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RUBBER LATEX

Abstract

This Letter Circular is intended to give general information on rubber latex and to direct the reader to sources from which special or detailed information may be obtained. Part I is a brief discussion of the production, composition, and properties of latex and its use in manufacture. Part II is a list of recent publications on latex, covering the period 1927-1931.

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INTRODUCTION

This letter circular has been prepared in response to inquiries and requests for information about rubber latex. The aim has been to give a concise description of the production, composition, properties and applications of latex, and to acquaint the reader with publications from which more detailed information may be obtained. The scope and variety of publications on latex that are already available are such that any attempt here to give a comprehensive discussion on the subject would be superfluous.

The present discussion is concerned primarily with commercial latex which is obtained by the tapping of the tropical rubber tree, Hevea brasiliensis, but in the bibliography reference is made to other natural latices, and to artificial dispersions of rubber which closely resemble natural latex in many of their properties and applications.

The references to publications, which comprise the second part of this letter circular, are largely but not exclusively confined to the period 1927 to 1931. Some publications of general interest that appeared prior to 1927 have been included. The reasons for restricting the bibliography to the last five years are two-fold. In the first place, there has been a recent widespread interest in latex and numerous publications have appeared dealing with a variety of theoretical and practical aspects of the subject. It is to this recent literature that the reader seeking general information would naturally turn first. Furthermore, the literature up to 1927 has been exhaustively surveyed in Hauser's monograph on latex which is available in an English translation.

The references have been classified according to topics as indicated in the table of contents. The scheme of classification has been adapted from that of the Information Bureau of the Research Association, British Rubber Manufacturers. Under each topic the references have been arranged by year of publication in the order 1931, 1930, 1929, etc., while under each year an alphabetical arrangement by authors has been followed. The names of journals have been given in full for the convenience of the reader who may have only a limited familiarity with the rubber literature. The place of publication, subscription price, and scope of most periodicals dealing with rubber are given in Letter Circular of the Bureau of Standards No. 305, A Guide to the Literature on Rubber.

The following paragraphs enumerate various governmental and other agencies which have to do with latex and indicate sources from which special information may be obtained.

The Office of Cotton, Rubber, and Other Tropical Plants of the

Bureau of Plant Industry, United States Department of Agriculture, deals with the collection, composition, and properties of latex in connection with studies on the production of rubber. The investigations carried on by this office include many rubber-bearing plants of both temperate and tropical habitat in addition to those which are employed as commercial sources of rubber.

The Rubber Division of the Bureau of Foreign and Domestic Commerce, United States Department of Commerce, collects and publishes statistical information on the production, export and import, and consumption of latex. The world trade in latex up to 1931 is summarized in Special Circular of the Rubber Division, No. 3147, International Trade in Rubber Latex, 4 pp.; November 30, 1931.

Commercial information regarding latex may be obtained from current rubber trade journals, two of which, published in the United States, are:

India Rubber World, published monthly by Federated Business Publications, Inc., 420 Lexington Ave., New York. Annual subscription, $3.00.

Rubber Age, published twice monthly by the Palmerton Publishing Co., 250 W. 57th St., New York. Annual subscription, $2.00.

The price of rubber latex, per gallon, is given in the market quotations which appear in the above journals and also in some daily newspapers. Statistics regarding export, import, and world trade in latex are also given in the rubber journals.

The names and addresses of firms which deal in natural latex, vulcanized latex, concentrated latex, and various latex preparations, may be obtained from the advertising columns of the rubber journals or from the Rubber Manufacturers' Association, 250 West 57th St., New York.

PART I. TECHNOLOGY OF LATEX

Rubber latex is a creamy liquid made up of microscopic rubber globules dispersed in an aqueous serum. Many different trees, shrubs and vines yield latex, but the tropical rubber tree, *Hevea brasiliensis*, is now almost the exclusive commercial source of supply. A large proportion of the latex produced is converted at once into crude rubber which is used as the raw material for the manufacture of rubber products. Within the last decade, however, developments in the preservation, concentration, and vulcanization of latex have rendered it available for direct use in manufacture, without the intermediate step of the preparation of crude rubber. Latex is

well suited for producing rubber coatings on metal and fabrics, for making thin rubber articles, and for use as an adhesive. Various processes are used in the manufacture of products from latex, one of the most unique being electrodeposition, which is analogous to the electroplating of metals. Rubber products made directly from latex are generally superior in strength, elasticity and durability to those made from crude rubber.

1. Collection of latex

Latex occurs in the leaves, in the inner bark of the branches and trunk, and in the cortex of the roots of the Hevea brasiliensis as well as other rubber-yielding trees. It is contained in microscopic tubes in which it exists under a certain pressure, although there is no evidence that it normally flows or circulates. Latex is wholly separate and distinct from the sap of the tree. The role of latex in plant economy has been the subject of considerable study and speculation, but no theory as to its function seems to have gained general acceptance.

Latex is obtained from the Hevea tree by tapping it near the base. The usual method of tapping consists in making an incision one quarter, one third, or one half way around the trunk and two to four feet above the ground. The bottom of the incision is shaped as a trough to carry latex, which oozes out from the severed latex tubes to a spout from which it drips into a clean glass, porcelain, or aluminum collecting cup.

Successive tappings are performed by paring a thin strip from the bottom of the previous cut by means of a special U or V-shaped tool. Tapping is a delicate operation; the cut must go almost through the bark so as to open the maximum number of latex tubes, but must not penetrate or injure the cambium or thin growing layer between the bark and the wood. The thickness of the paring is such that the cut is lowered at the rate of about one or two inches per month. When the cut reaches the bottom of the tree, a new tapping panel is opened on the opposite side, and the panel which has been tapped is allowed to rest so that the bark may heal.

Originally, rubber trees on estates or plantations were tapped daily, but this proved to be injurious to the trees, and now tapping schedules usually provide for rest on alternate days, weeks, months, or other periods. In some instances trees may be tapped only every third day. With the less frequent tapping, the total yield of rubber may be decreased somewhat, but the yield per tapping operation is greater, so that an economy in labor is effected.

The quantity of latex obtained each time a tree is tapped may range from a fraction of an ounce to several ounces, depending both on the frequency of tapping, weather and seasonal conditions, and

on individual characteristics of the tree. The average yield is of the order of one or two gallons of latex per tree per year, which is equivalent to 3 to 6 lbs. of dry rubber. Trees yielding 10 to 20 lbs. of dry rubber per year are not uncommon, and yields of 50 lbs. have been recorded. Considerable study has been given to the propagation of high-yielding trees, both by seed selection and by bud grafting. The transmission of latex-producing characteristics is by no means simple or direct, but in some cases bud-grafted trees have the yield characteristics of the tree from which the bud was taken. This affords a possibility of greatly increased rubber production. Yields of 1000 or 1250 lbs. of rubber per acre per year are predicted, instead of 300 to 500 lbs. as at present, but such returns have not yet been attained on any considerable area.

The daily routine of tapping trees, collecting and caring for the latex, is described in various books on rubber. A detailed and well illustrated account, which is no longer up to date in all particulars, is given in The Preparation of Plantation Rubber by Sidney Morgan and Henry P. Stevens, Constable & Co., Ltd., London; 1922. Some phases, such as tapping, are discussed in detail in a more recent book, Modern Aspects of Rubber Cultivation, by Charles Herbert Wright; Maclaren & Sons, Ltd., 37-38 Shoe Lane, E.C. 4, London; 1928.

The collection of latex and the production of rubber from wild Hevea trees in the Amazon valley is crude and inefficient in comparison to the well-ordered procedure on plantations in the Middle East. A well-illustrated description of South American methods is given in United States Department of Agriculture Bulletin No. 1422, The Hevea Rubber Tree in the Amazon Valley, by Carl D. La Rue; 1926. This publication may be obtained from the Superintendent of Documents Government Printing Office, Washington, D. C., for 15 cents, (stamps not accepted).

The collection of latex on an experimental scale is described in United States Department of Agriculture Technical Bulletin No. 65, Experimental Tapping of Hevea Rubber Trees at Bayeux, Haiti, by L.G. Polhamus; April, 1928; price, 5 cents, from the Superintendent of Documents.

2. Composition and properties of latex

When latex is observed under a microscope at a magnification of about 1000 diameters or greater, it is seen to consist of minute globules suspended in an aqueous serum. On account of their small size, the particles are in vigorous Brownian motion. They range in diameter from less than 0.5 micron to about 5 microns, and the particles large enough to be resolved distinctly appear to be pear-shaped and to have tails. The structure of the individual latex particle

has been studied by Hauser by micromanipulation with very fine glass needles. A particle, when punctured by a needle, appears to consist of a tough, elastic sac filled with a viscous fluid. Both the elastic shell and the viscous contents are regarded as different modifications of rubber, while on the exterior of the particle there is a layer of adsorbed protein. Another description and interpretation of the structure of the latex particle has been given by Von Weimarn.

The exterior protein shell plays an important role in the coagulation of latex by acids. As evidence for this, latex from which the protein has been removed by digestion with trypsin or by other means, is practically unaffected by acids in concentrations which would instantly coagulate the original latex. Coagulation phenomena in latex are by no means simple; they have been the subject of detailed study on account of their importance in the preparation of crude rubber.

The rubber content of the fresh latex may vary from 15 to 60 per cent, depending on the age and condition of the tree, the season, the tapping schedule, and the portion of the tree from which the latex was drawn. In most cases, however, the rubber content lies between 20 and 45 per cent by weight, normal or average latex being assumed as containing about one third of its weight of rubber. There is no agreement, however, as to the exact percentage of rubber in normal latex. Various authorities refer to 30, 33, and 35 per cent of rubber, and still others to 3 lbs. or 3 1/2 lbs. of rubber per gallon. The Bureau of Foreign and Domestic Commerce has sought to eliminate the uncertainty in latex import statistics by requesting that the dry rubber content of the latex be declared by weight.

The specific gravity of latex varies with the rubber content since rubber has a specific gravity of 0.914, and the latex serum from which the rubber has been removed, a specific gravity of 1.020. It is common practice on plantations to ascertain the approximate rubber content of latex by specific gravity determinations with a hydrometer graduated in per cent of rubber and known as a "metrolac".

The important constituent of latex is the hydrocarbon, rubber. Other constituents are proteins, mineral salts, reducing sugars, quebrachitol or monomethyl-l-inositol, and a variety of substances soluble in acetone which are commonly grouped together and designate as resins. When latex is coagulated some of these minor constituent are included with the rubber hydrocarbon to form crude rubber, while others remain in the serum which is separated from the coagulum. Th composition of latex and of crude rubber is shown in Table 1 which is taken from a review on the Chemistry of Rubber by Fisher.

Table 1

Substances in the latex and in coagulated rubber [1]

	In the latex	In the crude rubber
Crude rubber	30.0	100
Rubber hydrocarbon	28.0	92.0 - 94.0
Total solids	33.0 - 34.0	98.9 - 99.7
Mineral substances (ash)	0.3 - 0.7	0.15 - 0.45
Components containing nitrogen (calculated as proteins; 6 x % N)	1.0 - 2.0	2.5 - 3.5
Components soluble in acetone ("resins")	2.0 (?)	2.5 - 3.2
Quebrachitol	1.0 - 2.0	Trace
Reducing sugars	1.15- 0.35	---

[1]From "The Chemistry of Rubber", by Harry L. Fisher, Chemical Reviews, Vol. VII, p. 57; March, 1930.

3. Production of raw or crude rubber from latex

In the Amazon valley crude rubber is prepared by dipping a paddle into latex and rotating it in the smoke of burning urikuri nuts. The hot, astringent smoke coagulates and dries the rubber; part of the serum trickles away, the rest is dried with the rubber. Many dippings are required to build up a large ball or "biscuit" in which form Para rubber comes to the market.

On plantations latex is almost invariably coagulated by the addition of a small amount of acetic acid. The coagulum may be sheeted between corrugated rolls and dried in smoke houses to produce ribbed smoked sheet or it may be passed between rolls running at different speeds in a spray of water to produce pale crepe. The light color of the latter is preserved by the addition of sodium bisulphite to the latex prior to coagulation. In case of both of these important commercial grades of rubber, and particularly the latter, the serum constituents are rather completely removed from the rubber. This is not wholly an advantage since some constituents which improve the aging characteristics of rubber are removed.

With a view to remedying this shortcoming, various processes have been devised for making whole-latex rubber. One of the best known of these is the Hopkinson process whereby latex is evaporated in a spray drier. The latex sprayed rubber thus obtained has superior aging properties and is uniform and tough, but has the disadvantage of including a larger proportion of non-rubber constituents than standard plantation rubber.

4. Preservation, concentration, and shipping of latex

Latex normally begins to coagulate within a few hours after tapping on account of the formation of acid by bacterial action. Coagulation may be prevented by the addition of an alkali to neutralize the acid, or of an antiseptic to prevent the growth of micro-organisms. The alkalies commonly used are ammonia and sodium hydroxide. The former has the advantage that it is volatile and consequently may be readily removed from rubber products made with latex The ordinary latex available in the United States at the present time is preserved with about 3 per cent by weight of concentrated aqueous ammonia solution, specific gravity, 0.882. The preservation of latex with alkalies has the disadvantage that the protein layer on the latex particle is slowly hydrolyzed by the alkali with a resultant change in properties of the latex.

Formaldehyde has been used as a preservative of latex in the proportion of 2 to 3 per cent of ordinary 40 per cent formaldehyde solution. Although it has greater anti-coagulating power and is a better antiseptic than ammonia, it is not held in favor because the rubber produced from latex preserved with it has low tensile strength decreased rate of vulcanization and other unsatisfactory properties.

Various means are employed for shipping latex. One of these is in five gallon oil or gasoline tins which are packed in wooden boxes. Such tins are available second-hand in the tropics, and are convenient for handling latex in small quantities. Shipments of latex from plantations to regular customers are sometimes made in light metal containers so designed that they can be returned to the plantation packed in small space. Large shipments of latex are made in tank steamers and tank cars. In some cases oil tank steamers are used, but vessels have been built exclusively for the transportation of latex.

Since natural latex contains only about one-third its weight of rubber, shipment involves the transportation of two-thirds its weight of useless water. For this reason many means have been devised for concentrating latex prior to shipment. These include creaming, centrifuging, filtration, and evaporation. Creaming may be effected by adding an alkali such as sodium hydroxide to the latex an allowing it to stand for a few hours at 60° or 65°C. This causes the separation of the latex into two layers, the upper of which is thick and rich in rubber. Creaming may also be brought about by means of colloidal substances such as Irish moss, gelatine, ammonium alginate, and the like. The products thus obtained may contain as much as 75 per cent of rubber, but are reasonably stable and may be redispersed

when water is added to them.

The concentration of latex by filtration involves difficulties for large scale operation, and the same appears to be true of the use of the centrifuge.

The concentration of latex by evaporation is the basis of the "Revertex" process, which is operated on a commercial basis at the present time. The latex is treated, on collection, with a non-volatile alkaline preservative to keep it unchanged until it is subjected to the evaporation process. The evaporation is effected by means of a rotary dryer of special design. An alkaline protective colloid such as sodium oleate is added to the latex before evaporation and permits the concentration to be carried to a thick paste without destroying the capacity of the latex to redisperse on the addition of water.

5. Vulcanization of latex

The individual rubber particles in latex may be vulcanized without coagulating the latex and without altering many of its properties and characteristics. Vulcanization may be effected by as simple a procedure as stirring powdered sulphur into the latex and heating it in an autoclave for two or three hours at about 140°C. Vulcanization is quicker and more effective if the sulphur is used in the form of a dispersion which does not settle readily, or an alkaline pol sulphide, which remains in solution. Accelerators which are employed to speed up the vulcanization of ordinary rubber compounds have relatively less effect on the vulcanization of latex than on the vulcanization of rubber.

When vulcanized latex is evaporated a film of vulcanized rubber is obtained which is fully as strong as the product obtained by the vulcanization of crude rubber. Vulcanized latex may be coagulated or electrodeposited in the same way as ordinary latex, the only essential difference being that vulcanized rubber is obtained.

Vulcanized latex has the obvious advantage for many manufacturing processes that no treatment beyond drying is required to produce strong, durable rubber. Vulcanized latex is particularly suitable for use in the production of rubber-textile combinations where the h at or the materials employed for vulcanizing rubbe would affect the color or injure the fabric.

6. Manufacture of rubber products directly from latex

Rubber latex has been suggested for direct use in the manufacture of practically all types and kinds of rubber articles but the applications which have been most successful, thus far, have been those in which the rubber is formed in thin layers as in dipped goods, rubberized fabrics, and rubber coatings on metal.

The importance of latex in manufacture is indicated by the fact that in 1930 the United States imports were equivalent to almost 10 million pounds of dry rubber, or approximately one per cent of the total rubber imports. International Trade in Rubber Latex is the subject of Special Circular No. 3147 issued by the Rubber Division of the Bureau of Foreign and Domestic Commerce, Nov. 30, 1931.

Latex may be used in manufacture in either the natural or the vulcanized state. Where vulcanized latex is employed it is only necessary to deposit rubber in the desired form and dry it in order to secure a finished rubber article. Products made from natural latex are ordinarily vulcanized after they have been formed. This may be done simply and quickly by treatment with a dilute solution of sulphur chloride in carbon disulphide or carbon tetrachloride, but stronger and more durable rubber may be obtained by hot vulcanization with sulphur. This requires that the sulphur and accelerator of vulcanization shall have been incorporated in the latex before the rubber product was formed from it. Methods have been developed whereby not only sulphur and accelerators but also fillers, pigments, softeners, and the like may be dispersed in the latex so as to be co-deposited with it in a uniform and intimate mixture.

The processes in which latex is used for the production of rubber goods include spreading, dipping, electrodeposition, chemical deposition, and froth or foam formation. Fabrics may be coated with rubber by simply spreading latex on them and allowing it to dry. While this process is very simple in principle, careful attention to the composition and the consistency of the latex is required in order to obtain a product of good spreading quality. The impregnation of fabrics, ropes, and cords with latex may be accomplished by passing them through a bath of latex and subsequently drying them on heated rolls or by other means.

Thin rubber articles may be produced by dipping a form or mold into latex and allowing it to dry. This process is less expedient than the common dipping process employing cements made from rubber and benzene or gasoline, because the low viscosity of the latex necessitates a number of dippings in order to build up a layer of useful thickness.

This difficulty may be obviated by employing a porous form so that the serum of the latex is absorbed in the pores by capillary action while the rubber particles are deposited in a coherent layer on the surface.

Another means of depositing a layer of rubber on a form is electrodeposition. This method is finding extensive commercial application not only in the manufacture of rubber articles such as

gloves, toy balloons, tobacco pouches, bathing caps and rubber tubing, but also in the application of rubber coatings to metal surfaces including plates, rods, gauze, pipe, pipe-fittings, insulated wire, and the like. Rubber may be deposited with either a small or a large proportion of sulphur so as to produce on vulcanization either soft rubber or ebonite.

The basis for electrodepositing rubber from latex is the negative charge which resides on the latex particle. When electrodes are immersed in latex and a potential is applied, the rubber particles, by reason of this charge, move to the anode where they are discharged and coagulate to form a coherent layer. It might be expected that a very thin deposit of rubber would insulate the anode, but such is not the case for sufficient water is held in the deposit to permit the penetration of ions and layers of rubber as much as one quarter of an inch in thickness may be formed without difficulty.

The potential used for electrodepositing rubber is of the order of 100 volts, and the current density, from 3 to 5 amperes per square decimeter. The ratio of mass to charge in the latex particle is very high. The amount of deposit obtained per unit of current consumption is relatively much greater than in case of the electrodeposition of metals.

Various metals may be employed as the anode on which rubber is to be deposited, but zinc is most com only used and gives the most satisfactory results. A porous cup or semi-permeable membrane may be used around the anode and the deposit formed on this rather than directly on the metal.

Sulphur and many accelerators, pigments, and fillers may be dispersed in latex and co-deposited with the rubber. Consequently rubber compounds may be produced employing the same ingredients, in general, as are used in mill-mixed rubber. The hydrogen ion concentration in a latex bath must be carefully controlled in order to obtain a satisfactory deposit. If the attempt is made to electrodeposit rubber from commercial ammonia-preserved latex, the product obtained will be spongy and porous on account of the evolution of oxygen gas by the electrolysis of the alkaline solution. If the solution be dialyzed, however, until most of the ammonia is removed, the deposit will be uniform and free from inclusions of gas.

The "throwing power" of a latex bath is poor and the deposit in recessed portions of an irregular anode is apt to be thin. A uniform deposit may be obtained on irregular forms by the chemical deposition process in which the form is first dipped into a solution of a coagulant and then into the latex bath. The coagulant causes a layer of rubber to be deposited, the thickness of which depends on

the time of immersion in latex and on the nature and concentration of the coagulant. The deposit obtained by this means is similar in character to that obtained by electrodeposition. Coagulants which have been suggested for use in this process include acetic acid, alum, formic acid, and various other acids and salts.

Making use of this same principle, rubber thread may be produced by squirting latex into a coagulating bath in a fine stream, in a manner similar to that employed in making rayon and other synthetic fibres.

Rubber that has been freshly deposited from latex by coagulation or by electrodeposition, is soft and contains both water and some enclosed serum. The serum constituents which are soluble may be partially removed by careful washing. The drying of the rubber is best effected in an atmosphere of controlled humidity so as to avoid the early formation of a surface layer of dry rubber which would be difficultly permeable to moisture from the layers beneath.

Ordinarily when the rubber deposit from latex is dried the globules of latex shrink together as the water is removed and coalesce so as to form a product that is substantially without voids or porosity. A process has recently been developed, however, whereby it is possible to convert latex into a gel containing considerable proportions of water, and then to remove the water without destroying the structure of the gel. The product thus obtained is known as microporous rubber. The gel may be vulcanized to any desired stage before the abstraction of the water, so it is possible to produce either a microporous soft rubber, or a microporous hard rubber.

Quite different from microporous rubber is rubber sponge which may be produced from latex by whipping it into a froth or otherwise incorporating gas into it so as to produce a microscopically porous structure, and coagulating and vulcanizing the rubber in this state.

7. Properties of rubber produced directly from latex

Rubber made directly from latex is generally characterized by greater strength and resistance to tear, and better aging properties than rubber made by processes involving the milling of crude rubber. The tensile strength of latex rubber made without fillers is usually 4,000 to 6,000 pounds per square inch, though strengths as high as 7,000 pounds per square inch have been reported.

The better aging of rubber made from latex in comparison with that made from crude rubber may be attributed both to the lack of mechanical mastication, and to the inclusion of a relatively larger proportion of natural antioxidants. The natural antioxidants are present in the serum of latex and are to a large extent lost in the

usual preparation of plantation rubber.

A rubber compound made directly from latex has a lower resistance to some types of abrasive wear than a similar compound made frommilled rubber. This may be observed, for example, by scraping a latex glove with the fingernail or with a knife blade. It is relatively easy to roughen and "pick up" the surface of the rubber or even to remove small particles of rubber. It is much more difficult to produce this effect with milled rubber, though the latter may have a decidedly lower tensile strength. A critical study of the resistance of latex rubber to abrasion does not seem to have been made. This is not, however, a matter of particular practical consequence since the majority of the products made from latex are not of types that are likely to be subjected to severe mechanical wear.

8. Non-*Hevea* latices

Many plants in addition to the tropical rubber tree, *Hevea brasiliensis*, produce latex. In some cases such as "*Castilloa elastica* and *Funtumia elastica*, the latex may contain rubber equal in quality to that of the *Hevea*. The *Ficus elastica*, a tropical tree closely related to the household rubber plant, and other plants yield latices that contain a considerable proportion of resins along with the rubber. Still other latices contain not rubber, but related gums such as gutta-percha, balata, and chicle.

The various latices differ markedly in behavior as well as in composition. Some of them are readily coagulable by acids, just as the *Hevea* latex, while others are relatively stable toward acids. Formaldehyde,which is sometimes used to preserve *Hevea* latex, may actually coagulate the latex of other plants. Microscopic examination of latices indicates that the particles differ in size, and that in some instances the particles are globular, and in other instances, rod-shaped.

No latex, other than *Hevea* is commercially available, chiefly for the reason that the trees, vines, or shrubs producing the other latices are wild, and adequate facilities do not exist for collecting, preserving, transporting, and marketing them. It is true that gutta-percha is now cultivated on an experimental plantation, but the gum is obtained by collecting the leaves rather than by tapping the trees, since the latex does not flow freely.

PART II. SOME RECENT PUBLICATIONS ON LATEX

I. Books

LATEX, ITS OCCURRENCE, COLLECTION, PROPERTIES, AND TECHNICAL APPLICATION. By E.A. Hauser. Translated by W.J. Kelly. Chemical Catalog Co., Inc., New York, 1930. 200 pp. illustrated. Price, about $4.00.

HANDBUCH DER KAUTSCHUK-WISSENSCHAFT. Edited by Karl Memmler. S. Hirzel, Leipzig, 1930. Price about $15.00. Section A, pp. 23 - 183, by A. Zimmermann deals with the botany, production, cultivation, and preparation of rubber and includes chapters on latex, tapping, direct applications of latex, coagulation of latex, and conversion of latex into raw rubber.

THE ELECTROMETRIC DETERMINATION OF THE HYDROGEN ION CONCENTRATION IN THE LATEX OF HEVEA BRASILIENSIS AND ITS APPLICABILITY TO TECHNICAL PROBLEMS. By N.H. Van Harpen. Varekamp & Co., Medan, (Sumatra, Netherlands East Indies) 1930. 460 pp.

LATEX. By H.P. Stevens. Rubber Growers Association, London; 1928. 66 pp. A non-technical treatise on the production, properties, and applications of latex. This pamphlet is designed for the information and guidance of persons wishing to undertake experimental work on latex. A short bibliography is given together with a list of relevant patents with short abstracts. A revised edition was in preparation January 1932.

COLLOID CHEMISTRY OF RUBBER, Paul Stamberger. Oxford University Press, London, 1929.

THE COLLOID CHEMISTRY OF THE RUBBER INDUSTRY, E. A. Hauser. Oxford University Press, London.

Crude Rubber Survey Bulletins

The following Crude Rubber Survey Bulletins of the United States Departments of Commerce and Agriculture contain considerable information on the production and properties of latex. They are available in many public libraries and may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C., for the prices indicated (stamps not accepted).

David M. Figart, The Plantation Rubber Industry in the Middle East, Bureau of Foreign and Domestic Commerce, Trade Promotion Series, No. 2; 317 pages; 1925; price, 50 cents.

William L. Schurz, Rubber Production in the Amazon Valley, Ibid, No. 23, 364 pages; 1925; price, 65 cents.

H. N. Whitford and Alfred Anthony. Rubber Production in Africa, Ibid, No. 34, 136 pages; 1925; 25 cents.

John C. Treadwell and C. Reid Hill, Possibilities of Rubber Production in Northern Tropical America, Ibid, No. 40; 375 pages; 1926; price 65 cents.

Joseph W. Vander Laan, Production of Gutta-Percha, Balata, Chicle, and Allied Gums, Ibid, No. 41; 72 pages; price, 15 cents; 1927.

C.F. Vance, A.H. Huzzall, J.P. Bushnell, and Mark Baldwin, Possibilities for Para Rubber Production in the Philippine Islands, Ibid, No. 17; 101 pages; price, 20 cents; 1925.

Carl D. La Rue. The Hevea Rubber Tree in the Amazon Valley, United States Department of Agriculture Department Bulletin No.1422; 70 pages; price 15 cents; 1926.

2. Source of latex, - plant physiology, yield, tapping, variability.

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