre-heating the plastic to a fluid state it is possible also to secure a far greater adhesion to the filler used and this results in a stronger plastic.

Plastic glasses. *(Courtesy Modern Plastics)*

Plastic rowboat. *(Courtesy Modern Plastics)*

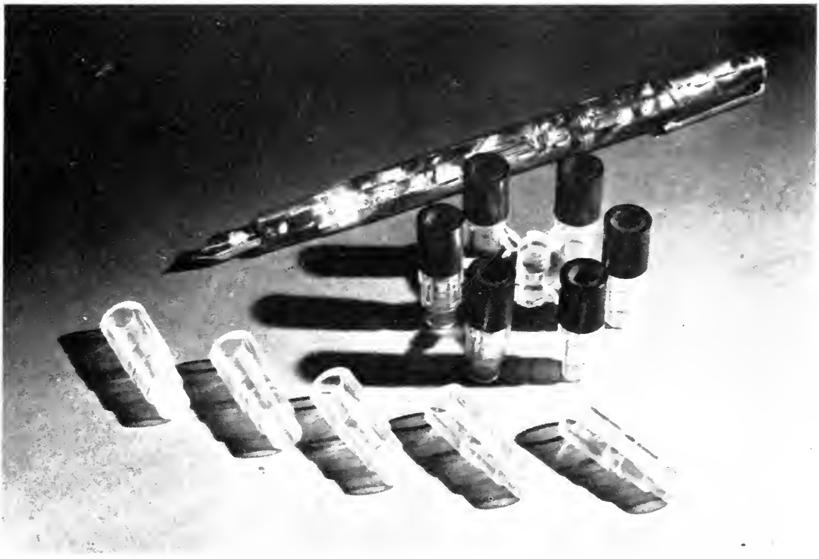


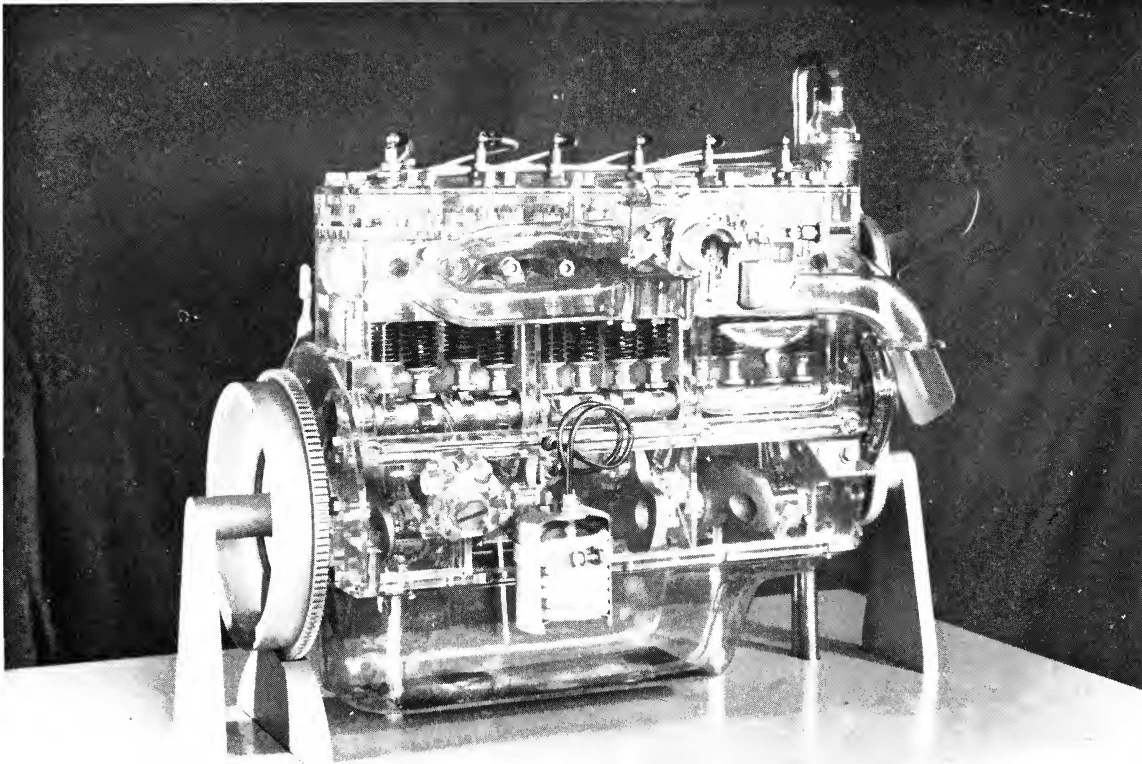
Plastic automobile headlight. *(Courtesy Modern. Plastics)*



Plastic tape measure cases. *(Courtesy Modern Plastics)*

Plastic fountain pen caps, as cast. *(Courtesy Modern Plastics)*





Demonstration engine completely covered by transparent plastic so that its workings can be observed from any point outside. *(Courtesy Modern Plastics)*

CHAPTER XXII

EXTRUSION MOLDING

Importance of this method – method explained – working plastics – machining, cutting, drilling.

Next to injection molding, no method of molding has received more attention from American engineers than extrusion molding. These two methods of molding are perhaps the most important of all, for they offer the greatest production. Both are readily adapted to mass production; both present some difficulties which have been largely overcome.

In extrusion molding the plastic is forced through a die and extrudes from the die in its final shape. By feeding in the plastic in a liquid state and then cooling it as it emerges, the form is retained. In this manner it is possible to make tubing and various other shapes.

After the method adopted in transfer molding, the plastic is placed first in a chamber where heat is applied so that it becomes fluid. It is then forced from the chamber by constant pressure, commonly exerted through the working of a screw. As it leaves the chamber it passes through a die. In the case of tubing, this die is in the form of a steel mandrel which is supported on the interior of the chamber and projects through the opening where the plastic is forced out. There is a clearance between the mandrel and the walls of the opening, and this determines the thickness of the flow of plastic. This thickness forms the walls of the tubing. As the plastic used in extrusion molding must be of a type that will be thermosetting, the molded tube becomes sufficiently hard to retain its form after it has left the opening. Once free of the opening, it is picked up on constantly moving belts and subjected to currents of hot air which set it firmly. In this manner any desired length of tubing can be obtained. In the formation of various shapes of plastic for other purposes, the system of picking up the extruded plastic is the same.

In the case of sheets which may be used for large surfaces, such as windows or formed parts of aircraft, the extruded plastic is picked up on the moving belts after it leaves a narrow rectangular slit in the mold. This slit determines the shape and thickness of the sheeting.

Plastics may be worked in practically every manner that is used in standard machine-shop practice. They lend themselves readily to the various methods of machining and can be turned out in various forms by the automatic machines commonly used for steel- and woodworking.

After machining plastics, it is customary to subject them to a polishing operation. This is usually done by using cloth buffing wheels impregnated with a very mild abrasive. As is the case in all the operations, the heat must be carefully kept below the point where it would be apt to have a bad effect on the plastic.

Cutting with mechanical saws of the band type is another method widely used in working plastics. Many thicknesses of sheet can be cut at a single operation. In most cases, buffing of the cut surface is necessary after the operation.

The drilling and threading of plastics are operations that are easily performed, and for this the automatic type of machine is usually used.

Part Five

Specific Uses of Plastics in Industries

CHAPTER XXIII

LISTS OF USES IN VARIOUS INDUSTRIES

Aeronautical — electrical — clothing and ornaments — photographic field — railways and shipping — medical and surgical — scientific laboratories — toys, games and sports — building trades, architecture and furniture.

THE AERONAUTICAL INDUSTRY

AS indicated in earlier chapters, plastics find a wide use in the aeronautical industry. Below is a list of the more prominent plastics in this field and their uses:

Molded Phenolic Resins: Antenna masts, bearings, ignition parts including distributors and coils, escutcheons, fairleads, gears of the laminated type, handles for various apparatus and closures, housings for the instruments, panels of all types, turning knobs for instruments, lights and shields, control cable pulleys, windowframes, instrument holders, control tabs, general insulation for electrical installations.

Phenolic Resins in Laminated Form: Bearings, gears, fairleads for controls, various ignition parts, housings and panels for instruments and radio, plywood panels and other plywood parts, propeller blades in the lightplane types only, control pulleys, control tabs, ailerons and other control surfaces, insulation of electrical parts.

Molded Urea: Escutcheons, handles for various closures and instruments, panels, housings for instruments and radio, light fixtures, windowframes and other structure frames, aileron tabs.

Urea Resin in Lamination: Housings and panels for instruments and radio installations, plywood parts and laminated propellers, frames for minor structural parts, aileron tabs.

Cellulose Plastics: Radio masts, cockpit enclosures, cowlings of the transparent types, escutcheons, gun-turret coverings, nose and tail coverings, handles for various instruments and closures, ignition parts, lights and lenses, windows, insulation.

Methyl Methylacrylate: Radio masts, cockpit covers, windshields, transparent cowlings, escape hatches, gun-turret covers, nose and tail covers of transparent types, astral hatches, escutcheons, handles, radio and instrument housings, lenses, lights, reflectors, windows.

Plastic Plywood: Bomb-bay closures, escape hatches, doors to various parts of plane, fuselage, tail structure, wing panels, control surfaces, interior bulkheads, wing ribs, spars, propeller blades, interior fittings.

Polystyrenes: Radio masts, radio-set panels, radio housings, ignition parts, lighting parts, insulation.

Vinyls: Various parts in ignition systems, radio parts, pulleys, windows, insulation.

THE ELECTRICAL INDUSTRY

Cast Phenolics: Insulators of all kinds, control handles and knobs, panels, housings.

Molded Phenolics: Bases for various radio tubes and fixtures, plugs, jacks, dials, knobs and controls, housings of all kinds, insulators of all kinds, forms for various instruments and devices, telephone instrument housings, switches, *practically every phase of the industry.*

Phenolics in Laminated Forms: Terminal blocks where stresses are high, bases for sockets where stressed.

Molded Urea: Insulators for fixed condensers, insulation of all kinds, dials, housings, sockets of all kinds, forms for various instruments and devices, plugs, handles, terminal blocks, circuit breakers, plates, switches.

Urea in Laminated Forms: In sockets and terminal blocks where stresses are present.

Cellulose Acetate: Instrument dials, faces, housings, terminal blocks, switches.

Cellulose Nitrate: Various instrument dials, control knobs of all kinds.

Cellulose Ethers: Various instrument dials and the control knobs.

Polystyrenes: General types of dials, knobs of all kinds, stand-off insulators.

Cellulose Acetate Butyrate: Dials for instruments, knobs.

Plastic Plywoods: Used in limited quantities for cabinets.

Methacrylates: Use chiefly confined to instruments, in the form of dials and knobs.

CLOTHING, ORNAMENTS AND OTHER ITEMS

Cast Phenolics: Arch supports, toilet accessories of all kinds, buttons, ornaments, jewelry, pens, pencils, shoe heels, shoe tips, cigarette and cigar holders, closures of all kinds, handles of all kinds, novelties, games, counters, trays and so forth.

Molded Phenolics: Buttons, containers of all kinds, atomizers, fasteners, hairdressers' accessories, toilet articles, ornaments, pens, pencils, smoking accessories, handles of all kinds, novelties.

Ureas: Buttons, containers of all kinds, accessories, ornaments, fancy handles.

Cellulose Acetate: Arch supports, belts and fasteners, buttons, closures, compacts, atomizers, perfume bottles and other toilet sets, fasteners for garters and other personal attire, clasps and frames for all sorts of bags, handles, coverings, millinery, ornaments, shoe parts, lighters, glasses, thimbles, zippers, eye shades.

Cellulose Nitrate: Belts, fasteners, buttons, toilet articles, coverings, closures, frames and covers for all kinds of bags, ornaments, novelties, shirt fronts, collars, millinery, pens, pencils, shoe parts, watch crystals, visors, zippers.

Casein: Buttons, closures of all kinds, artificial wool, felts, ornaments, pens, pencils, novelties, sweaters and so forth.

Methyl Methacrylate: Buttons and fasteners, toilet accessories, frames for bags, handles, jewelry, ornaments, millinery, heels, smoking accessories, glasses, handles of all kinds, crystals, faces for instruments and so forth.

Polystyrene: Women's accessories such as compacts, toilet articles, ornaments.

Vinyl: Buttons, belts, billfolds, shirt fronts, capes of various kinds, protective coatings, toilet accessories, coverings for bags, shirt collars, millinery, pens, pencils, shoe parts such as fabric coverings, evening slippers, suspenders, raincoats, crystals, watch straps.

Vinyon: Gloves, coverings for various items, dress goods, shirt fronts, slippers, fabrics, interlinings, laces, stockings, bathing suits, raincoats.

Nylon: Gloves, bristles, wave lotions, coverings, dress goods, threads, stockings, laces, interlinings, ropes, fish-lines, fabrics, raincoats, straps, personal clothing.

Rayon: Men's clothing, garters, gloves, fabric coverings, dress materials, stockings, bag handles, ties, linings, ornaments, flowers, shoe accessories and fabrics, sweaters, personal wearing apparel.

THE PHOTOGRAPHIC FIELD

Molded Phenolics: Camera housings, developer and other chemical trays, tanks, housings for instruments, washer closures, housings and so forth.

Phenolics in Laminations: Housing for flash synchronizer, panels where stresses are present, boards.

Cellulose Acetate: Camera housings, panels, control knobs, holders, gears and sprockets, photographic color film, other film of all types, fluorescent powder, spring tongs.

PLASTICS

Cellulose Nitrate (flammable): Control knobs, commercial film.

Methyl Methacrylate: Filters, lenses of cruder types.

Vinyl: Microfilm equipment, fixing spray, photolithography.

Shellac Resin Coatings: For protection of trays and tanks from effects of chemicals.

RAILROADS AND SHIPPING

Molded Phenolics: Lights, insulation, electrical panels, switchboards, marine light fixtures, signal equipment, anti-corrosion coating.

Urea and Phenolic Laminations: Light fixtures of all kinds, panels of all kinds, furniture, insulation, rail plates, relay equipment and other electrical equipment, partitions in vessels, signal equipment.

Urea Molded: Light fixtures, insulation, electrical equipment panels, marine signal equipment.

Cellulose Acetate: Light fixtures, interior trim, safety glass.

Vinyls: Safety glass.

THE MEDICAL AND SURGICAL FIELDS

Molded Phenolics: Cases and inclosures for all types of instruments, housings for instruments, closures for medicines, stoppers for closures, handles for instruments, microscope frame parts.

Ureas: Surgical windows in post-operational work.

Cellulose Acetate: Parts for various instruments, appliance parts, face-mask parts, artificial torsos for student studies.

Methyl Methacrylate: Contact lenses for eyes, lenses for instruments, shields, dentures, illuminated instruments, splints, cases for instruments and so forth, demonstration torso.

Vinyls: Demonstration torsos, gloves, shields.

Nylon: Sutures.

SCIENTIFIC LABORATORIES

Molded Phenolics: Beakers, burettes, closures, capping devices, purifiers, salt-water freshener.

Cast Phenolics: Cases for instruments, parts for microscopes, holders.

Cellulose Acetate: Beakers, funnels, covers, slide holders, frames.

Methyl Methacrylate: Transparent pumps, tubing, analyzers.

Polystyrene: Coating for acid-resistant parts, closures for acids.

TOYS, GAMES AND SPORTS

Molded Phenolics: Boat trim, fishing reels, binoculars, dice, chess and checkers, poker chips and racks, cribbage boards, rakes, dominoes, bridge boards, Mah Jong sets, puzzles, shuffleboard disks, blocks, dishes and cups, doll houses and furnishings, parts for model planes, models of all kinds, guns, train tracks, stocks for shotguns and rifles, ferrules for golf clubs.

Cast Phenolics: Artificial lures for fishing, dice, chess, dominoes, checkers, cribbage boards, poker chips, toy blocks, doll-house furnishings.

Cellulose Acetate: Windshields, visors, field glasses, golf tees, stocks for shotguns and rifles, playing cards, poker sets, model airplane parts, blocks, furnishings for doll houses, models, babies' accessories, toy soldiers, trains and so forth.

Ureas: Mah Jong sets, dominoes, bridge boards, roulette chips, poker sets, blocks, dishes and cups, rattles, teething rings and babies' accessories.

Cellulose Acetate Butyrate: Fishing equipment such as bait, leaders, reel parts; chessmen, dominoes.

Methyl Methacrylate: Windshields, croquet mallets, wickets, balls, puzzles, light lenses, dishes.

Plastic Plywoods: Bicycle frames, hulls for boats, oars and paddles, chessmen.

THE BUILDING TRADES, ARCHITECTURE AND FURNITURE

Phenolics: Architects' instruments, bathroom fixtures, chairs, table tops, clock housings, desk tops, door knobs and handles, furniture trim, ornamental plates, shelves, dispensers, floorings, plumbing fixtures, toilet seats, varnishes, ventilators.

Cast Phenolics: Housings of all kinds, handles and knobs, furniture trim and facings, models, paints, lacquers, adhesives, bonding agent for plywood.

Ureas: Housings of all kinds, handles and knobs, surfaces, coatings for fabrics, light fixtures, paints and lacquers, toilet seats, ornaments, novelties, adhesives, bonding agent for plywood.

Cellulose Acetate: Housings of all kinds, handles and knobs, screens, toilet seats, panels, coverings, fixtures.

Cellulose Acetate Butyrate: Handles and knobs, interior panels, moldings, trim, wainscoting.

Cellulose Nitrate: Handles and knobs, coatings for fabrics, paints, enamels, toilet seats and fixtures, novelties.

Ethyl Cellulose: Paints, enamels, varnishes, moldings.

Methacrylates: Handles and knobs, surfaces, furniture, furniture trim, light fixtures, panels, paints, varnishes, enamels, partitioning, shelves, screens, railings, toilet fixtures, ornaments, novelties.

Polystyrenes: Trim, railings, light fixtures, stairs, wall tiles, roofing, and so forth.

Vinyls: Fabric coatings, floor tile, furniture trim, paints, enamels, lacquers, fixtures, floorings.

Laminated Plastics: Furniture, surfaces, interiors, shades, partitions, panels, screens, booths, toilet fixtures, wainscoting.

Plasticized Plywoods: Surfaces, furniture, drawers, partitions, panels, screens, shelves, booths, walls.

Coumarone-Indene: Tiles, paints, enamels, lacquers, roofing, flooring, varnishes, and for impregnating fabrics.

Rayons and Nylons: Fabrics for trim and decoration, shades, wall coatings, partitions.

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