UNITED STATES DEPARTMENT OF COMMERCE • Charles Sawyer, *Secretary*
NATIONAL BUREAU OF STANDARDS • E. U. Condon, *Director*

Plastics Research and Technology at the National Bureau of Standards

A Review and Bibliography

By Gordon M. Kline

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Contents

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This paper consists of a summary of the activities of the National Bureau of Standards relating to plastics. It gives a brief outline of the work carried on in each of eight different fields of investigation and concludes with 160 references to publications by members of the staff of this Bureau.

I. Introduction

Work in plastics at the National Bureau of Standards began in 1917, less than a decade after the discovery of the first synthetic resin by Dr. Baekeland. Phenolic insulating materials were being used by the Government for radio apparatus in World War I. Practically no measurements had been made of the properties of these materials at radio frequencies. The Bureau was requested to obtain such data, and the project soon broadened into a general research on the properties of the phenolic laminates, the results of which were published in 1922.

The next phase of the Bureau's activity in this field began in 1929. The Army Quartermaster Corps asked that an investigation be undertaken to determine how the domestically available synthetic resins could be used to replace leather, rubber, shellac, tung oil, and other strategic materials in essential military equipment. From this time on there has been a continuing program of research on plastics at this Bureau. Their growth in importance as a new material of commerce was recognized in October 1935 by the formation of the Organic Plastics Section.

A notable portion of the work of the section has been concerned with the use of plastics on aircraft. These two industries practically grew up together, and the lightweight products of the one were of distinct interest and advantage to the other. It was quite logical that the Bureau would be called upon to provide much of the basic data needed for proper selection and use of the synthetic materials for aeronautical applications. The Plastics Section is at present working on research projects sponsored by the Department of the Air Force, Navy Bureau of Aeronautics, and National Advisory Committee for Aeronautics.

The nature of the Bureau's activities on plastics changed markedly when we entered World War II. It became a proving ground for plastics in all types of military equipment. The facilities of the section were utilized in the development and testing of plastic products by the various war agencies, including the War and Navy Departments, the Maritime Commission, Office of Civilian Defense, and the War Production Board. Many of the items made of plastics became standard stores in the various branches of the service. Typical of the diversified applications of plastic materials that were submitted for testing during the war years are the following: aircraft light covers, baking-type resinous coatings for protection of steel hardware, bayonet handles, binocular coverings and housings, buttons, canteens, card holders, clock housings, combs, compass dials, dopes for airplane fabric, foot tubs, fuze parts, goggles, insignia, helmet liners, insect screening, shaving brushes, tableware, transparent plastics for aircraft enclosures, and whistles.

With the end of the war, emphasis has been shifted to the determination of fundamental properties and constants and the development of methods of test and specifications for plastic products. At the present time about 30 professional and subprofessional employees at this Bureau spend their full time in this research program on plastics. The work is financed in part by direct congressional appropriation and in part by transfer of funds from other Government agencies.

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International contacts were established in 1942 when the Chief of the Organic Plastics Section spent a month in Great Britain at the request of the British Ministry of Supply and British Ministry of Aircraft Production. The wartime activities of the two countries in the plastics field were reviewed and coordinated in a series of conferences and visits to British production centers. This exchange of information was furthered in 1943–44 by the visits to this country of N. J. L. Megson, Chief of the Plastics and Rubber Advisory Service, British Ministry of Supply, and C. D. Philippe, Plastics Engineer, British Ministry of Aircraft Production.

Developments in plastics in Germany during the period of World War II were investigated in April, May, and June 1945, by the Chief of the Organic Plastics Section who was detailed to the Army Ordnance Department for this purpose. A wealth of previously unpublished information on German production methods and research activities was accumulated in the course of this 3-month survey and has been made available in a series of reports.

II. Plastics Research and Technology

The experimental work of the Organic Plastics Section falls generally into three categories. The first of these relates to evaluation of plastic materials and products for other Government agencies; the results of these tests are generally of limited interest and are submitted in the form of reports to the specific organization concerned. The second category pertains to the preparation of specifications; the data accumulated in the course of this work provide the basis for the selection of the test methods and requirements incorporated into the published specifications. The third and largest category consists of systematic studies of the properties and physical constants of plastics. In many instances the materials and properties selected for investigation relate to some particular field of application such as aircraft, adhesives, dentures, shoe soles, and the like. The results of these studies are usually reported in the form of printed publications.

Over the years the research investigations and advisory services on plastics at the National Bureau of Standards have led to the publication of over 160 papers by members of its staff. The various subjects covered in this work are listed in this section, accompanied by a brief description of what has been accomplished in each separate phase. References are cited, by numbers in parentheses, to the original publications, classified under the same headings in section III.

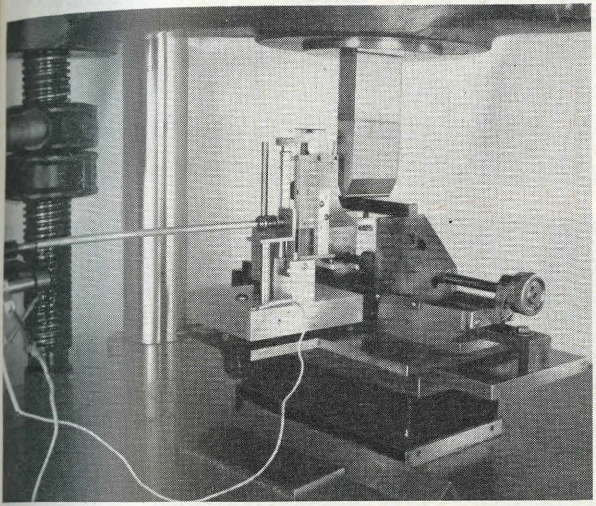
1. Properties of Plastics

A major phase of the experimental program of the Organic Plastics Section since its formation in 1935 has been the determination of the properties of plastics. This Bureau has always been a recognized center for such work because of its exceptional testing facilities and personnel trained in making precise measurements. The new plastics industry, therefore, like the older rubber, textile, paper, and leather industries, has cooperated with this Bureau from the start to obtain a better knowledge of the performance characteristics of its products. Some of these investigations have been concerned with the evaluation of plastics for particular applications; these will be discussed in another section. Others have been concentrated on special properties; these will be discussed in this section.

Mechanical Properties. The tensile, compressive, flexural, and impact properties of several types of plastic laminates, which are either in use or have potential application in aircraft structures and parts, were determined at −70°, +77°, and +200° F. The materials investigated were unsaturated-polyester laminates reinforced with glass fabric and phenolic laminates reinforced with as-

Tensile strength tests on resin-bonded glass-fabric laminates are made in a universal testing machine, employing Templin grips to obtain uniform loading of the specimen. The recording extensometer attached to the specimen provides an autographic record of the stress-strain properties. These glass-fabric laminates have high tensile strengths, running up to 50,000 pounds per square inch for cross-laminated fabrics.

Hydraulic universal testing machine with electrical mechanical extensometer and autographic recorder used for determining the stress-strain properties of plastics.



A variable-span flexure test jig for plastic specimens with recording extensometer and deflection lever attached. This apparatus was designed and constructed because of the significant effect which span-depth ratio has on measurements of the flexural strength of plastics.

bestos fabric, high-strength paper, rayon fabric, and cotton fabric. Both high-pressure and low-pressure types of cotton-fabric phenolic laminates were included [101.3, 101.5, 101.6, 101.7].[1]

The relationship between the strengths of molded plastic articles and strength data obtained with standard test specimens was the subject of another report. Tensile, flexural, and impact properties of phenolic molding materials containing woodflour, cotton flock, macerated fabric, tire cord, asbestos, and mica fillers were studied [101.2].

Tensile, compressive, and Haigh tensile fatigue tests were conducted on a laminated paper-base plastic proposed for use in molding airplane propellers [101.1].

Thermal Properties. An analysis of the causes of internal stress concentrations in molded parts with metal inserts and in resin-bonded sheet materials led to the conclusion that stress concentrations can be eliminated in many cases by matching the coefficients of thermal expansion of the component parts. A stress-equilibrium formula for calculating the thermal expansion coefficients of mixtures involves the density, modulus of elasticity, coefficients of thermal expansion, and proportion by weight of the ingredients [102.1]. The thermal expansion coefficients of a number of plastics with and without fillers are reported.

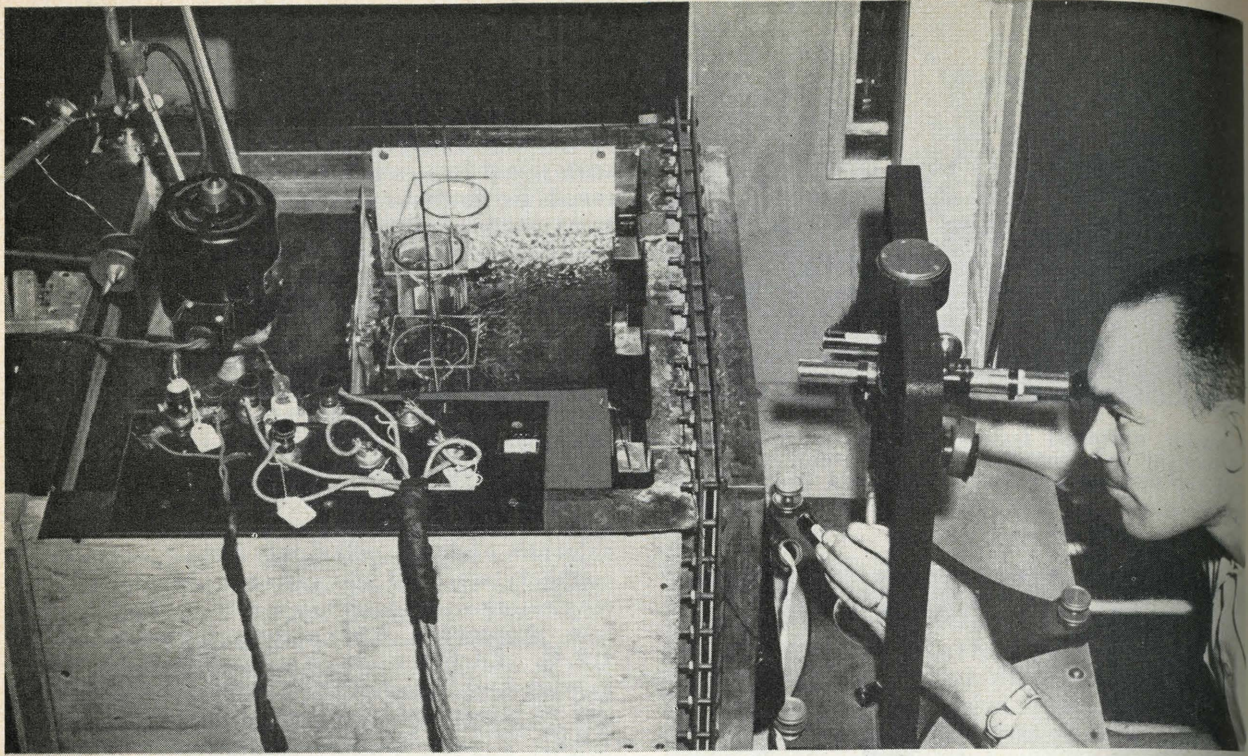
Optical Properties. Ultraviolet and visible light transmissions have been determined for many types of plastics, including polystyrene, polyvinyl chloride acetate, polyvinyl acetal, polymethyl methacrylate, allyl and glyceryl phthalate resins, ethylcellulose, and cellulose nitrate, acetate, acetate propionate, and acetate butyrate [103.3, 103.4]. Earlier work on ultraviolet light transmission and infrared absorption spectra of plastics is presented in two research papers [103.1, 103.2].

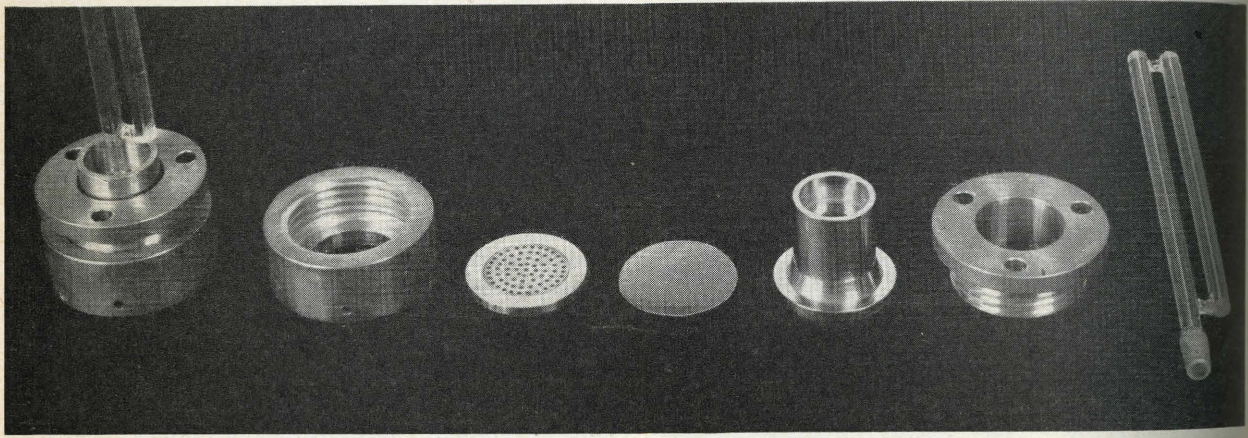
Electrical Properties. As previously mentioned, the first project on plastics at this Bureau was a study of the properties of electrical insulating materials of the laminated phenolic type [104.1]. Because of the importance of plastics as insulators in modern electronic equipment and instruments, new investigations of the electrical characteristics of these materials at ultrahigh frequencies have been undertaken recently.

Permanence Properties. The effects of conditions encountered in service involving exposure to moisture, heat, ultraviolet light, and chemicals are of major importance in determining the suitability of plastics in most applications. These environmental factors can lead to critical changes in dimensions and shape; crazing, cracking, or marring of surfaces; impairment of clarity; and loss of strength and insulating characteristics. Our investigations in this field have included exposure of laminates to weathering and various combinations of temperature and humidity [105.4, 105.6], resistance of plastics to chemicals [105.3] and microbiological organisms [105.5], and effects of outdoor and accelerated weathering on transparent plastics [105.2, 105.7]. The methods used in determining the effects of these deteriorating agents on plastics have been reviewed [105.1].

Permeability. The transmission of water vapor and gaseous materials through films of organic polymers is of significance in many fields—protective coatings, balloon fabrics, packaging and wrapping materials, and the like. Considerable work has been done on this problem at the Bureau,

[1] Figures in brackets indicate the literature references beginning on p. 9.





Studies of the basic properties of high polymers are conducted at the National Bureau of Standards. The apparatus shown was designed at the Bureau for determination of the molecular weight of a plastic substance by measurement of the osmotic pressure it produces in solution. Top: Measurement of the position of the meniscus in the capillary of the apparatus contained in a constant temperature bath. Bottom: Disassembled parts of the osmometer.

particularly with respect to the passage of hydrogen and helium through film-forming materials suitable for coating balloon and airship fabrics [106.1, 106.4, 106.5]. Other reports dealt with the water vapor permeability of synthetic resin finishes for aircraft [106.3] and films used in the packaging trade [106.2].

Water Absorption. The mechanical and electrical properties and dimensional stability of plastics are definitely affected by water absorbed by them. Low water absorption is of considerable advantage in a plastic material. The rates of absorption and desorption of water by 16 types of plastics for periods up to two years and the concomitant dimensional changes have been determined [107.1].

2. Testing of Plastics

Systematic studies of the properties of plastics for the most part date back less than a decade. Hence most of the investigations described in the reports already cited involved exploratory work on the test methods used. In addition, there have been papers dealing with the preparation of test specimens [200.3] and methods of testing transparent plastics [200.2]. A particularly noteworthy contribution was made to the testing of asphalt tile [200.1]. This paper described a portable instrument for indentation testing and presented a formula for relating the depth of indentation to the time during which a loaded sphere acts upon such a plastic body.

3. Chemistry of Plastics

The synthesis of pure resins for use in experimental work on the molecular structure and physical constants of high polymers is a phase of the research program at this Bureau, which has been initiated only recently. These polymers of known composition and history will be used in the evaluation of quality control methods for determining the size, shape, and weight distribution of the macromolecules and in studies to correlate composition with mechanical and electrical properties. Based on previous experience in the compilation of such data for natural rubber, this information should prove to be a fruitful source of new basic principles and new product developments in the plastics field. A fundamental investigation of the polymerization of olefins was reported some years ago [300.1, 300.2].

4. Plastic Materials

The experimental work on plastics at this Bureau has included practically all types of commercial materials. There are three groups of these products, however, that have been the subject of especially concentrated endeavor.

Transparent Plastics. Although no organic plastic has yet been developed that has the scratch resistance and low price of glass, nevertheless, transparent plastics have found many significant uses. Among the outstanding examples of these may be cited the methacrylate resin used for aircraft windows and enclosures, the polyvinyl butyral used for the interlayer in safety glass, and cellulose acetate used in the manufacture of goggles. A study of this important category of plastics was undertaken by the Organic Plastics Section when it was organized in 1935, and several reports relating to this work have been published in this country and abroad [401.1, 401.2, 401.3]. More recent investigations have been concerned with antiscatter treatments for glass to provide protection against this hazard during air raids [401.5] and with plastic mountings for windshields on airplanes having pressurized cabins [401.4].

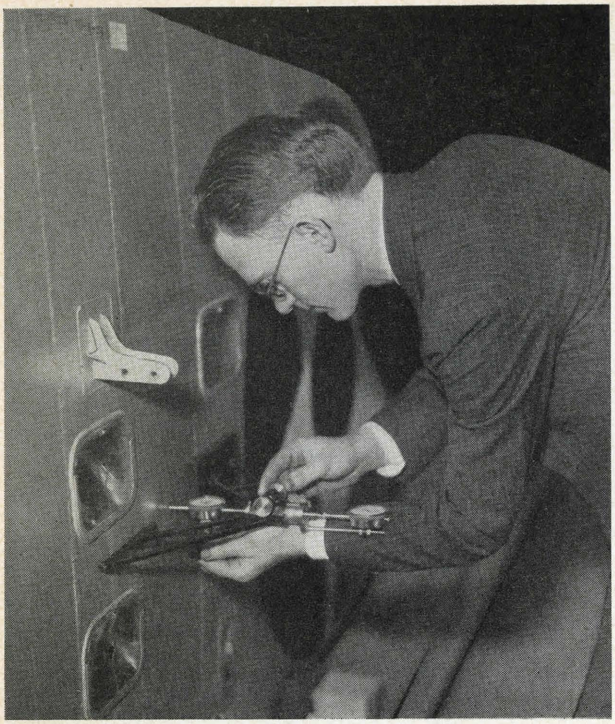
Laminated Plastics. Laminates prepared by impregnating and bonding together layers of paper, cotton cloth, glass fabric, asbestos sheets, or wood veneers, are growing in significance as materials of construction for use in the aircraft, building, chemical, electrical, and other industries. Their properties have been determined in a series of extensive investigations and reported for use by design engineers [101.1, 101.3, 101.6, 102.1, 104.1, 105.3, 105.4, 107.1, 402.1]. Further work is under way to add to our knowledge of the performance characteristics of these materials, particularly at the high temperatures likely to be developed in transonic and supersonic flight.

Expanded Plastics. Organic polymers can be converted into low-density porous spongelike products that have thermal and sound insulating qualities. With proper strength-density ratio, they are also useful as core materials in combination with high-strength high-density facing materials in sandwich structures for aircraft. One report on the properties of expanded plastics has been published [403.1]. Further exploration of this relatively new group of materials is in progress.

5. Applications of Plastics

The evaluation of materials for specific end uses has been a major phase of the work on plastics at this Bureau. These activities result from the advisory function of the Bureau to other Government agencies on technical matters, particularly properties of materials and performance standards. Developments in the applications of plastics for aircraft structures and accessories have been the subject of a considerable number of investigations for the National Advisory Committee for Aeronautics and the Navy Bureau of Aeronautics. Many items of equipment were evaluated for the military services during World War II. These and other application studies are reviewed in the following sections.

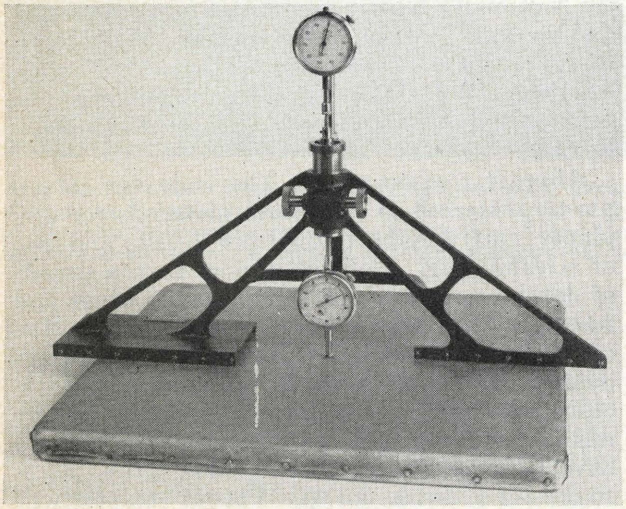
Aircraft Construction. The endeavor to use plastic materials as structural materials for airplanes is attributable to their low density and ease of streamlining. Following more than a decade of development work on this problem, wings and fuselages have been molded from a combination of synthetic resin and glass fabric that offers promise of providing the strength and dimensional stability required for this purpose. Several reports relating to investigations of materials of this type have been published [101.1, 101.3, 101.6, 105.4, 402.1, 501.1, 501.2, 501.3]. Plastic compositions for application to aircraft surfaces, welds, and junctions of metal plates, and to rivet depressions to improve the aerodynamic efficiency at high speeds, have been described [501.4].

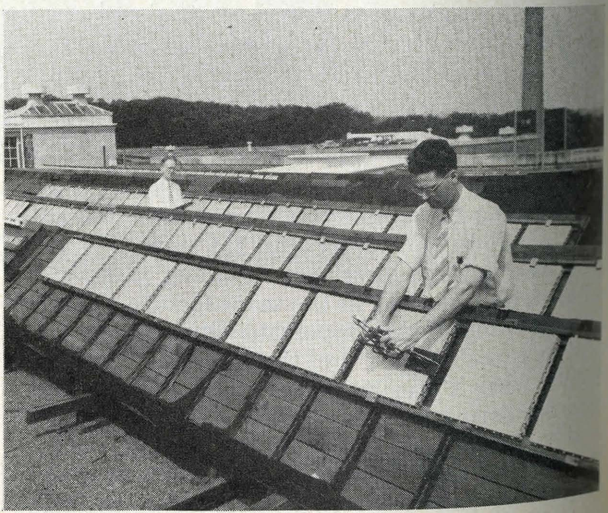


Cellulose acetate butyrate dope for fabric-covered wing and control surfaces on aircraft was developed by the National Bureau of Standards to replace the highly flammable and less durable cellulose nitrate dope. The dope developed by this Bureau was used on Navy carrier-based aircraft during World War II and has also been used exensively on light civilian airplanes. The photograph shows a tautness reading being made on a doped fabric surface of an airplane wing.

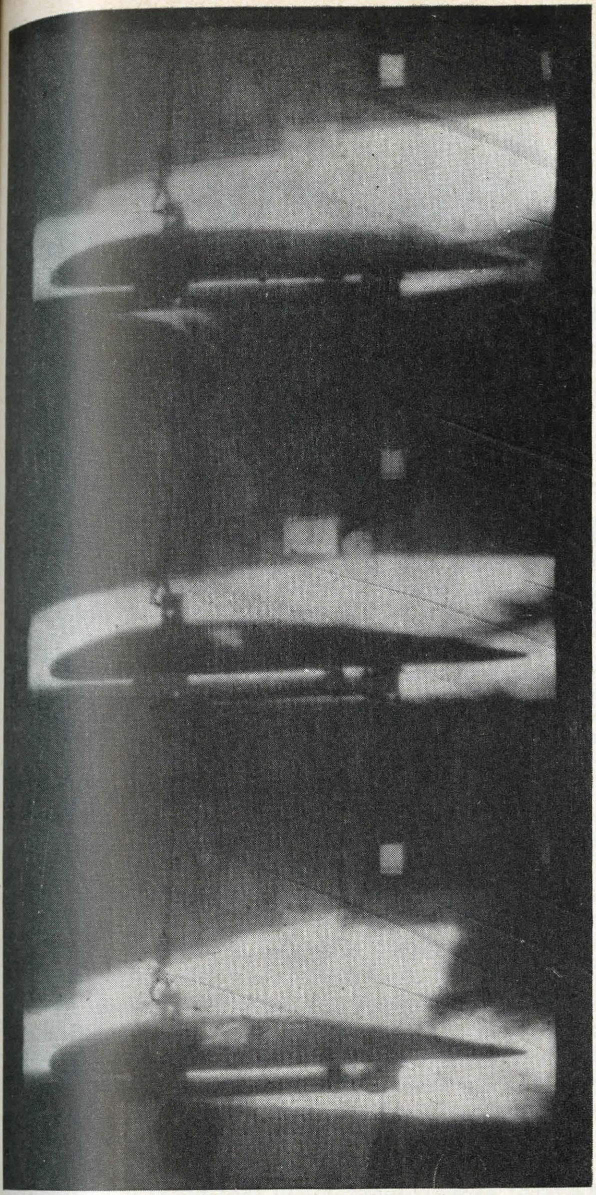
Airplane Dopes. The problem of developing a fire-resistant airplane dope to replace the hazardous cellulose nitrate product was undertaken in 1937 at the request of the Navy Bureau of Aeronautics. A dope based on cellulose acetate butyrate was formulated, which has been in continuous successful use on naval aircraft since 1940 [502.5, 502.8]. In addition to being less flammable, its superior resistance to deterioration under tropical weather conditions proved especially advantageous in World War II. The basic data obtained in the course of this investigation concerning the effects on film characteristics of the four variables involved in the formulation of film-forming compositions—namely, plastic, plasticizer, solvent, and diluent—have proved to be valuable in the solution of other problems involving such systems [502.7]. Earlier research showed that airplane fabric can be made resistant to ignition by application of a 3:7 boric acid borax mixture [502.2, 502.3, 502.4]. An instrument for estimating the tautness of doped fabrics on aircraft and other methods and equipment for evaluating the performance of aircraft coverings were developed during these studies [502.1, 502.6].

Coatings for Balloon Fabrics. Production of a suitable coating for balloon fabric that will withstand severe flexure under varying conditions of temperature and humidity and will be virtually impermeable to the lifting gas is another problem that has been worked on for the Navy Bureau of Aeronautics. In common with all structural materials employed in lighter-than-air craft, emphasis is placed upon optimum properties—strength, durability, impermeability—per unit weight of





A spring-loaded tautness meter was developed to provide a means for determining the tautness of wing and fuselage sections on the airplane itself and during their storage in vertical positions. Weight-loaded tautness meters available before the development of the spring-loaded instrument could be used only on approximately horizontal surfaces. The photographs show the tautness meter in position on a test panel and measurements being made on panels undergoing roof exposure tests.



Sample motion picture record of wind-tunnel burning tests conducted jointly by the National Bureau of Standards and the Civil Aeronautics Administration to evaluate fire-retardant coatings developed by the Bureau for fabric-covered aircraft. A steel wing section is shown suspended at the outlet of an open-type wind tunnel which provides a 70-mile-per-hour air stream. In an opening 12 inches square in the lower surface of the wing are test panels, consisting of doped fabric with fire-retardant coatings. A uniform spray of 90-octane gasoline, ignited by a high-tension spark, envelops the wing section in burning gasoline. In addition to the motion-picture record of the fire, observers provided with stop watches noted the time for destruction of the outer coating and the time of fabric failure.

fabric. A considerable number of reports pertaining to the use of synthetic rubber and other elastomers for this purpose has been issued [106.1, 106.4, 106.5, 503.1, 503.2. 503.3, 503.4].

Dental Materials. The American Dental Association has maintained a Research Fellowship at the National Bureau of Standards since 1928 for the investigation of dental materials. In cooperation with members of the Bureau's staff the research fellows have conducted tests of plastics marketed for use as denture bases [504.1, 504.2, 504.3, 504.4, 504.5, 504.6], liners for dentures [504.8], and teeth in full and partial dentures [504.7]. Most of these dental products were based on methyl methacrylate resin; however, the denture bases included also acrylic-styrene, acrylic-vinyl and vinyl chloride acetate copolymers, phenol-formaldehyde resin, cellulose nitrate plastic, and hard rubber.

Resin-Bonded Map Paper. Early in World War II a new map paper was developed that greatly improved the quality and performance of war maps. Unique properties built into this paper gave satisfactory performance in contact with the water, mud, and grime of the battlefield that had disintegrated papers used heretofore. The most important feature of the paper is its high wet strength, which is obtained by the addition of melamine-formaldehyde resin [505.1]. This Bureau cooperated with the Army Map Service of the Corps of Engineers by conducting semicommercial papermaking experiments in its paper mill to establish how to make the paper from commercially available raw materials and by assisting in the preparation of the purchase specification used by the Army [505.2, 505.3, 505.4].

Preservation of Documents. The suitability of cellulose sheetings as protective coverings for documents was investigated as part of a general study of problems relating to the preservation of records. Cellulose acetate film was found to have the advantages of good stability and ease of application by the use of heat and pressure [506.1, 506.2, 506.3]. When the National Archives of the United States was confronted with the necessity of preserving the vast amounts of documents transferred to it from the various Government agencies, lamination with cellulose acetate was selected as the most feasible method. Their experience during the past decade has indicated that the process is eminently satisfactory.

Motion Picture Film. Photographic film is another important material used for recording documents of all types. Records on this medium require only a fraction of the storage space needed for the same information on paper. Cellulose acetate film was demonstrated to be suitable for this purpose if properly made and processed [507.1, 507.2, 507.4, 507.5]. Test methods for folding endurance, pH, copper number, relative viscosity, and limiting values of quality for use in selecting such film for record purposes have been described [507.3].

Adhesives. The attachment of materials and parts together by adhesives is an efficient and rapid method of assembly. This use of synthetic resins is expanding and accounts for approximately 10 percent of current production [508.5]. A research project is in progress at this Bureau under the sponsorship of the Office of Naval Research to obtain a better understanding of the physical and chemical forces involved in adhesion. A comprehensive survey of the theoretical aspects of adhesion and the techniques used in evaluating bond strengths has been prepared [508.3]. Experimental phases of the project have dealt with the effects of various catalysts used to cure the resinous adhesives on the strength properties of plywood, particularly with regard to the degree of acidity developed [508.1, 508.4], and on the bonding strengths of adhesives at normal and low temperatures [508.2, 508.6].

Miscellaneous Applications. Wartime research on the radio proximity fuze and other electronic devices led to the development of the NBS casting resin, based on styrene, dichlorostyrene, divinylbenzene, and hydrogenated terphenyl. This resin combines the low power factor essential to high-impedance, high-frequency circuits with low dielectric constant, short polymerization period at low temperature and atmospheric pressure, high impact strength, small volume shrinkage on polymerization, dimensional and electrical stability, and low moisture absorption [509.4].

The repair of porous metal castings by sealing with synthetic resins was investigated. Of fourteen resins tested, only two showed promise for this purpose. Only fifty percent of the castings subjected to one treatment with either one of these two resins was sealed; a second impregnation increased the sealing efficiency to 80 percent [509.3].

The critical supply situation with respect to sole leather during World War II, attributable to both increased demands by the military services and dependence to a large extent on foreign sources for hides and tanning materials, made it necessary for the War Production Board to seek replacements wherever possible. Plastics based on vinyl resins were found to have suitable properties for this application [509.2].

In April 1942 the Joint Optics Committee of the Army-Navy Munitions Board held a meeting to discuss possible replacement materials for the aluminum used in binocular bodies, aluminum being at that time among the more critical materials. It was recommended that a binocular housing be fabricated from a plastic material. The development work on this problem was carried on jointly by the U. S. Naval Observatory and this Bureau. Binoculars were fabricated with phenolic-asbestos housings that satisfactorily fulfilled all of the requirements for a general-purpose service instrument [509.1].

A plastic housing for a 6×42 binocular was developed during World War II in a cooperative project of the U. S. Naval Observatory and the National Bureau of Standards. The optical system for this binocular was designed by the Optical Instruments Section. A similar cooperative project on a plastic carrying case made of fabric impregnated with a phenolic resin and coated with a vinyl resin provided a container superior to the former leather case in resistance to fungus, moisture, and abrasion.

6. Specifications for Plastics

The 1,311-page National Directory of Commodity Specifications [600.2] and 322-page Supplement [600.3] prepared at this Bureau devote several pages to specifications for plastic products. Each standard or specification is listed by title, designating number, and sponsoring organization. A summary is given of the technical characteristics, scope, and special applications.

The many different plastic products used by the Federal Government from drawing instruments to tableware are purchased under Federal Specifications that set standards of quality, performance, and dimensions. The general methods of testing for plastic products are described in Federal Specification L–P–406a [600.1]. Members of the staff of this Bureau participate in the preparation of these specifications.

7. General Information on Plastics

In addition to its work for other Government agencies, the Bureau is required "to supply available information to the public, upon request, in the fields of physics, chemistry, and engineering." Individuals and small-business firms constantly are asking for assistance. They are furnished information on specific topics relating to plastics or given references to other sources of information.

To facilitate performance of this function, surveys of the materials, methods of fabrication, and applications of plastics [701.1 to 701.10], annual reviews of developments [702.1 to 702.10], and reports on special subjects have been prepared. The latter have included the significance of plastics to the building [703.3, 703.5] and food container [703.1] industries, and the potential production of plastics from lignin-containing substances [703.4] and petroleum [703.2].

8. Investigation of German Technology

The conversion of nature's raw materials by synthesis into a myriad of useful products has always been a special forte of scientists in Germany, the birthplace of organic chemistry. Their efforts toward attaining self-sufficiency in domestic supplies of fuels, oils, rubbers, textiles, and fats are well known to the world. Similarly, in the synthetic resin field their scientists have developed many of the compounds that are used for the production of molded plastics, films and foils, improved leather-type goods, and protective coatings. An investigation of the formulations, manufacturing processes, fabricating techniques, and applications of plastics in Germany was made by the Chief of the Organic Plastics Section in 1945 under the auspices of the Office of the Chief of Ordnance, War Department. The information obtained has been made available to the American public in the form of surveys [801.1 to 801.3], special subject reports [802.1 to 802.8], and translations of important technical documents [803.1 to 803.15].

III. Bibliography

This section lists 160 published reports, prepared by members of the staff of this Bureau, arranged under the same headings used in the preceding text. The titles of the publications show the scope of its research and technological investigations on plastics. Many other reports of limited interest have been submitted to other Government agencies and given circulation at the discretion of those agencies.

A large number of the reports listed are Government publications available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at the prices indicated. The prices quoted are for delivery to addresses in the United States and its territories and possessions and in certain foreign countries that extend the franking privilege. In the case of all other countries, one-third the cost of publication should be added to cover postage. Remittances can be made very conveniently by coupons obtainable from the Superintendent of Documents in sets of 20 for $1.00, good until used. Checks and money orders should be made payable to "Superintendent of Documents, Government Printing Office" and sent to him with each order. The Government Printing Office does not accept stamps in payment of orders. A quantity discount of 25 percent is given on orders for a single publication purchased in lots of 100 copies. Publications marked "(OP)" are out of print and are consequently no longer available. They may in general be consulted in technical and public libraries.

The NACA publications are available in limited quantity from the National Advisory Committee for Aeronautics, 1724 F Street NW., Washington 25, D. C.

The PB (Publication Board) reports are available from the Library of Congress, Photoduplication Service, Publication Board Project, Washington 25, D. C., in microfilm (mf.) or photostat (ph.) form at the prices indicated. Orders should be sent to the above address with check or money order made payable to the Librarian of Congress.

Neither the Government Printing Office nor the National Bureau of Standards is in a position to supply copies of the nongovernmental technical and trade journals mentioned in the bibliography or reprints from them. Information regarding their availability and price can be furnished by the publisher or organization sponsoring the publication. Their addresses can be obtained from the "List of Periodicals Abstracted" in part 2 of the December 20, 1946, issue of Chemical Abstracts. The name and location of libraries where these journals can be consulted can also be found in this same list.

100. Properties of Plastics

101. Mechanical

[101.1] Strength and fatigue tests on a laminated paper-base plastic proposed for use in molding propellers. B. M. Axilrod, NACA Advance Restricted Report (Aug. 1942).

[101.2] Correlation between strength properties in standard test specimens and molded phenolic parts. P. S. Turner and R. H. Thomason. NACA Tech. Note No. 1005 (May 1946). Modern Plastics **23**, 146 (May) and 154 (July 1946).

[101.3] Impact strength and flexural properties of laminated plastics at high and low temperatures. J. J. Lamb, I. Albrecht, and B. M. Axilrod. NACA Tech. Note No. 1054 (Aug. 1946).

[101.4] Tensile properties of rolled silver chloride. B. M. Axilrod and J. J. Lamb. J. Applied Phys. **19**, 213 (1948).

[101.5] Tensile stress-strain relationship of laminated plastics at small strains. J. J. Lamb and B. M. Axilrod. ASTM Bulletin No. 151, 59 (Mar. 1948).

[101.6] Tensile and compressive properties of laminated plastics at high and low temperatures. J. J. Lamb, I. Albrecht, and B. M. Axilrod. NACA Tech. Note No. 1550 (July 1948).

[101.7] Mechanical properties of laminated plastics at —70°, 77°, and 200° F. J. J. Lamb, I. Albrecht, and B. M. Axilrod. J. Research NBS **43**, 257 (1949) RP2028 (20¢).

102. Thermal

[102.1] Problem of thermal-expansion stresses in reinforced plastics. P. S. Turner. NACA Advance Restricted Report (June 1942). J. Research NBS **37**, 239 (1946) RP1745 (10¢). Modern Plastics **24**, 153 (Dec. 1946).

[102.2] Discussion of paper on the ignition temperature of rigid plastics. N. P. Setchkin. ASTM Bulletin No. 151, 66 (Mar. 1948).

103. Optical

[103.1] Data on ultraviolet solar radiation and the solarization of window materials. W. W. Coblentz and R. Stair. J. Research NBS **3**, 629 (1929) RP113 (15¢)

[103.2] Infrared absorption spectra of plant and animal tissue and various other substances. R. Stair and W. W. Coblentz. J. Research NBS **15**, 295 (1935) RP830 (5¢).

[103.3] Ultraviolet and visible light transmission by various plastics. Modern Plastics Encyclopedia, p. 756 (1947).

[103.4] Infrared prism spectrometry from 24 to 40 microns. E. K. Plyler. J. Research NBS **41**, 125 (1948) RP1911 (10¢).

104. Electrical

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