Courtesy of The B. F. Goodrich Co.

THE SOURCE OF RAW RUBBER TAPPING A RUBBER TREE IN MAYLAYA

THE REIGN OF RUBBER

BY

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ILLUSTRATED WITH
MANY PHOTOGRAPHS

NEW YORK
THE CENTURY CO.
1922

PRINTED IN U. S. A.

This book is dedicated to

Mr. BERTRAM G. WORK

under whom the author first became

acquainted with rubber

ACKNOWLEDGMENT

Happy is he who has found a wealth of cordial co-operation. Such assistance to me in the preparation of this book has been noteworthy.

The aid of Miss Frances McGovern and Mr. W. Don Harrison of Akron has been especially valuable.

In the gathering of material and data many have heartily assisted. It would be impracticable to mention all, but among them are: Professor William H. Goodyear, Curator of Fine Arts at the Brooklyn Museum; the officials of The United States Rubber Company, The Fisk Rubber Company, The Firestone Tire and Rubber Company, The Goodyear Tire and Rubber Company, The Boston Woven Hose and Rubber Company; my associates, the executives of the B. F. Goodrich Company, and many of the staff; A. G. Spalding & Bros.; Brigadier General Amos A. Fries of the Chemical Warfare Service, United States Army; the officials of the Bureau of Aëronautics, United States Navy; the officials of the Air Service, United States Army; The Rome Wire Company; Mr. C. R. Boggs of the Simplex Wire and Cable Co.; M. A. Cillard, Editor of Le Caoutchouc et La Gutta-Percha, Paris; Mr. W. M. Morse, Editor of the India Rubber World; Mr. J. K. Mitchell, President of the Philadelphia Rubber Works Company; Mr. Oswald Latham and Mr. Herbert Standring of London; and Mr. W. E. Hemenover.

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CHAPTER I

THE EVOLUTION OF AN INDUSTRY

My purpose in writing this book is to confess to you who employ rubber goods in any way, who take home from shop or store the water-bottle, the garden-hose, or the tire, something of the successes, failures, limitations, and hopes of those whose lives are spent in the creation of rubber products. Mystery has surrounded rubber factories; secretiveness has been the watchword; the methods of manufacture have been little revealed.

But the old days of competitive reticence are past. Because, perhaps, of the harmony engendered of the World War, rubber men are more friendly with each other. Exchange of ideas has been found of mutual value. Research in each of the many units of the rubber industry has developed to the point where it may be said that there are few secrets left. Thus the time has now come when the makers should take their friends, the users of rubber products, into their confidence.

I shall be most happy if from this effort may come to you a clearer understanding of rubber commodities, and a warmer sympathy toward the active participants in this fundamental industry.

We live in a world of things and forces, in which things are the visible evidences of ideas, and forces are the means through which the creation of things is accomplished. Down through the ages men have struggled, thought, studied, tortured, and bled to gain control of forces, that their children might have things of comfort. The American loves his New York, the Englishman his London, the Frenchman his Paris; for in them he finds the things which satisfy. Late in the afternoon an observer upon the corner of one of the crowded thoroughfares of these great cities may find much of interest. The day is done. The workers (are not we all such?) hasten to the streets—the banker into the limousine; the clerk, after a purchase or two, into the bus, the underground, or the subway; the young bridegroom, with eager face—rushes off to take advantage of the fastest transport available. Men go to the one place for which the things of life are created—home. Each carries with him things made in the industries which supply directly or indirectly products rendering life happy and comfortable. So intent are we each day to leave business for home that we rarely stop to delve into the reasons for our possession of the necessary comforts of civilization. The sources of our food, the origin of our clothing, even the roofs over our heads, are taken for granted. If the trolley fails to run, if the electric light goes out, we blame the public service corporation. A dead telephone may mean a late dinner; a blown-out tire requires hard work, and we in these days are too little used to it. The luxuries of yesterday have become the necessities of to-day, but they have come into use too rapidly to permit a real acquaintance. The things of rubber have become essential to the activities of life because of the valuable services they render. Without them our daily affairs would be strikingly different.

The many enterprises which collectively compose the vast rubber industry rose from small beginnings in years so recent and into ramifications so numerous that our modern world may truly be said to be under the reign of rubber. The ruler of the realm is, in democratic fashion, the servant, not the master. The products serve, but do not dominate.

The substance used to produce these various articles was made known to Europeans by the explorers of the Americas. When Columbus landed in the West Indies, he set men at work chopping trees. How our forefathers did love to chop trees! Certain of these trees oozed a white milk from the cut bark. Columbus remarked upon this. Later, in 1525, Spaniards in South America observed the natives playing with a ball made of a black substance, left when this milk was evaporated. Because of the wealth of unusual substances brought back to Europe by these explorers, it is not singular, perhaps, that one of them, from the weeping tree, should have afforded nothing of value during more than two hundred years.

The South American Indians went on with their ball play. Politics and wars absorbed the Europeans, until during the later eighteenth century samples of this weeping-tree product found their way into England. Now, the Englishman has ever been a person of imagination, with zest to search out the new and unusual. Therefore he studied the new American product in laboratory and office. With his commercial instinct, he placed pieces of it on sale. These attracted the attention of Dr. Joseph Priestley. This famous chemist, clergyman, teacher, author, who discovered "dephlogisticated air,"—afterward named oxygen,—wrote the following notice appended to the preface of his "Familiar Introduction to the Theory and Practice of Perspective," printed in 1770: "Since this work was printed off, I have seen a substance excellently adapted to the purpose of wiping from paper the marks of a black-lead pencil. It must, therefore, be of singular use to those who practise drawing. It is sold by Mr. Nairne, Mathematical Instrument Maker, opposite the Royal Exchange. He sells a cubical piece of about half an inch for three shillings; and he says it will last several years." The French had called this substance caoutchouc, which was as close as they could come to *caa o-chu,* meaning "weeping tree." Priestley did not name it, but the men in the art shops christened it, in true colloquial English, "rubber" because it rubbed out pencil marks, and "Indian" because of its origin in the West Indies. But three shillings for a half of a cubic inch! It is the highest known recorded price for raw rubber. Would not our friends the owners of plantations rock with joy could they charge that price to-day when a bit less than *two* cubic inches brings but *one cent?*

Ideas arise from observation of objects. Some men see; but do not gain thoughts or stimulus to imagination from the things before them. Here was something new—a firm, elastic substance from a country of dreams. It was not soluble in water. Stories of cloth waterproofed by the milk poured on and dried, had filtered through to England and France. French chemists undertook the first chemical study of the material; for, as in the case of all our modern rubber and industrial problems, research must ever precede production. And the play of genius in bringing forth ideas began. With characteristic energy, the English people went forward most actively. Exactly where, when, and how the first rubber factory of the world started seems to be in some dispute, although it is stated that in 1803 rubber thread for use in suspenders had been invented by an Austrian in the suburbs of St. Denis, near Paris.

Whether the purpose was the making of thread to hold up the trousers of mankind or the making of water-proof garments, the first books on the rubber industry do not seem to agree. We do know that the English were early the most successful manufacturers, and that the first practical articles were clothing and shoes. Many were the difficulties, uncertain the results.

The names of Charles Mackintosh and Thomas Hancock are names ever to be remembered, because of their extreme activity in building up the industry. Discovering the solubility of rubber in various solvents and producing air-tight materials by "proofing" fabric, they made pillows, air mattresses, and life-preservers. Although as early as 1791 the Englishman Samuel Peal had constructed waterproofed clothing with a single layer of fabric and a rubber layer on the outside, he made no success. In 1823, however, Mackintosh overcame some of the difficulties. He invented what was known as double-texture clothing, and the "mackintosh" came into being. The mackintosh was popular among men who rode on top of the English coach. Things progressed swimmingly in England; Mackintosh's factory grew. Hancock was an indefatigable inventor. He went on with the making of hose, bumpers, carriage tires, and a large number of other products. Rain-coats were shipped to America. Rubber overshoes made on the Amazon River were sent to Europe and America. The first rubber to be imported into Boston was a rubber bottle from the Amazon. S. C. Smith & Sons of New York were the first firm in the business of dealing in rubber goods, and the Roxbury India Rubber Co. of Roxbury, Massachusetts, which was started in 1832 by John Haskins and Edward M. Chaffee, was the first to manufacture these rubber products in this country. Popular indeed were the rubber products. A rubber boom had begun.

But there was a fly in the ointment; for this rubber, though water-proof and moldable into many shapes, possessed a basic fault. The rain-coats hardened in cold weather, so that the poor consumer felt himself encased as in tin armor; in the summer the rubber softened with the heat, melted, and fell apart.

Many efforts were made to dry up the rubber and prevent this stickiness and also to overcome the effect of oil and grease, but without success. So completely had rubber goods failed the American people because of warm summers and cold winters, that down to about 1840 they were filled with dislike for anything that related to "gum elastic." People had become disgusted and rightly so with goods that hardened like a rock in winter and melted in summer. Even body temperature melted the threads in suspenders, and wearers of the celebrated mackintosh had to keep away from a fire or find their rain-coats oozing from them. The only reliable articles were Indian-made shoes from the Amazon. Large quantities of clothing, mail-bags, and other water-proof articles melted, decomposed, and were returned. Therefore resentment followed favor, and the rubber bubble burst.

Such conditions could not persist in connection with so flexible a substance. Men may come and companies go, but ideas grow in the minds of other men, who form new companies to carry on. Charles Goodyear, of New Haven, Connecticut, conceived it possible to dry up this sticky, melting, freezing material. Finally after years of effort, in 1839, he made a far-reaching discovery. He heated a mixture of sulphur, white lead, and raw rubber, and he observed a marked change of properties. This erstwhile softish, doughy substance became firm, and strong; it no longer hardened in cold weather or melted in the summer.

Even in the face of trials, failures, and discouragements, there are always a few men with vision enough to see and to support a new idea. So a factory was started in Springfield, Massachusetts, in 1841, to carry out Goodyear's idea. Here began the real rubber industry; for vulcanization, as this process of heating with sulphur was termed, is the one essential process even to-day. Without vulcanization, rubber as we know it would not be possible.

A little later, in England, and by wholly different means of experiment, Thomas Hancock in 1843 discovered the same characteristic displayed by sulphur and rubber; thus about simultaneously in England and America the modern manufacture of rubber goods began. A complete change had been brought about by Goodyear—a basic process discovered. How he did it and what he did are left for a later chapter. Yet so fundamental was this effect, and so intense his activity that for twenty-five years, from 1835, the history of the rubber industry is little else than the personal history of Charles Goodyear. An industry based upon a far-reaching idea now took shape. These enterprises that men create measure their periods by ideas and grow with mankind, provided the products they offer render useful service. Rubber could now capably serve; therefore growth was a natural consequence.

It is strange how men strive to reap where others sowed. I shall not here discuss Goodyear's troubles. Some men were pirates. His patent was infringed, but finally sustained. Then came many companies. Boots and shoes claimed almost exclusive attention of inventors and organizers for years.

The first rubber overshoes delivered into this country, in 1800, were made by the Indians on the banks of the Amazon River; but to-day the old shoes have given way to the new, and we are protected from the weather by "rubbers." Rubber boots have come to be a part of the fisherman's outfit, and short ones are used by lumbermen; the liveliness of our tennis matches is in no small part due to the flexibility, lightness, and firm grip of the rubber-soled tennis-shoe. Through vulcanization, rain-coats have changed from tin armor in winter and the melted clothing in summer to a permanent, light, flexible, water-proof, useful commodity.

In 1858 the trade in rubber products amounted to between four and five million dollars annually, and ten thousand men were engaged in the enterprise. The Roxbury company was reincorporated as the Goodyear Manufacturing Co., later to become, as it is still called, the Boston Belting Co.

There were many keen men of high purpose and a few pirates. But some notable companies were formed, and many of them are still producing. Three great rubber manufacturing centers slowly developed. There was the New England district where Goodyear began, and the New Jersey centers where several footwear factories began. A number of these companies combined in 1892 to form the United States Rubber Co. The district of Akron, Ohio, began in an equally small way in 1870. The start resulted from the belief in rubber of Dr. B. F. Goodrich and the enterprise of the business men of the district.

Were I at this point to trace the history of rubber goods development, the reader would observe a profusion of inventions offered to the Patent Office; and, characteristically, many of them were ahead of their time. Ideas were written down, disclosed, or kept secret; but no use was found for them until decades later.

Up to 1879, however, the industry strengthened; the value of the products amounted in that year to $25,310,000. It was truly an era of inventions and business development, for this chemical change called vulcanization had succeeded in making rubber sufficiently permanent to warrant labor by inventive genius here and abroad in the creation of articles.

In this period were developed the conveyor belts, which to-day are hundreds of feet long, serving to carry ore from crushers to furnaces for a large number of different purposes. These, together with the elevator belts, have become as essential a part of mining operations as the crushing machinery used in reducing ore to a state ready for furnaces. Rubber has paralleled other inventions. To-day, in the trains which carry us from point to point rapidly and safely, we find rubber in the insulated wire for the lighting, in the air brake, and in the steam-hose between the cars themselves.

The "hose pipe" invented by Hancock in England to replace the old leather hose for breweries has come down to us through this creative stage, and now the fire-hose has become a most essential development. We might well stop to think what would happen when fire-engines go shrieking down the street if there were no vulcanized rubber in the hose so necessary in the distribution of water to the conflagration. Fire prevention is one thing; but when a fire is started, hose that will not burst is an essential feature for rapid extinction.

One need not run through a catalogue to show how these early ideas have been carried down and improved for our use; that will be done with more detail in later chapters. I wish merely to anticipate and to mention, further, how large a part is played by rubber in sport, with its base-balls, golf-balls, tennis-balls, and billiard cushions; how in the home, floor-coverings, jar rings, garden-hose, fountain-pens, and other articles make life more comfortable. Even in 1899, these articles were so numerous that the industry had grown to the stature of $49,212,000 in the value of products.

In about that period began a noticeably rapid change. Since nothing has quite so greatly stimulated the imagination of business men as the possibilities of the automobile, there is no period of the rubber industry quite so filled with competition and with bubbles that have been blown and burst as the period from 1899 to the present time.

When you drive your automobile into the mountains, you give little attention to the part that rubber is playing in making your trip interesting and comfortable. If, however, a tire blows out and you are found fifteen miles from the nearest service station, you consider how necessary a commodity rubber has become at least to that particular expedition.

The rubber-tire part of the industry is now a giant; it serves to carry ten million automobiles upon forty million tires. Figures now astonish us, particularly as we look back and mark the change after even this short period of seventy-five years; for in 1914 the value of the products of the rubber industry had jumped to $300,994,000, and it produced in 1919 products to the value of $1,138,216,000, made by 475 factories.

This is the period of Akron's rapid advance. The enterprise of her business men expanded the B. F. Goodrich Co., and organized in 1898 the Goodyear Tire & Rubber Co., and in 1900 the Firestone Tire & Rubber Co., each of which has now grown to tremendous size, until into this city, to be used by over twenty rubber companies, comes more than one third of the total raw rubber consumed in the world.

During these stages of development the industry prepared for the world war, into which it threw itself with whole-hearted abandon. It is strange how war reacts upon the soldier in the interests of a common cause. The sensitiveness and secretiveness of youth gave way before the broader views of maturity. Competitive strife disappeared; the units of this maturing industry made balloons and compared notes upon the methods of construction. And it was rubber between two plies of thin fabric that held the hydrogen and kept the balloons aloft. Even in the big guns rubber gaskets were necessary in the recoil mechanism. The hospitals performed wonderful service, and rubber gloves, catheters, tubing, and water-bottles greatly assisted the skilled surgeons in the care of the wounded. Possibly the most notable service performed by rubber products lay in the gas-mask development—a romance in itself. The gas mask bids fair to become a defensive commodity of the greatest moment in the future.

You may find this industrial man not quite "the justice, in fair round belly with good capon lin'd," as after a large Thanksgiving dinner. We all enjoyed in the year 1919 the comfortable feeling of satiation. We have suffered the indigestion of youth from overindulgence. Money flowed into buildings and materials; however, that stage of growth is happily passing. The factories are ably managed, they have survived the shock of depression, and they go forward to a greater service to mankind.

The rubber industry is distinct in its principles of manufacture from any other. We are familiar with the metal group, such as steel and copper, in which chemical changes are brought about upon mineral ores, by which one substance at a time, such as iron, copper, or zinc, is produced. We know that each of them goes to the world in a variety of forms. This group is different from leather, for in that industry an animal product is altered by chemical change in a way that produces a tougher and more serviceable commodity, which later is worked up into a variety of forms. The manifold uses of cotton and the textiles come about from the mechanical purification of vegetable products and the weaving of them into sheets from which artisans create final forms without alteration of the substance which they modify. The great chemical industry, with its dye-stuffs, its caustic soda and sulphuric acid, its nitrogen products, begins its operations with two or more fundamental materials; and by the proper relations of time; temperature, and concentration it brings forth to us a great variety of new, different, and pure substances, each of which, as such, is used in a multitude of different ways.

The rubber industry is peculiar in that it brings together a large number of different animal, vegetable, mineral, and chemical materials. It chooses a number of these to be scientifically acted upon mechanically to produce a mixture. It then forms those mechanical mixtures into the approximate shape of a new and useful commodity. This then is heated to bring about the chemical change, vulcanization. As a result of vulcanization, each of these articles is capable of service.

Since by common practice the word "rubber" is not used in its original meaning, as describing the product from a tree, there has arisen a confusion in terminology. Most books and articles upon this subject have begun the story with a description of the preparation of the raw product, the early word for which technically came from the Indian term for the tree: *caa,* meaning wood, and *o-chu,* meaning to weep; hence, the word "caoutchouc." It is probably the rapid growth of caoutchouc products, called rubber before the discovery of vulcanization, which has led to the confusion; for to-day we speak of rubber products which have been vulcanized as "rubber." We also speak of rubber as meaning the raw unvulcanized material. Technically, therefore, "caoutchouc" means raw rubber; and "rubber" to-day means vulcanized rubber. Throughout this book the meaning will be evident in each case.

The rubber industry usually groups its products under the names: mechanical rubber goods, tires, footwear, clothing and proofed materials, druggists' sundries, and hard rubber. These classes will not be discussed, but rather the story will be written about certain particular ones, representative of the classes most frequently known and used. Each has a story of its own; each is interwoven with a romantic history from the old days down to the present.

Since raw rubber exists in a variety of forms and comes from a large number of different places in the world, since also its method of preparation and the story of its growth are chapters by themselves, since, likewise, vulcanization is the one fundamental process necessary to an understanding of the industry as it now exists, I shall not follow the order of chronology, but plunge at once into a discussion of the fundamental processes which have made the rubber industry possible. This will give us a basis of understanding, and the series of short stories of different rubber products will assume that the idea of vulcanization is known to the reader.

CHAPTER II

PROBLEMS OF A PIONEER

Our eyes are holden that we cannot see the things that stare us in the face until the hour when the mind is ripened.

—Emerson.

The struggles of inventors in attempts so to change the properties of raw rubber as to avoid hardening in winter and softening in summer are truly the stories of men who burned their fingers without realizing that fire was the cause. Several of them were close to the solution of the problem, and yet they passed it by. Their failures make one believe that "our eyes are holden that we cannot see" until discoveries may properly coördinate with others.

A knife cut into the bark of certain evergreen tropical trees permits a milky sap to flow. It looks like the juice of a milkweed or a dandelion. When it dries, there is left a brownish mass of a firm, tough substance. This is the same stuff that came to Priestley's laboratory and was called "Indian rubber." Frenchmen brought it to Europe, where many enterprising Englishmen studied it and the great Faraday analyzed it. Germans experimented. Thomas Hancock writes in 1856: "It is a singular fact that although this substance had attracted the notice of chemists from the earliest date of its importation into Europe, they failed to discover any means of manufacturing it into solid masses or to facilitate its solution." That is a damaging arraignment of chemistry, but we must remember that the era of the chemical engineer had not arrived. In those days the chemist was an analyst whose chief aim in life was to find out what things were made of, not to develop their uses.

The grand old man of rubber, Thomas Hancock, owned a private laboratory. Not satisfied with a day's work, he studied at home by night. He dissolved rubber in turpentine, and made many rubber articles. Charles Mackintosh, in 1823, at Glasgow, invented a process for spreading a rubber solution on two pieces of fabric and bringing them together under pressure; he thus created the double-texture, water-proof garment known even to-day as the mackintosh. Hancock developed a machine for softening raw rubber. He called it a "masticator," and his first experimental machine held one pound. He invented iron molds; and, with a brick oven constructed by a bakery-oven builder, he formed blocks of rubber under heat and pressure. A little later, in 1822, he developed steam-heated vessels and, several years after, a masticator capable of holding two hundred pounds. It is fate that heat was used by him, and that a little later sulphur played its part, but that he did not connect the two. In his most interesting description called "Personal Narrative of the Origin and Progress of the Caoutchouc or India-Rubber Manufacture in England," there were many difficulties and handicaps mentioned.

Hancock, however, was a business man. Despite the losses and the worries suffered through the effect of light in decomposing the caoutchouc, he continued to invent new uses for rubber and patented them. He made artificial leather by a combination of cotton and other fibers in a rubber mixture. Much trouble was occasioned when the tailors sewed rubberized garments together, for water crept through the holes made by the needles. Then, too, because the grease in the woolen cloth was absorbed into the raw rubber and destroyed it, many were returned. Hancock was fortunate in living in England with its equable climate; for the heat was not great in summer, or was the cold severe in winter. Consequently, the numerous products from his real inventive genius did not seriously interrupt his profits.

I have wondered why he did not employ a research laboratory. Although research in those days was not conceived of as in our generation, he was so far ahead of others that he might well have begun the practice. He may have reasoned, though, in the way many of our modern business men do, who seem to feel it advisable to reduce the appropriation for research laboratories during periods of depression. As a result, discoveries have been delayed and opportunities lost because of the lack of a little money expended for research at the right time.

Hancock was on the verge of a great discovery, but he lacked just the necessary something possessed by another. While Hancock worked in England, there was some activity in America. In 1833, in consequence of goods returned because they had melted in the heat of summer, the Roxbury India Rubber Co. was on the verge of dissolution. The firm had sent out products with nothing done to prove their value except the test of actual service; it has taken years to develop in the minds of men the fact that in fairness to the consumer tests of quality should precede sale. In the hot rains of August, rain-coats oozed rubber, while mail-bags fell apart, and letters were scattered. During zero weather the shoes sent from the Amazon became wooden, like the "klomps" of Holland. An unreliable article was the suspender in those days; perhaps that is why Americans came to prefer the belt to "galluses."

One day Charles Goodyear of New Haven, Connecticut, a man of thirty-three, passed by the New York store of the Roxbury company. He was not a business man, for he had failed in the hardware and farm implement business. He saw some life preservers. Because he could not help inventing, he designed a new one and returned a few months later to submit his sample to the clerk in the store. The clerk, wishing to do the enterprising Goodyear a service, confided to him the troubles of the Roxbury company. Placing a difficulty in the way of a genius creates the stimulus that ever has brought forth latent activity. Goodyear set to work. Cast into prison for debt, he shaped small test samples of raw rubber with a rolling-pin from the family kitchen. He mixed rubber with lamp-black, magnesia, and turpentine. With true research spirit, he submitted each of his mixtures to a weathering test in the open air.

A "presentiment of the future" spurred him on, until he became shabby and emaciated. His hands and clothing seemed to be covered continually with India rubber, and many of his friends tried to dissuade him by telling him that the India rubber business was now below par. At this time some one in New York was asked how he might recognize Mr. Goodyear. The reply was: "If you meet a man who has on an India rubber cap, stock, coat, vest, and shoes, with an India rubber purse without a cent of money in it, that is he." The friends who had backed him were ruined in the panic of 1836-37. By treating caoutchouc with nitric acid, he nearly suffocated himself in 1837. But nothing can stop genius.

When the officials of the Roxbury company offered to help him with the use of the machinery at their plant, he removed to Roxbury. Although his inventive genius was used in the production of better articles, the thought of using sulphur did not occur until 1838, when he became acquainted with Nathaniel Hayward of Woburn, Massachusetts, who was the foreman of the factory of a rubber company that had just failed. Hayward was a practical man. He had approached the discovery of vulcanization, but he had not found it. His contribution to Goodyear was a process for partly hardening rubber by spreading a small quantity of sulphur over the surface of the raw rubber article. Then the mixture was put in the sun to dry. His patent, which was taken out in 1839, was purchased by Goodyear; and Goodyear used it in the manufacture of life-preservers.

Goodyear was approaching the solution of the problem that so far had seemed the doom of the rubber industry. Several different tales have been told, each of which sets forth the accidental nature of his great discovery. Possibly the best way to bring to light the truth is to let Goodyear himself explain; this he does in that rare old book "Gum Elastic," published in 1853. I shall not use his exact words throughout, but I shall quote him sufficiently to indicate the creativeness of his mind and the research character of his efforts.

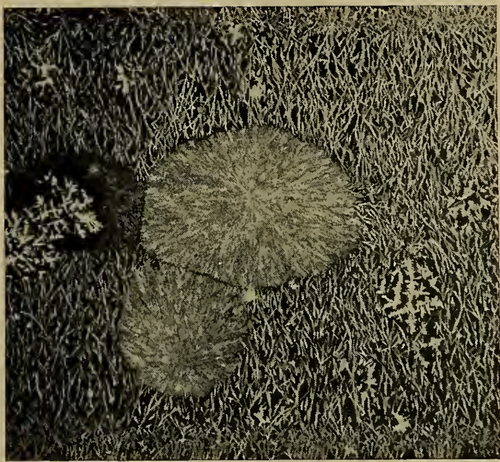
He was on a visit to the factory at Woburn, where he had met Hayward. At the dwelling there where Goodyear resided, he made some experiments to ascertain the effect of heat upon the same compound that had decomposed in the mail-bags and other articles. He was surprised to find that the specimens, being carelessly brought in contact with a hot stove, charred like leather. He, however, directly inferred that if the process of charring could be stopped at the right point, it might divest the gum of its natural adhesiveness throughout, which would make it better than the native gum. He was further convinced of the correctness of this inference by finding that India rubber could not be melted by boiling in sulphur at any heat ever so great, but always charred.

Other trials were made in which similar fabrics were heated before an open fire; and the same effect, that of charring, followed. "There were further and very satisfactory indications of ultimate success in producing the desired results, as upon the edge of the charred portions of the fabric there appeared a line or border that was not charred but perfectly cured." With characteristic ability, he then tried other methods of heating, including steam. That this discovery of curing rubber was no accident, he himself makes evident when he says: "While the inventor admits that these discoveries were not the result of scientific chemical investigations, he is not willing to admit that they were the result of what is commonly termed accident; he claims them to be the result of the closest application and observation."

The discovery of rubber vulcanization was made in January, 1839. Possibly the season was fortunate, because of the ease of performing heat tests near stoves on the inside and because of the severe cold for the weathering tests outside. But Goodyear had by no means finished; for after his years of want and misery, discouragement and lack of support, he then went on to the next stage, that of convincing people of the value of his invention and of protecting it from the aggressions of those who now claimed that it was not his invention at all.

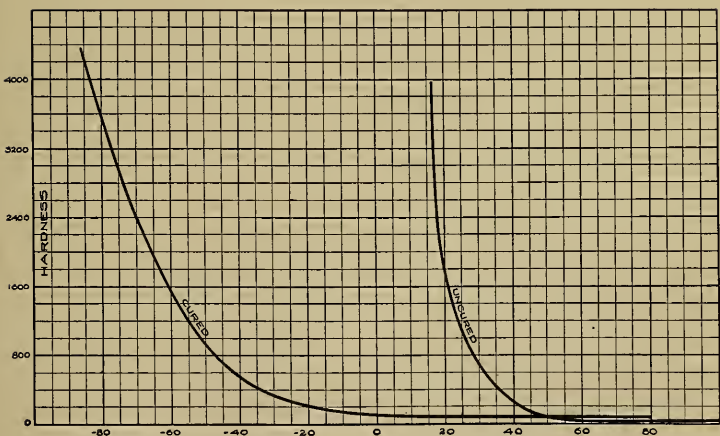
Dr. Baekeland has well written: "I believe it was George Westinghouse who reminded us that every successful invention passes through three stages: The first, when it is said: 'Such a thing is absurd or impossible.' The second stage, after the patent descriptions have become public and have given others the means to imitate and try to find loopholes in the patent claims, begins when it is said: 'The thing is not new.' And finally, after the usefulness of the invention has become so obvious and the details connected therewith have penetrated through the hard skulls of the laggards, then it sounds: 'There is no invention at all.' "

So human inertia held back Goodyear: it was 1841 before he convinced men with money, William Rider



Courtesy of The B. F. Goodrich Co.

A PHOTOMICROGRAPH OF SULPHUR CRYSTALS INSIDE A RUBBER SHEET



Courtesy of The B. F. Goodrich Co.

Temperature Degrees Fahrenheit

THE PHYSICIST'S INTERPRETATION IN THE FORM OF CURVES OF THE RELATION BETWEEN HARDNESS AND TEMPERATURE, SHOWING THE STRIKING DIFFERENCE BETWEEN VULCANIZED AND UNVULCANIZED RUBBER

and William DeForest of New York, of the value of his discovery. Shortly thereafter the factory from which the rubber industry in this country has sprung was started in Springfield, Massachusetts. Ever secretive, Goodyear was afraid of losing his rights; and while he obtained protection under a deposition of discovery in December, 1841, it was not until June, 1844, that the specification for his original patent was granted by the Patent Office at Washington.

Meanwhile, he had sent to England a representative to learn if the secret could be sold to the rubber manufacturers there.

Thomas Hancock here takes up the story, in which he describes how in the early part of the autumn of 1842 an assistant of his named Brockedon showed him some sample bits of rubber that had been brought over by a person from America. It was said that cold would not stiffen them and that they were not much affected by solvents, heat, or oils. But business men feared the idea of an inventor: the Mackintosh company told the agent that, as he could give no information, they could not judge of the merits of the invention and they were afraid that the product might not be capable of manufacture on a large scale, without a fresh outlay of money. Meanwhile, Brockedon, being interested in stoppers for beer-barrels, was impressed with the suggestion; he gave samples to Hancock, who at that very time was engaged in a study of methods by which rubber goods could be divested of their adhesiveness and made more permanent.

Hancock took the usual industrial competitive point of view and set to work "to match the competitor's samples.'' Those of my readers who are chemists in the rubber business, will recognize this as one of the daily demands made upon them; they may be cheered in realizing how this system has been handed down from the early days. We rubber men are victims of our circumstances; every one of us pulls, bites, and smells new samples. Hancock was no exception. He found in the samples strength, resistance to heat and cold, and a slight odor of sulphur. To solve the secret of the new compound, he heated raw rubber in molten sulphur. For a second time the sulphur-caoutchouc combination was effected by heat. Hancock promptly patented his discovery in England in November, 1843. His assistant, Brockedon, termed the process ''vulcanization.'' Thus, an American discovered the process; an Englishman named it; all the world has come to use it.

Goodyear had made the short indispensable step in rubber manufacture; yet his discovery was the objective of pirates, infringers, and guerrilla warfare. His claims, however, were sustained by litigation; Daniel Webster was his counsel, and Rufus Choate was the lawyer for the defendant. These legal controversies resulted in establishing clearly Goodyear's priority and led to the extension of his patent for seven years from June, 1858. As Judge Grier, in giving judgment in 1864, stated: ''Envy robs him of the honor, while speculators, swindlers, and pirates, rob him of the profits. Every unsuccessful experimenter who did, or did not, come very near making the discovery, now claims it. . . . Every man who has made experiments with India Rubber, sulphur, lead, or any other substance; who has heated them in a stove or furnace; who has annoyed his family and his neighbors with sulphurous gas; who has set up a rubber factory and failed; who has made India Rubber goods that no one would buy, or if bought, were returned as worthless, are now paraded forth as the inventors and discoverers of vulcanized India Rubber. . . . We are of the opinion, that the defendant has most signally failed in the attempt to show that himself, or any other person, discovered and perfected the process of manufacturing vulcanized India Rubber before Charles Goodyear."

Poor man, he died in New York in 1860 with debts of more than $191,000. A brilliant mind, a persistent worker he was, but a life of trouble was his. He was not a money-maker but an investigator. He never belonged to any of the so-called "Goodyear companies," or has any member of the Goodyear family since his death ever been in the rubber business. The name became a trademark. When his estate was finally settled, the debts were paid and a comfortable fortune was left to his family. But, despite that, there ended pathetically one of the greatest names in inventive history. Emerson has written: "Every action is measured by the depth of the sentiments from which it is produced." Goodyear's persistence and his ability, the depth of his driving force, gave to the world the basis from which has sprung this tremendous industrial development of rubber. Thomas Hancock, with that fairness so characteristic of the English, acknowledged him to be the discoverer.

Goodyear was a persistent investigator. He not only discovered the fact of the rubber-sulphur union with heat, but he developed the range of temperatures from 212° to 350° Fahrenheit, within which vulcanization can occur. Further, he observed the necessity for removing the material at the end of a suitable time. And to-day the properties of rubber obtained from vulcanization depend upon the amount of sulphur and other substances in the mixture, the temperature at which the mixture is heated, and the time during which it remains under the influence of heat. The whole of rubber compounding practice, which will be discussed in another chapter, is purely one of adapting different materials, different amounts, different times, and different temperatures to accomplish definitely sought properties.

Sulphur is as important to the rubber industry as rubber. For while other substances have been found which, adding themselves to rubber, vulcanize it, sulphur is the only one that combines cheapness with the ability to produce high qualities in the resultant vulcanized mixtures.

CHAPTER III

FUNDAMENTAL METHODS AND MACHINERY

The entire rubber industry can be summed up thus: It is the business of making and vulcanizing mixtures the chief ingredient of which is raw rubber. Cotton fabric is necessary to give strength and shape to particular articles, but there would be no rubber goods without rubber mixtures. Mechanical processes serve to form the articles with speed and precision, but mixing is the fundamental process. Even were rubber and sulphur the only substances employed, it would be necessary to have machinery of some kind in order to incorporate this dry powder, sulphur, into the tough raw rubber.

Rubber is a plastic; it is a body that when pushed does not break, but yields slowly. If a block of raw rubber is placed upon a table under a heavy weight, it gradually settles to a position of balance; that is, it settles until the resisting forces of the rubber counterbalance the downward pressure of the weight.

This plastic nature of rubber makes it possible for us to mix substances into it. The earliest known machine used in any type of rubber manufacture was a mixer, called a "pickle" by its inventor, Thomas Hancock. In his early days, about 1820, Hancock was engaged in the matter of elastic fastenings for garments. He made springy stockings and elastic gloves.

In the course of his work, he accumulated considerable quantities of scraps. He also made elastic bands of rubber by cutting up small thin bottles imported from South America. These bottles had been made by evaporation of the latex upon forms. With the cuttings to save, Hancock cast about for some means of forming them into uniform pieces. His first step was to procure a hollow punch an inch square and to cut out squares of rubber. He then tried pressing the pieces with a plunger in an iron mold. These ideas seeming not to succeed, he invented the first mixing machine.

This machine was simply a hollow, round box of wood, with a crank for a handle and spikes upon a cylinder revolving between spikes in the wood about it. By these means, he was able to tear the rubber into small threads. If the cuttings were previously heated and the action was continued long enough, they gradually worked up into a homogeneous mass. Seeing the success of his experiment he went to a firm of machinery builders in England and had them make for him an iron machine of the same character. The improved apparatus he kept a deep secret until about 1832. Continuously the active Hancock improved and developed this hollow cylinder affair, making it larger and larger and driving it by horse-power. The earlier name "pickle" was shortly changed to the more expressive designation of masticator or masticating machine. The old pickle was slow. Hancock had one made to hold 180 to 200 pounds, but it did not mix dry powders and raw rubber with speed and accuracy.

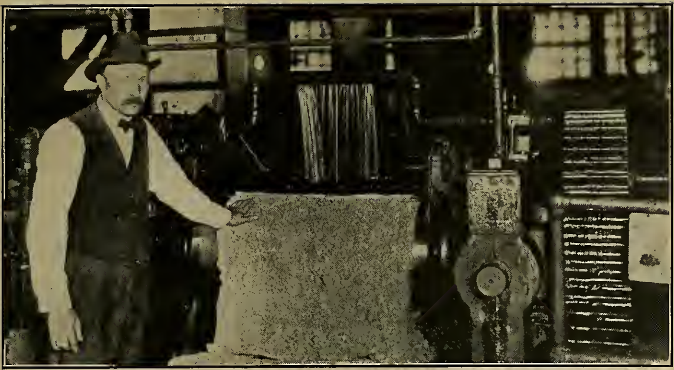
But let us go on to the processes of the modern rubber factory and follow them along. To-day raw rubber comes chiefly from plantations, clean and ready for the first step in the manufacturing operation. There are, though, scraps from the trees and "wild" rubber from South America. These grades are dirty and wet. Therefore each factory needs a wash-room where the dirty raw rubber may be cleaned. The clean raw rubber needs only inspection. As each sheet is separated from the other sheets in the box, it is easily brushed free from any chips or foreign matter that may have been picked up in the course of transportation.

Because the wash-room employs heavy machines, hot and cold water, and steam, it is a sloppy, wet, dirty department. The workmen, in rubber boots and aprons, throw the solid bales or lumps of crude rubber into tanks, slightly to soften it with warm water. Then pulling apart the sheets of baled plantation rubber, they pass them between the two rolls of the washing machine known as a cracker. The two steel rolls, placed horizontally and parallel to each other, are corrugated; and they, to loosen the dirt, grind the sheets in contact with water. The washer, the next machine, has smaller corrugations cut into the rolls, which bite into the rubber and bring to the surface any foreign particles, which are washed out in the stream of water that constantly runs upon the mill. A step at a time, the sheet is corrugated more and more finely, or "creped," while new surfaces are exposed to the washing action.

There are several different kinds of washers, such as two-roll washers and three-roll washers, inclosed washers, tub washers, beater washers, and various others. But let us go along from the washing room to the next step, which consists in drying the rubber. Before any other substance can be mixed with rubber, it must be dry.

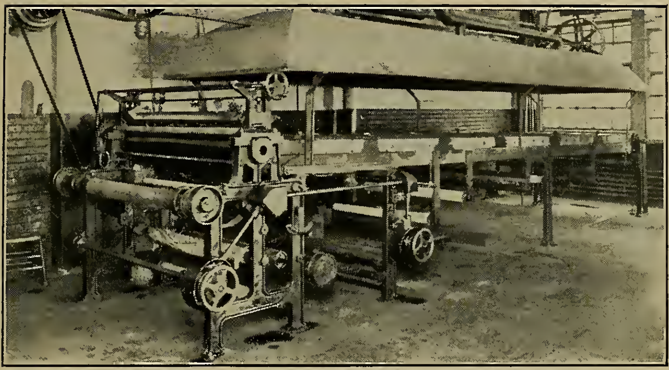
The wet sheets, which are probably one sixteenth to one eighth of an inch thick, about twenty-four inches wide, and vary in length from six to fifteen feet, are taken on trucks to the dry room. Several different methods of drying are used. In the old days, these sheets of rough-surfaced rubber were simply hung up in a room and allowed to dry over a period of time varying from two to six weeks, since raw rubber does not lose its water so rapidly as cotton cloth. They were never hung in the sunlight as we do clothing. In bright light, raw rubber oxidizes and spoils; therefore the dry room must be dark and free from smoke and dust. Because inventors dislike any six-weeks long process, to speed up drying they forced the air in by fans and carried it out by exhaust. Six weeks dwindled to one.

Then came a German invention, the vacuum chamber, into America, with still more rapid but safe drying. The vacuum apparatus is nothing but a metal chamber with hollow steam-heated shelves in it. The rubber is laid upon trays, slid in upon these shelves, and the door closed. By means of a powerful vacuum pump the air is exhausted. Steam is turned into the plates, and the rubber is heated to a much higher temperature than that used in the air drying rooms. In the presence of a vacuum, though, the danger of deterioration by oxygen is avoided. The temperature



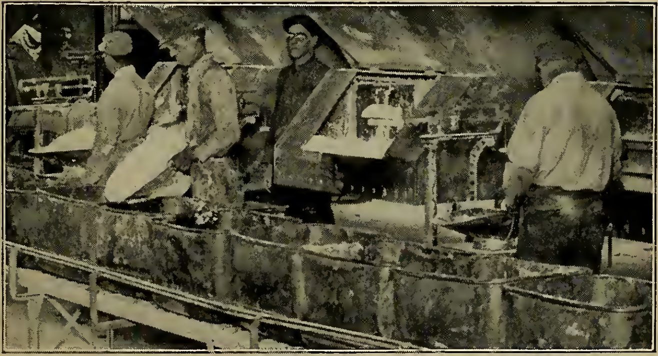
Courtesy of The B. F. Goodrich Co.

WASHING CRUDE RUBBER ON A WASHING MILL



Courtesy of The B. F. Goodrich Co.

A SPREADING MACHINE FOR COATING RUBBER CEMENT UPON CLOTH



Courtesy of The Firestone Tire & Rubber Co.

WEIGHING OUT COMPOUNDS IN THE COMPOUND ROOM OF A RUBBER FACTORY

may now be raised considerably higher; and since water evaporates more rapidly in a vacuum than in the open air, the time required to remove the water from the rubber is reduced to two or three hours.

But the vacuum drier did not seem wholly satisfactory for all types and kinds of rubber and for all purposes. In recent years, there has been another method that has entered into rubber manufacture, that of drying in the presence of moist air. It seems a bit singular to dry anything in wet air. Nevertheless, the method, with several systems of rooms in which rubber is placed on racks or trays, has been successfully used. The raw rubber dries in twenty-four hours. Really the air is only relatively wet. The water passes to the air because the air is drier.

Many advocates of each of these systems of drying are found in the rubber industry. Each system is valuable for different types and grades of rubber to be used for various purposes. We are, however, here interested more in the fact that after the rubber comes out of the sloppy wash-room, it is dried before it goes into the next stage in the process of its manufacture.

Now our rubber, whether of one grade or several, is ready for the weighing-out of the mixture. Here we step into the holy of holies of the rubber factory. From the beginning of the industry, rubber plants have carefully guarded the composition of their mixtures; they are the recipes of the business. Each one of them is made for a particular purpose. Since every rubber factory is convinced that its own formulas are better than the formulas of any other, each guards its recipes as something sacred. So careful are they, that the recipe, as it issues from the laboratory to this weighing-out or compounding room, must needs be divided up into different parts by the chief compounder or confidential man. The grades and quality of rubber to be used are written on one card, the dry pigments on another, the reclaimed rubbers on still another, and the sulphur on a last one.

In the compounding room the final work of the chemists really comes into play. In this part of the factory great accuracy is required. To be sure, if the manufacturer happens to be a rubber man of the old school, he may call his chemist into the private office and tell him how in the early days there were no chemists and no laboratories. He may even try to convince him that powders were measured by the bucket and rubber by the yardstick. But because the demands made upon rubber goods have become more and more exact, greater accuracy is required at the present time.

Care is necessary in preparing these various substances other than crude rubber. The dry pigments must be sifted through fine silk screens free from foreign ingredients. The coarse particles, the chips from the bales, or any other accidental substances are thrown into the scrap-heap. The compounding room is one of the places in the rubber factory where purity of substance is accomplished. Obviously, there would be tremendous irregularities in rubber composition were the scales not exact upon which these substances are weighed. At regular intervals, standard weights are taken about the compounding room; and each set of scales is adjusted. Although there have been some efforts made to develop automatic scales to weigh the right quantity of a single substance for each of a large number of batches, up to the present time none of them seems to have come into sufficient use to warrant its being considered as accurate or reliable.

In the best of the compound rooms, the powders, after sifting, are automatically dropped through the floor into metal hoppers, each containing its own particular pigment. From these bins, which are placed side by side, the operator weighs out the proper ingredients. Conveyor systems are used for handling the boxes, so that the pigment boxes and the rubber boxes move systematically from one end of the room to the other, each receiving the correct quantity of the right substances. When these various substances are accurately weighed and placed in their respective boxes, they are conveyed down to the mixing room, or, as the rubber man terms it, the mill-room.

We speak of the masticator, the mixer, or the mill. By common consent, a rubber mill is considered to be that particular piece of machinery upon which the various ingredients of a compound are mixed together in form for the next step in the operation. Edwin M. Chaffee, one of the pioneers of the American rubber industry and a co-worker with Charles Goodyear, was the inventor, in 1836, of the first iron-roll, steam-heated rubber mixer. It was a different machine from Hancock's, for Hancock kept his rubber inside a chamber. Chaffee had his rubber outside, but in such fashion that it was compressed between two rollers. From the original Chaffee mixer to the modern mixing machine is not a great step in fundamental principle, and Chaffee may be considered the father of rubber factory machinery.

Of different sizes, the largest of these machines today consists of two mixing rolls, twenty-four inches in diameter and eighty-four inches long, set in a heavy frame, and made from either chilled or dry sand iron. One roll has a driving gear operated by a pinion on the shaft underneath, on one side. On the other end of the drive-roll is a gear which meshes into another gear on the end of the front roll. These gears are of different sizes, to give friction or different speeds to the rolls, so that there is a wiping action upon the rubber as it passes between them. This wiping action seems to be efficient in forcing the dry powders into the plastic rubber. Set beneath each of the mixers is a metal pan; for when the rubber is being masticated and mixed, not all of the dry pigments remain on top or go immediately into the rubber. A good deal falls through into the pan; and the operator, with a brush and a shovel, gathers this up and shovels it from time to time to the top of the mill.

Let us go down into the mixing room and see how a batch of material is mixed. Stand in front of this piece of machinery. The speed of the rollers is not high,—only a matter of fifteen to twenty revolutions a minute,—but one gets the impression of great power. Our operator, standing in front of his mill, picks the rubber out of the boxes; and, placing it in position on the upper side of the moving rolls, pushes it so that it is caught and drawn in between them. With a powerful action, with grinding and screeching, with the bursting of little blisters as they form, the rubber is carried between these two rolls and broken up into various large chunks. An automatic mechanism known as an "apron" brings the rubber that falls between the rolls up again to the top, where the operator pushes it once more over into the space between them. He is protected against accident by an automatic tripper. If he leans his hand against the tripper, the motor will be disconnected from the mill and the resistance of the several mills on the same shaft will cause them all to stop. So our workman, without danger, protected by the best of safety devices, continues to see that the tough, cold rubber is sent back through the rolls.

You observe how the rubber gradually softens; it begins to smooth out in spots. The noise and creaking of it subsides, until, after ten or twelve minutes, it is smooth and clings to one of the rolls sufficiently so that it goes around in the form of a sheet the thickness of the space between the rolls, usually about three quarters of an inch. A little excess of rubber known as a "bank" stands on the top between the rollers.

Then the rubber is masticated. It has been softened by the friction developed by the two rolls running at different speeds, by the heat generated, and by the mechanical working. When it is thus softened, it is ready to have the dry pigments added. The operator now shovels the dry pigments from the compound box, in which the mixture was brought down from the compounding room, upon the upper parts of the rolls. Some day all rubber mixing apparatus will be equipped with automatic mixers. The workman shovels the other substances upon the rubber, without knowing what they are, where they came from, or their quantities. Quickly the masticated rubber, as it comes around, catches up a coat of dry pigments. Since it takes a little time for the rubber to absorb these substances, much of the pigments slips through and is not pressed into the rubber.

Rubber is a peculiar material; it cannot be quickly forced as machines can force brass or steel; it yields, and then returns to its original position. It seems to have a temperament; it can be guided, but only slowly driven. Therefore the workman shovels on the pigments at about the rate that the rubber wishes to eat them up. The sheet on the rollers looks streaked and irregular. After five or ten minutes more have elapsed, though, all the dry pigments will have disappeared; but the rubber still seems grainy, like wood. At this point it is probably in its most critical state, so far as uniformity is concerned. If this batch in its present condition were to be taken from the mill, it could not yield a product of good quality. There would be more powder in one part of it than another. The sulphur would probably be concentrated at one end.

The workman is obliged now to perform the final but most necessary operation, that of true mixing, which he does by what we call "cutting back and forth." With a sharp knife and the skill born of experience, he cuts his rotating, thick, slow-moving sheet of rubber, so that a long strip probably a foot wide is removed from one end of the roll. This strip he quickly throws over across the roll; thus he transfers a portion of the rubber from one end over to the other end. When that has passed around, he cuts from the other end a similar long strip and throws it back in the opposite direction. In this way, different parts of the batch are removed from the places where they were and are put in contact with rubber in other parts of the batch.

The operator is now a busy man, for he cuts and throws these big ribbons over against the sheet. Back and forth, back and forth, on a large-scale operation, he acts as the druggist when he mixes his pill powders, or the housewife when she mixes bread; he intermingles all parts of the batch. The rubber is now soft and hot. Temperatures of 180° to 200° Farenheit are generated by the heat of friction, despite the fact that a stream of cold water is forced into the hollow cavity of these rolls for the express purpose of regulating the temperature of the mixture. So high is the heat of friction that if the rolls were not cooled, the composition would partly vulcanize while mixing. We call this "semi-vulcanization" or "scorching." Because the mill-room operators must constantly guard against scorching, cold water has come to be a necessity in the rubber industry. I do not mean ice-cold water. That would be too cold. In the economics of the rubber industry, the location of a rubber factory where good, cool, water, and plenty of it, is found, is as fundamental as that of a location upon a railroad.

The technique of mixing is varied; it is one of the skilled operations of the rubber industry, compositions of different character requiring variation in handling;

and the temperature of some naturally rising higher than that of others. It is interesting to those who follow the details of the history of the rubber industry to observe how within the last few years inclosed mixing machines have gradually come back into use. The first Hancock masticator was an internal machine, and the Chaffee was made on the external principle. In a limited way, we now again mix in chambers by the internal action of the rotating parts; this action softens the rubber by working it against the side of the shell that incloses it.

When our workman is finally satisfied that the rubber is thoroughly mixed with the pigments, his next step is to remove it from the mixing machine. This he does by cutting a large sheet from the masticator as it rotates in front of him; he then throws it by a quick movement upon a cooling-table. Here it is allowed to stand for an hour or two until it is cooled sufficiently to avoid a scorching tendency. From this place, it is transported to the storage room, or into the factory where the next operation is performed.

It we take a trip around the plant, we logically go from the mixing room to the department where the rubber is made ready for the forming operation. In the old days, the mixed rubber was dissolved and then applied upon fabric by means of a spreading machine. This machine was constructed to permit a sheet of cloth to pass over a rotating cylinder, above which hung a flat metal bar called a knife or doctor blade. The blade was accurately adjustable. So close could it be set to the fabric that it permitted only a thin film of solution to pass between it and the fabric.

Thus a thin layer of rubber cement could be applied to cloth.

One day in 1835, Mr. Chaffee went to the directors of the Roxbury company, saying he could save them the expense of the solvent that they had been using by the old process, which, by the way, cost them about fifty thousand dollars a year. He was instructed to build the necessary machinery. The invention of the calender machine resulted.

His coating machine was called the "monster" or the "mammoth," on account of its dimensions. It weighed about thirty tons, and was finished toward the end of the year 1836 at a cost of thirty thousand dollars. The Roxbury India Rubber factory purchased from Mr. Chaffee his entire interest in the "monster." But during the month of October, 1843, the huge machine was sold at a public auction for only $525 to John Haskins, who at the same time purchased a patent on it for $1.50! During the year following, 1844, Haskins disposed of the "monster" to Charles Goodyear, who later transferred it to the Naugatuck India Rubber Co.

A calender is simply a machine with three or more heavy steel rolls set parallel to each other, in such a way that when the soft, warm, unvulcanized rubber mixture is fed against the space between two of the rolls it will be forced between them in a thin sheet. This is called a sheeting calender. Likewise, when it is desired to apply rubber to cloth, cloth is drawn between the rolls, which are separated far enough so as in no way to crush the fabric, and which push the soft rubber into and around the threads. This is termed a "friction calender," and the operation "frictioning." In the parlance of the trade, we speak of the compound as the "friction" and the cloth as "frictioned fabric." In other machines, the cloth, after frictioning, can have a coat or layer of rubber applied upon it. For tire fabric purposes, we are accustomed to speak of "friction and coated fabric," or "friction and skin coat."

If in the calender room we stand in front of one of these machines, which are from seven to ten feet high, we find masses of rubber compound, as they run from the rolls, taking the shape of sheets. To keep them from sticking to each other, they are wound up with cloth or "liners" to separate them. The sheets issue from the machines at considerable speed, and are whirled into rolls, which are carried to the various other parts of the factory on hand-pushed or electric trucks.

Many other machines are employed to make particular articles in the rubber industry, but those described are the essential ones.

The manufacture of rubber goods may be likened to a tree. Thousands of materials—raw rubber, powders, sulphur—are the roots. These are combined in the trunk, through a few basic methods. The mill-room, where mixing is done; the calender room, where the first process of forming is accomplished, are the steps essential to manufacture. The final step of forming and, last of all, vulcanization, are carried on in the several divisions of the factory within which the special articles are produced. They are the branches of our tree.

Rubber mixtures are the basic materials; the chemist formulates them; cotton cloth and these mixtures are put together in forms and shapes by the designing engineer who creates articles; and, to manufacture them expeditiously and uniformly, the inventor and production engineer must invent and use many kinds of machinery. The rubber industry, therefore, stands on three legs; the mixture, the design, and the machine —each essential.

CHAPTER IV

THE RUBBER MAN'S COOK-BOOK

Oh, I am a cook and a captain bold,
And the mate of the Nancy brig,
And a bo'sun tight, and a midshipmite,
And the crew of the captain's gig.
—Gilbert: "The Yarn of the Nancy Bell."

The old-fashioned rubber superintendent was a versatile chap. From dawn on, there came to him for decision essentially all the manifold problems of the rubber factory. Personally he selected the laboring men; he was the power engineer, and if the coal was bad, it was his duty to keep the plant running. He figured costs and made prices. A chemist also, he wrote the formulas or recipes for the various mixtures used in the goods manfactured. He was even the first-aid doctor; since in the early days machinery was not surrounded by the safeguards that we find to-day, and many a man whose hand was caught in the mixing mill was carried to the superintendent's office for first-aid dressing. In many cases, he was a salesman; and he certainly was the production driver. As both an inventor and a promoter, he labored. Truly those were strenuous days for the superintendent.

I once talked to one of those men, long since retired from active participation in rubber factory work. He told me how the mixtures of rubber, which we call by the name of "compound," were studied in his office. By means of a little piece cut from a sheet with a pair of shears, he tested the quality. This fragment he twisted, pulled, and worked in his fingers. Finally allowing it to come to rest, he examined it, to see how much longer it was than the original piece from which it was cut. The ease of pulling, the "feel," and the additional length were prime factors in determining the quality of a particular mixture. Even teeth were trained to bite pieces from a specimen, the resistance to the bite being a measure of its strength. A testing laboratory was ever with him in the form of fingers and teeth.

Those old formulas were clouded with secrecy. In the compounding room were employed only most reliable men, known for honesty and loyalty. A recipe was a great secret of master importance. Before long, however, ambitious youths came to realize that quality as produced by good formulas was the basic principle on which the success of a given rubber plant was built. Therefore many of them left, taking with them the secrets; and competition rapidly grew.

To-day, with the coming of the chemist, a different tone has been given the industry; no longer does the rule of thumb method apply. No longer is it necessary for competing institutions to worry much about the compositions used in the factories of each other. There has come in these recent years a fuller understanding of why various materials act in particular ways when used in rubber mixtures. The chemist, the physicist, and the engineer have brought real knowledge into rubber making. To promote such knowledge, each of the larger rubber companies has organized laboratories, in which highly trained chemists study new materials and, as a basic function of such study, learn how each material performs in a rubber mixture. There are testing laboratories, too, where each rubber composition may be studied and where each new product may be tested in terms of actual service.

The rubber that you see in the form of a rubber band, the heel that you wear upon your shoe, or the tread of a pneumatic tire, is not just a simple vulcanized mixture of rubber and sulphur or is it so simple a composition as the combination of rubber, sulphur, and white lead used by Goodyear. The compositions are much more complicated than they formerly were. In the course of the evolution of this industry has come a revised point of view, so that to-day each substance used in a mixture is there for a particular purpose.

The field of substances from which the rubber chemist chooses those for any desired compound is extensive. In one of the large rubber factories, five hundred raw materials, known as pigments are used. Pigments are dried powders, such as zinc oxide, litharge, whiting, barytes, clay in various types, carbon black from natural gas, and so on through the long list. Even crude rubber has ceased to be of one or two grades. It has become fifty different types, with different sources, methods of preparation, degrees of hardness, physical properties, and workability. The factories use between fifty and one hundred grades known as reclaimed rubber, which is the result of processing previously vulcanized rubber products that have ceased to perform their usefulness—scrap tires, old shoes, and the like.

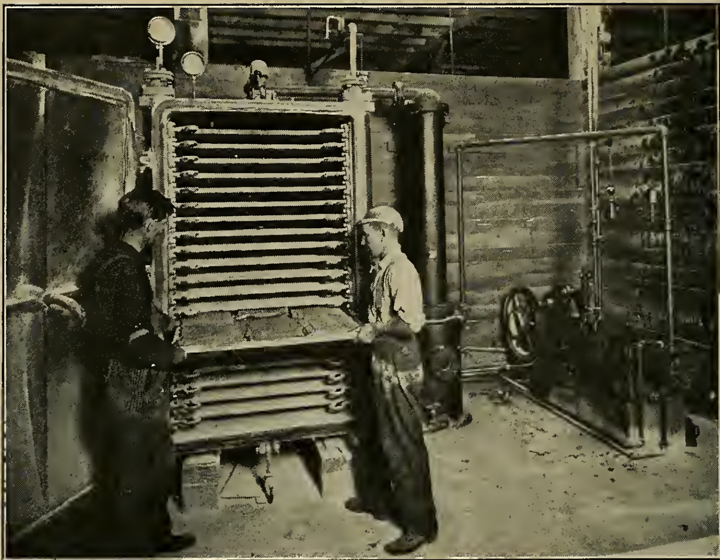
The rubber chemist, therefore, has come to know intimately many thousands of materials. Like a good cook, he must understand by experience what each one will do in his mixtures; and, like a highly scientific investigator, he must know accurately if the results will be worthy of production and sale. In the refinement of his business, he has become, therefore, a sort of highly sublimated chef; and his formula books are the cook-books of rubber.

Let us follow the work of the rubber chemist. He operates quite differently from the cook in the home; for, if she has something new to make, she works it out in the form of a real mixture on the kitchen table, putting in a pinch of this and a little of that, using her experience as a guide. In the rubber laboratories, systems have been developed so that the chemist does not himself weigh out his mixings; instead, he writes his formula or recipe in his office. Here are his books of reference, his samples of raw materials. If we follow the formula written by this chemist from his office through the various changes of its manufacture and test, we shall go to a laboratory, in which are little machines the same in principle as those in the great factory. Here we obtain the fundamental information that is expressed on larger scales in tires, shoes, and other articles.

Our chemist may show us how he would make an inner tube for an automobile tire. Inner tubes must hold air, and be soft and flexible. They must stretch with relative ease without tearing. A typical formula would probably be: rubber of the highest grade, one hundred parts by weight; sulphur powder, five parts by weight; zinc oxide, three parts by weight; and an accelerator such as hexamethylenetetramine or, as the doctor knows it, urotropin, one half of one part by weight. Written on a card, this formula is sent into the laboratory compounding room. In this room works the reliable old employee, who accurately weighs these ingredients and places them in a tin box that is carried out into a room where operate a number of little mills, calenders, and vulcanizers.

Were our formula to be mixed on the full factory scale, it would have appeared, before that process, very much as it does in the photograph.

For purpose of test, it is customary in the laboratory to vulcanize such a compound in the form of a sheet. In the photograph of the hydraulic press you will notice two flat plates or platens with a little table attached to the lower one; this is moved up and down by hydraulic pressure. Upon the table lies a mold, which is, in point of fact, a simple metal frame, made to retain within a definite length, width, and thickness the rubber to be vulcanized. The workman removes the rubber from the mixing mill for testing purposes in the form of a sheet of fixed thickness a little more than that required in the mold. After he places the cover upon it and slides it in between the two press plates, he turns on the hydraulic pressure; then the mold is squeezed, and the soft rubber compound fills the cavity of the mold. Rubber, being a soft plastic and flowing slowly under pressure, is not melted as



Courtesy of J. P. Devine Co.

DRYING RUBBER IN THE VACUUM DRYER

Courtesy of The Hunter Dry Kiln Co.

DRYING RUBBER IN THE AIR DRYER

iron is melted when cast into various shapes in the foundry. If we were to try to melt it, a useless product would result. In the mold there is always a little extra volume of rubber, which flows out into grooves and which we call the overflow, rind, or flash. This overflow insures uniformity of pressure and vulcanization in a solid, unblemished piece.

To furnish heat, steam is passed through the hollow platens or the plates of the press. The particular composition that we are discussing would probably vulcanize in forty-five minutes, with press plates at a temperature of 290° Fahrenheit. To be sure, an inner tube would not be cured between plates in this way; the formation of a tube we shall discuss in another part of the book. In performing a test to determine the properties of this composition after vulcanization, the chemist would not simply pull it by hand, as the old-time superintendent did. He might, it is true, observe differences in the amount of force necessary to pull out such a piece a definite distance; but such a test would not give data accurate enough to distinguish between compositions of various kinds, with materials in different proportions. Therefore the rubber chemist, after removing the vulcanized rind, takes his cured piece into the testing laboratory.

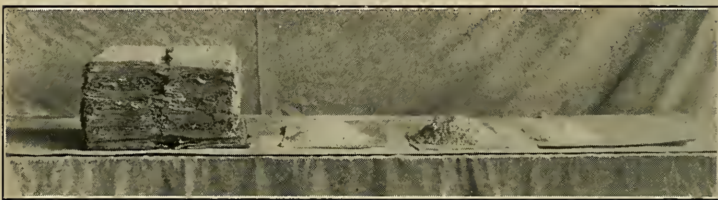
Here are machines and apparatus designed particularly to test rubber. Since rubber stretches to a greater degree than any other known substance, we must allow for length of pull in our test machinery. Steel stretches but fractions of inches before it breaks; rubber, six, eight, to ten times its original length. It thins down as it elongates. Specially made jaws automatically contract against the piece of rubber to be tested and prevent it from slipping out.

Let us watch the test piece in the laboratory. On the machine there is a dial to indicate the number of pounds required to pull the piece a definite distance. The operator marks lines two inches apart upon the piece. When the rubber breaks, the distance of separation of these two marks gives him a definite figure that he calls elongation, or stretch.

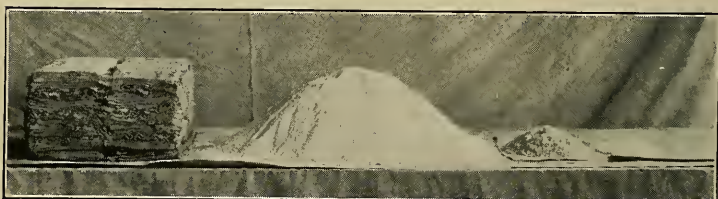
Of late years, the chemist has been accustomed to draw a picture of the course of this testing. As you stand in front of the machine, you will notice at once that the rubber piece stretches considerably with but little increase in the number of pounds indicated on the dial or the chart; but that after it has stretched a considerable distance, it resists more and more further distortion. The little picture being drawn will show us the force required to do the stretching. Known to the chemist as the "stress-strain," or "force-stretch" curve, it portrays the relation inch by inch between the elongation of the rubber and the force producing it. Thus rubber writes its own autobiography, from the reading of which our rubber chemist is able to determine a good deal of its value; he is able to determine particularly the differences in the values of substances to be used in the mixings.

In the formula an "accelerator" is used. Let us concentrate our attention upon this substance for a moment. Charles Goodyear might not have succeeded in taming rubber had he not used in his mixture a mineral powder known as white lead. Without white lead, the mixture would have taken so much longer a

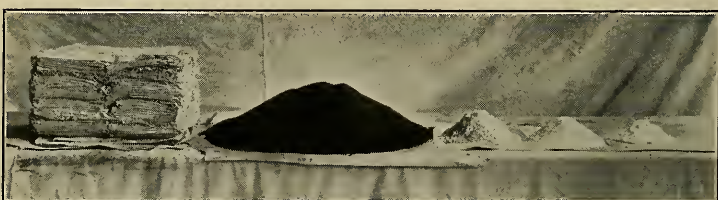
A WEIGHED-OUT RUBBER MIXTURE CONTAINING 100 PARTS RUBBER, 8 PARTS SULPHUR



A WEIGHED-OUT RUBBER MIXTURE CONTAINING RUBBER 100 PARTS, ZINC OXIDE 3 PARTS, SULPHUR 5 PARTS, HEXAMETHYLENETETRAMINE 1 PART

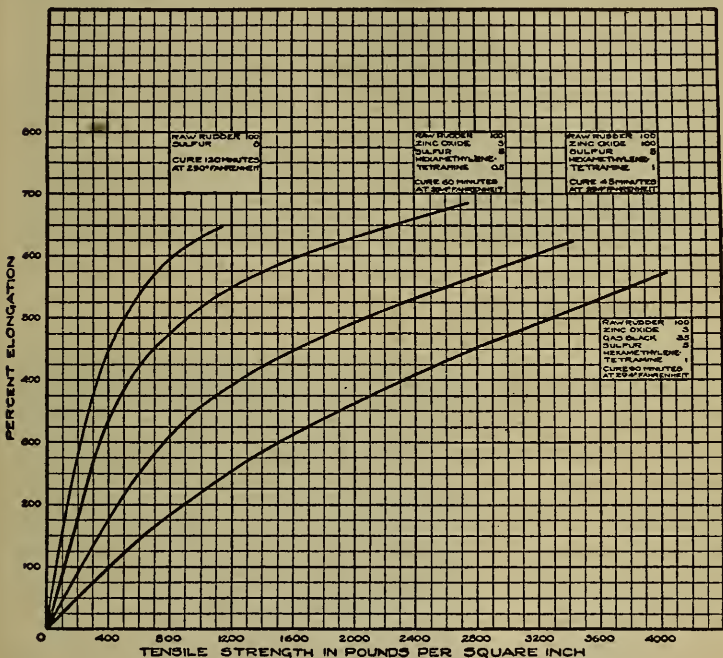


A WEIGHED-OUT RUBBER MIXTURE CONTAINING RUBBER 100 PARTS, ZINC OXIDE 100 PARTS, SULPHUR 5 PARTS, HEXAMETHYLENETETRAMINE 1 PART



Courtesy of The B. F. Goodrich Co.

A WEIGHED-OUT RUBBER MIXTURE CONTAINING RUBBER 100 PARTS, GAS BLACK 35 PARTS, ZINC OXIDE 3 PARTS, SULPHUR 5 PARTS, HEXAMETHYLENETETRAMINE 1 PART time to vulcanize that he might not have observed, at least so quickly as he did, the change in the properties of the rubber. Because white lead when used in a rubber mixture shortens the time of vulcanization, we call it an accelerator. The combination of raw rubber



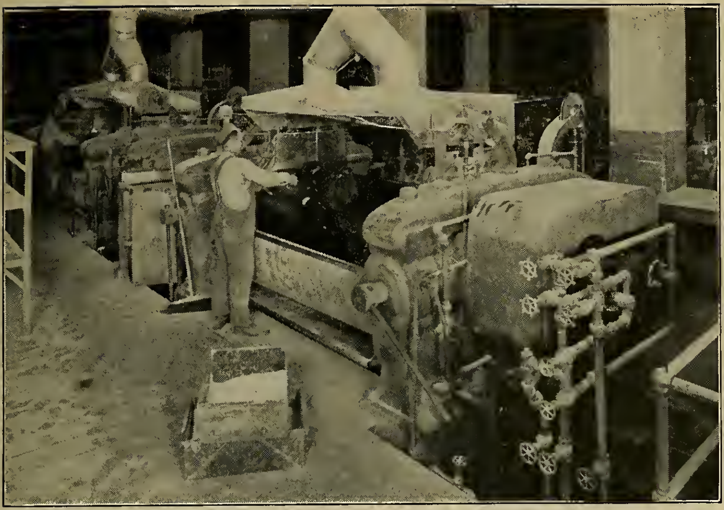
Courtesy of The B. F. Goodrich Co.

THE AUTOBIOGRAPHY OF THE FOUR RUBBER COMPOUNDS MENTIONED IN THE TEXT

and sulphur by themselves would require several hours under heat before enough sulphur would be combined to give snappiness and the other properties of vulcanized rubber. When white lead is used with the rubber and sulphur, however, this time is reduced to a short period. It happens in this particular case that white lead itself changes in the presence of sulphur from a white to a black substance because, as the chemist will tell us, of the formation of lead sulphide, which is black.

These accelerators seem to serve as stimulants to the combination of sulphur and rubber, just as when you place your foot on the accelerator of your automobile, you permit more gas to flow into the cylinders, and your automobile increases its speed. In a like manner, when accelerators are used in the rubber mixture, a more rapid flow or combination of sulphur with the rubber takes place. In the chemical world they are called "catalysts," and they are widely used in chemical processes. The making of sulphuric acid requires the use of catalysts in order that the combination of sulphur dioxide and oxygen may take place not only within reasonable lengths of time, but with sufficient completeness to make the process one of commercial value. In the rubber process, the catalysts themselves change somewhat; yet the definition is broad enough to include any substance which facilitates the course of vulcanization. The first catalyst, or accelerator, was the white lead used by Goodyear. For many years only such mineral substances were used. Litharge or lead oxide aided in making many of the best tires produced in this country. Lime, magnesium oxide, and others have been and still are common in rubber manufacturing practice.

Within the last few years publications have been setting forth the details of this ultra-secret phase of rubber compounding. The better-trained chemists

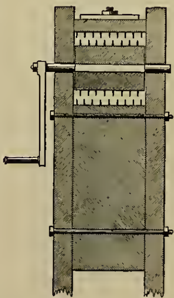


Courtesy of The Firestone Tire & Rubber Co.

MIXING RUBBER COMPOUNDS IN THE MILL ROOM

Courtesy of The Firestone Tire & Rubber Co.

FRICTIONING CLOTH WITH UNVULCANIZED RUBBER MIXTURES ON THE CALENDER



HANCOCK'S PICKLE. INVENTED IN 1820. TAKEN FROM "PERSONAL NARRATIVE" BY THOMAS HANCOCK

have come to use synthetic organic chemicals as accelerators, for they have found them remarkable in powers of action and in giving a quality to rubber mixtures that had not been dreamed of before. The organic compounds are, in the majority of cases, products derived from chemical processes upon coal-tar. They are related to the organic dyes, many of which are good accelerators. Some of them are drugs, the one used in this formula being of that type. Only a small amount of these organic accelerators is necessary. Of the old inorganic, or mineral, ones, such as white lead, formulas required from 5 to 15 per cent. by weight; these new substances employed so largely in later years, however, require less than 1 per cent. to give even more active acceleration. They seem also to increase the strength of the rubber and its resistance to abrasion, to heat, and to oxidation and aging. The discovery and first use of the organic accelerator was nearly as great a step forward as that of vulcanization.

To make history reliable, one must mention at this point the name of a most able man of the younger generation, Mr. Arthur H. Marks, and his assistant, Mr. George Oenslager. To them goes the credit for the first introduction of a typical organic accelerator in commercial rubber manufacturing practice. In 1906 the records of the Diamond Rubber Co., of Akron, Ohio, later combined with the B. F. Goodrich Co., show that they first employed aniline oil as an accelerator of vulcanization. Because of its poisonous nature, this substance had one disadvantage. It is quite natural, once Mr. Mark's mind turned in this direction, to find him making every effort to determine the properties of other organic substances that might vulcanize rubber with equal speed, furnish equal strengthening properties, and be free from poisonous characteristics. This was too secret a matter to permit of publication. As a result, these men have up to now never received public credit for this tremendously potent advance step in rubber manufacture. In 1912, however, some Germans patented in this country a considerable number of organic substances for this purpose. Once these disclosures were made, chemists in the rubber business went ahead with great strides, until to-day there are a large number of organic accelerators in current use.

It is safe to say that there is scarcely a rubber mixture that does not contain as an essential ingredient some such substance. Of the many processes and substances that have increased the efficiency of automobile tires, no one of them deserves greater credit than the organic accelerator; it has so greatly improved the quality of rubber mixtures that tires run much longer by virtue of it. The autobiographies, called curves, strikingly show the gains attained by these substances. Without an accelerator, a time of two hours is needed to vulcanize a rubber-sulphur mixture; the strength attained is but 1150 pounds per square inch; the piece stretches 6½ times. Add one half of 1 per cent. of accelerator and a little zinc oxide to hustle the accelerator, and the mixture vulcanizes in one hour, the finished product showing a strength of 2760 pounds and a stretch of 6¾ times.

If these tests of mixtures were the only ones used in making rubber products, the operation of the technical department and of the factory in the industry would indeed be simple. The current belief probably is that any substance other than rubber and sulphur used in tires or rubber shoes is employed to make them cheaper. This is far from the case. Hardness and resistance to abrasion are properties needed for some articles and not for others. If a solid tire for truck service were to be created by vulcanizing the composition that I have just given, it would be soft and flexible; it would tear with ease and be of slight value as a tire.

Subject to choice, for the purpose of increasing the resistance of finished rubber to abrasion, are a large number of substances; but I shall use, as an illustration, zinc oxide. This substance is a dry, white powder that has for years been used in the manufacture of white paints. In one form or another, milady uses it for whitening her summer sport shoes. It has some use as a mild, non-acid base for ointments. Despite the large number of zinc ores throughout the world, few possess the high degree of purity required to yield good zinc oxide for use in rubber compounds. Peculiarly, there are but few zinc ore deposits in which lead ores are not mixed with the zinc. Freedom from lead is an important chemical characteristic of the zinc oxide to be used in the rubber trade. So important is zinc oxide in rubber mixtures, so valuable are the properties given to rubber compounds by it, that the industry in 1919 consumed 71,000 tons of this substance.

Let us write another formula, in this case consisting of zinc oxide one hundred parts by weight, sulphur five parts, plantation raw rubber one hundred parts, and the accelerator hexamethylenetetramine one part. The photograph shows the relative volumes of these substances after they had been weighed out. The new compound cures in about the same length of time, forty-five minutes, at a temperature of 290° Fahrenheit, as did the other. The autobiography of the test specimen though, is quite different. It is harder; more force is needed to stretch it. When it extends to six times its length, a load of more than 3400 pounds to the square inch is required to break it. It resists abrasion better.

The chemist and physicist, who must really be the same individual in the rubber testing laboratory, measures another property, the energy stored in rubber when it is stretched. Engineers compute work in terms of resistance to lifting weights against the force of gravity. If one pound of a material of any kind be lifted one foot the engineer and physicist call the work done the foot-pound. When our rubber test piece was stretched in the machine, it was necessary for the machine to perform work upon it. From the autobiography or stress-strain curve, a definite meaning regarding an interesting property of rubber is obtained. This stretched piece has a strong desire to return to its original length. That is why it is rubber. If you stretch wood and steel, they also have a desire to return; but the distance you can stretch them without destroying that desire is very small. Rubber, however, is something like the small boy who climbs the old windmill. He goes up quickly at first; and then much slower as he gets near the top. His feet lag toward the end; his enthusiasm seems to die. Rubber acts in much that way. Yielding easily to a light load in the beginning, more and more force must be exerted to perform the work of stretching it to its maximum distance.

Engineers say that whenever any substance is lifted above the ground against the force of gravity, there is stored in it a certain amount of energy some of which can be regained in the form of useful work by machinery properly designed. Although rubber is not stretched against the resistance of gravity, the work performed is done against the desire on the part of the rubber to return to its original length. From our chart we are able to measure the amount of this work or energy in the engineer's unit of foot-pounds and to compare the amount of stored energy in the rubber with the amount that may be stored in other substances.

Each substance has a definite limit to its ability to return to normal condition. Steel, for instance, may be stretched but a short distance and still return nearly to its original length. If steel be stretched beyond that short distance, which is measured in small fractions of inches, it cannot return. This limit of stretch beyond which substances cannot return has been called, in our books of physics, the elastic limit. Thus, if a bar of ordinary steel one inch square and of a length sufficient to be placed easily in a testing machine have applied upon it a force of 40,000 pounds, it can be pulled out only about one-hundredth of an inch; from this extension it will return to its original length. To break the piece, however, would require

68,000 pounds; the same force would stretch it about four one-hundredths of an inch. Thus, any load upon this test piece of steel between 40,000 and 68,000 pounds is too great for it to bear and still return to its original dimensions. For almost all metals, the elastic limit is decidedly less than the number of pounds required to break the piece.

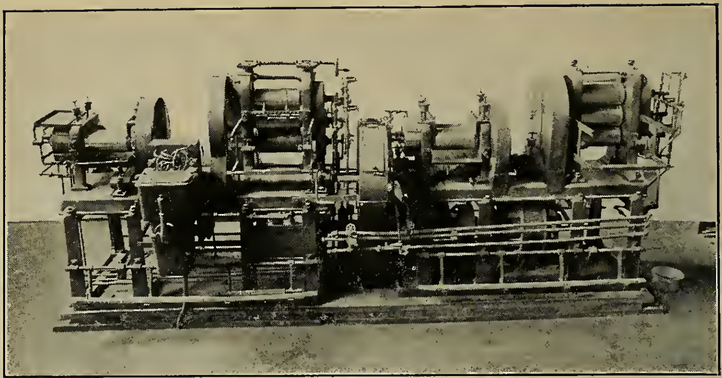
Rubber is singular and different from other substances in the fact that its elastic limit and breaking point coincide. One can stretch a piece of rubber to any distance under its breaking point; and when the load is removed, it promptly returns to approximately its original length. This slight increase in the elongation after stretch and release, known as the "permanent recovery" or "permanent set" or "permanent elongation," is a characteristic of all rubber articles. On long standing, this permanent recovery gradually becomes less and less; and it varies widely in rubber mixtures of different composition.

The ability of rubber to store energy is great; that is, we may pull rubber to nearly its breaking point. If it were possible to harness this energy so that useful work could be performed, we should find a relatively large amount of it stored in rubber. If, in a machine, one pound of tempered spring steel be stretched just to the elastic limit, an action which would require a bar an inch square in section and weighing one pound to be loaded with 82,000 pounds, one can store in it 95.3 foot-pounds of energy. Hickory wood when pulled along the grain is elastic enough to permit the storing of 122.5 foot-pounds at its elastic limit. In this way, our pure gum rubber compound, without the accelerator that we have already described, would permit us to store in it a matter of 3186 foot-pounds. However, with the accelerator, we can store 7633 foot-pounds; the zinc oxide composition, on the other hand, would store 7988 foot-pounds.

But, you protest to the chemist compounder, most rubber articles are not white! Tire treads are black; at least, they are that color when the gray bloom is rubbed off. Heels and shoes are usually black. If zinc oxide is so valuable a material, why use any other dry powder? Then all articles would be white except those articles where other colors were desired. But you would not be quite happy were the rubbers you wear always white, because they would discolor too easily; they are deliberately made black. However, a discovery in this field was made which brought into use a material that was formerly well known, but that entered rubber in a new way.

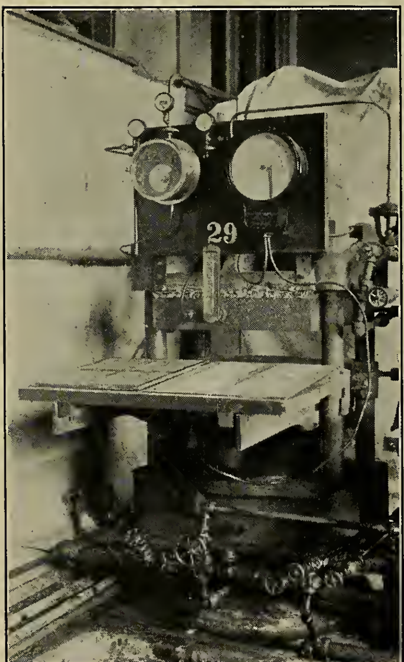
Carbon-black is a soot made by incomplete combustion of natural gas; it is composed of very fine, light particles. Let us now make a new formula in which this black dust is used, to see how it compares in physical properties with the others. This will lead us to the reason for its wide use in the rubber industry. A formula composed of rubber one hundred parts by weight, zinc oxide three parts, gas-black thirty-five parts, sulphur five parts, and the same accelerator one part, is a good one. If this composition be vulcanized, we find relatively little change in the time of vulcanization. When its autobiography is inscribed on the chart, we find that with a cure of seventy-five minutes at 290° Fahrenheit, a load of twelve hundred pounds has stretched the piece only a matter of 2.6 times its original length. But a force of nearly four thousand pounds to the square inch is needed to break it; and under this load, it has stretched to 5.5 times its length. The mixture is therefore stiffer and stronger. The piece stores 14,887 foot-pounds. In weight it is very much lighter than the zinc oxide mixture; as we find, on measurement, that the specific gravity of this particular mixture is only 1.09, a figure which means that the weight of a cubic foot is sixty-eight pounds; the zinc oxide mixture with a specific gravity of 1.56 shows a weight of a cubic foot to be ninety-seven pounds. In the formulas approximately the same volume of zinc oxide and carbon-black was specified. Zinc oxide is heavy and dense, and so a cubic foot of the compound weighs more than that which contains black.

The gas-black formula will wear away less readily than the others. Since this substance produces radical improvement in the physical properties required for wearing qualities, it is valuable in the treads of automobile tires. The gas-black tread has become standard. In the interior of the tire a carbon-black composition would be worthless; it generates heat as it is stretched back and forth. In masses of rubber it becomes a heat insulator, and compositions in which it is used become very hot in service. Without organic accelerators, though, gas-black compositions are too "dead" for practical use; with the accelerator and with zinc oxide, they are valuable and economical. Zinc oxide alone gives a strong but more resilient composition.



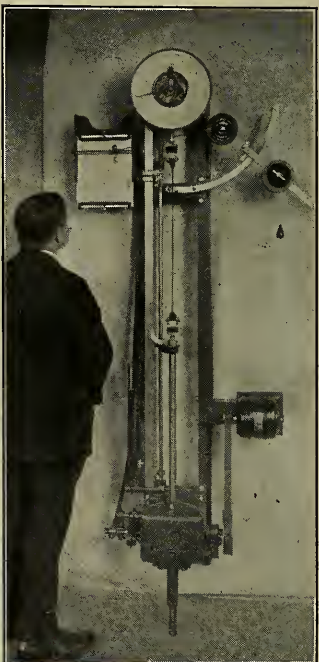
Courtesy of The B. F. Goodrich Co.

A SMALL SET OF LABORATORY MILLS AND CALENDERS FOR MIXING AND SHEETING RUBBER COMPOUNDS FOR EXPERIMENTAL PURPOSES



Courtesy of The B. F. Goodrich Co.

A VULCANIZING PRESS, SHOWING THE AUTOMATIC TEMPERATURE CONTROLLING APPARATUS AND THE RECORDING THERMOMETERS



Courtesy of Henry L. Scott & Co.

A RUBBER TESTING MACHINE FOR MEASURING THE TENSILE STRENGTH, ELONGATION, AND THE AUTOBIOGRAPHY OR CURVE OF VULCANIZED RUBBER TEST PIECES

Each of these two substances then has its own particular properties, and the chemist uses them to improve the compositions. We could not do without either of them. They are the royal family of the rubber pigments. Each rubber chemist chooses which one of them is to be the king. One thing is perfectly sure: the addition of dry mineral powders is necessary to obtain valuable properties in rubber mixtures for different uses.

It would not be wise to say that all dry pigments used in rubber mixtures should be only zinc oxide and gas-black. If that were the case, there would be many common articles that would render less service than they now do, as each pigment has its own particular value and each one is used in rubber for the service that it renders.

We may mention other materials: such as mineral rubber, a material derived from pitch and soft, flexible, mineral hydrocarbons; rubber "substitutes," resins and many others.

I shall not at this point discuss reclaimed rubber, a valuable substance made in the recovery of old vulcanized tires, shoes, and so on. Since the saving of waste is a most vital part of industry and human management, it would be folly for a great industry to permit the total loss of these waste products. Old iron goes back into the melting pot and is reworked into various articles. So the rubber industry has succeeded in reclaiming its vulcanized products after they have performed all the service possible.

Colored goods introduce another phase of rubber compounding. It seems that the human race demands artistic products. To meet this demand, our water-bottles are made red by antimony sulphide, or vermilion; blue products are colored by ultramarine blue, greens by chrome greens, and white by proper quantities of zinc oxide or lithophone.

So I might decribe probably fifteen hundred different materials that go to make up the twenty to thirty thousand articles that are the result of rubber manufacture. A versatile individual must be the rubber chemist; for he must understand their sources, composition, and properties. He must know a great deal about how each of them affects rubber mixtures. In the choice of substances, he combines them to give valuable properties. He must make compositions to withstand the action of heat, as in the layers which separate the plies of cotton in automobile tires; and, too, he must make them to contain air, as in inner tubes, to resist abrasion, as in solid tires and pneumatic tire treads, and to be permanent in balloons under the action of light and oxidation. Some must not swell in oil. He develops special mixtures for steam-hose and steam-packing. Throughout the whole line, it is special study and expert mixing that produce the properties in the rubber necessary for the best service to the consumer.

CHAPTER V

RAW RUBBER

The ups and downs of rubber during its history convince us of its elasticity. Until approximately four hundred years ago, little was known of it in the economy of human life. With relative rapidity it rose into an important position; it ascended to heights of speculation. Rubber booms came, and rubber bubbles burst. It has dropped to the depths of economic depression, but again rebounded—a varied history and an interesting one.

Columbus seems to be the European who first saw in the Americas a peculiar elastic substance. On returning to Europe after his second voyage, he told about it. Subsequent travelers made records of the substance.

Antonio de Herrera Tordesillas, one of the most prominent historians of Spain, writing in 1615 "The General History of the Voyages of the Castilians in the Islands of America," evidently loved a ball-game, for he says:

> The ball was made of the gum of a tree that grows in hot countries, which having holes made in it distils great white drops that soon harden, and being worked and moulded together turn as black as pitch. The balls made thereof, though hard and heavy to the hand, did bound and fly as our

foot-balls, there being no need to blow them. . . . They might strike it every time it rebounded, which it would do several times one after another, in so much that it looked as if it had been alive.

He alludes to the natives of Tierra Firme, who "on their festivals, painted or daub'd themselves with a sort of clammy gum, sticking on it feathers of several colors."

F. Juan de Torquemada, in the third volume of his "De La Monarquia Indiana," of which the first edition appeared in 1615, describes the Mexican Indians as making shoes, head-gear, clothing, and other watertight articles of the gum of a tree.

The actual introduction of any useful articles into Europe seems to have followed the colonization of Brazil in the early part of the sixteenth century by the Portuguese.

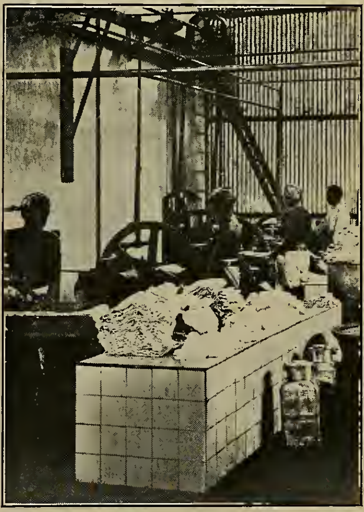
In 1736, in company with Bouguer and Godin, La Condamine, a French savant, was sent by the king of France to South America for the purpose of measuring a degree of the meridian. On their return journey to Europe, these men brought the first specimen of caoutchouc from Peru, by way of the Amazon River. La Condamine reported having also found this "most singular resin" to the north of Quito in Ecuador, exuding from a tree named *hévé* or *hyévé*. It was called *pao de xyringa* by the Portuguese colonists. The result of his observations was published in the "Transactions de l' Académie des Sciences," wherein he described the various methods of collecting the juice and

Courtesy of The B. F. Goodrich Co.

A RUBBER PLANTATION IN SUMATRA

Courtesy of The Commercial Museum of the Colonial Institution—Amsterdam, Holland

COAGULATION TUBS IN THE "GO-DOWN" OF THE PLANTATION



Courtesy of The Commercial Museum of the Colonial Institution—Amsterdam, Holland

WASHING COAGULATED BUT NOT DRIED RAW RUBBER IN THE WASHING ROOM OF THE PLANTATION

of treating it for the production of many useful articles.

Hérissant and Macquer published in 1761, in the "Mémoires de l'Académie," the results of the first chemical investigations of India rubber solutions. Five years later, Macquer reported fully on the means of dissolving the "resin caoutchouc" in ether, and on repeatedly coating forms, so that they retained a covering of the gum after the evaporation of the ether.

In 1759 the government of Pará presented to the king of Portugal a suit of rubber clothes; four years previously he had sent several pairs of his boots to Brazil to be waterproofed. One of the Portuguese drank some of the milk, but his stomach did not care to be waterproofed and he passed on to his fathers.

An Italian engineer suggested in 1791 the suitability of petroleum as a solvent; but he was ahead of his time, for that substance did not come into general use until as late as 1860, with the exploitation of the American oil-fields.

But on May 2, 1791, Samuel Peal was granted in England the first known caoutchouc patent. It was for a method of rendering "perfectly waterproof all kinds of leather, cotton, linen, and woolen cloths, etc." His coating consisted of India rubber dissolved "by distillation or by infusion in a small quantity of turpentine over a brisk fire, or by infusion in other spirits and in most kinds of oil; or of Indian rubber used in its native fluid state."

Samples of this crude rubber coming into England found their way into various laboratories, where the great chemist Priestley examined them in 1770.

What is this raw rubber? If you were so to travel around the world as to allow yourself journeys into tropical countries, at almost any point 250 miles on either side of the equator you would find growing wild in the jungles certain evergreen trees, vines, and even shrubs which, when the bark is broken, give forth a white milk. This milk, which we might naturally call sap, or technically latex, if allowed to stand in the air and evaporate, leaves a brown residue. The residue is raw rubber. The milk comes from glands in the inner layers of the bark. From more than five hundred individual species in this great group of milk-producing trees can be obtained, after evaporation or other treatment, the brown, elastic substance.

The trees giving the best quality of raw rubber are those mentioned by La Condamine; the botanist named the species *Hevéa brasiliensis*, a modification of the original. Naturally, after the discovery of the trees in South America and the knowledge of the wonderful properties of the rubber left after evaporation on shoes and fabrics, the South Americans pushed forward the making of rubber for export to Europe, where commercial development of the product was progressing. So in 1825 Brazil exported thirty tons of this dark brown material from the rubber-trees. In 1850 the exportation had jumped to 1467 tons, and in 1897 to 21,260 tons.

In the jungle these wild trees of the *Hevéa brasiliensis* species grow to a height of seventy-six to one hundred feet and measure from four and one half to twelve feet in circumference. The restriction of the branches, which are small, largely to the crown of the tree gives, as do the pine-trees from which turpentine is obtained in our Southland, a large area of bark for tapping. Where the temperature averages about seventy degrees Fahrenheit and the annual rainfall is at least ninety inches, the trees flourish. The natural transportation lines in these aboriginal countries are along the rivers; consequently, the areas exploited in collecting rubber in South America have been along the Amazon River and its tributaries.

Here, the native rubber tapper leads anything but an easy life. The jungles are dense, overrun by innumerable vines and creepers, and filled with snakes, tarantulas, and poisonous ants. Since the flood season occurs from November to May, during which time the rivers overflow their banks, the rubber tapper is obliged to spend his time in his hut, which is built on piles above the water. During the rest of the year or the dry season, vegetation is luxuriant. Innumerable swamps from which fevers and disease come, though, add to the discomforts of this poor native.

He rises about four in the morning, while it is still dark, and starts out into the forest, with a small hatchet and a tin bucket. On the first of two trips around his territory, with the hatchet, he gashes long wounds into the rubber-trees. The resulting flow of sap or latex runs down the tree and into a little tin cup below the gash. In order to make his living, it is necessary for the rubber tapper to cover a large territory by winding paths. Breaking his way through the rapidly growing vegetation in the jungle, he taps and collects latex from seventy to one hundred trees in the course of a day. After he has properly tapped the trees in his territory, he goes back over it and pours the milk from the little cups into his tin bucket.

His milk collected, he comes back to his hut which, during the dry season, is usually a temporary one on the ground. While he prepares his meal, he lights a fire made from wood and specially collected palm nuts. Over this fire he places a conical, baked clay flue to concentrate the smoke. Obtaining a dense, hot smoke, he begins the work of preparing the raw rubber for market. He warms a long stick or a paddle over the fire; then he pours some milk upon it. This he rotates in the smoke until the milk has dried on the stick. Again he pours the milk, and again he dries it over the fire. If he is not asphyxiated at the outset of the performance, he keeps at it, building up layer after layer of evaporated rubber until a mass is obtained nine or ten inches in diameter and about eighteen inches to two feet in length. This forms the biscuit of wild rubber called "fine pará" seen in our markets. Weighing about sixty to eighty pounds, it constitutes a day's work for the tapper. It smells like fine old Virginia ham.

At the end of the day, which for him is about three in the afternoon, he may be found in his hammock, with sore eyes, parched and smoked face, bitten by insects, and covered with soot. It is no wonder that we find a high death-rate in the Brazilian swamps and that there has been from the beginning a steady deterioration in both numbers and quality of labor. At the end of the dry season, for the tapper cannot work at all during the wet or rainy season, he collects

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FIELD HANDS GATHERING COTTON, WHICH IS THE BACKBONE OF RUBBER ARTICLES

and binds together the product of a year's work, and floats it down the river to the nearest chief, who accepts it in payment for money previously advanced.

The Brazilian rubber industry was important for a considerable number of years, but the history of it is dark and morbid. The prevailing practice has been to make peons, mere slaves, out of these poor Indians. Couple this with the heavy government taxes and fees, the high freight-rates, the dishonest gradings of rubber, and you will not wonder that the collection of raw rubber in Brazil has sagged during recent years. Attempts have been made to import farmers; but because of unhealthy conditions, the lack of proper food, the absence of business ability on the part of the Brazilians, their indifference to progress, and the damp air and lands, the attempts came to naught.

The slowness of evaporating the several coats of latex to produce the thin layers of rubber built up step by step into the biscuit, together possibly with the chemical constituents of the smoke, served to yield a tough, high-quality raw rubber. Although the native lost his health and life, he succeeded in producing the finest grade of crude rubber that came into the market. This was known as "fine hard pará." It is singular how a name is preserved, for Pará was the original port of shipment. In later years the port became Manáos, although the name "pará" rubber was still given to the best grade from Brazil. Not only that, but all high-grade rubber is colloquially known as "pará" rubber. If the workman is not skilled, the layers on his biscuit are apt to be thick and soft; the grade "medium" is the result. When the tapper collects the little strips of rubber that have gathered on the trees, and on the leaves on the ground, he rolls them, full of dirt and bark, into balls known as "coarse" or "sernamby." In the bottom of the cups are always little cakes of rubber; these come in mass form into the market under the name "cameta." These are but a few of the many grades, each distinct from the other, produced from this exudation from the wild trees in the Amazon Valley. Therefore the rubber manufacturers' problem during the days when wild rubber was at its ascendancy, was one of making the correct selection for many different products. Because all the grades were wet, it was necessary, and still is, to wash these wild crude rubbers free from sand and other particles of foreign matter and to dry them before they are ready for use in the factories. In washing and drying there is a loss of weight called "shrinkage," from both dirt and moisture. In the highest grade the shrinkage is about 17 per cent.; in the softer, weaker grade, such as the cameta, it runs as high as 48 per cent.

Rubber-trees in different districts seem to be a little unlike even in the same species. This, with slightly differing methods of production, results in many grades. Names of different rivers are used in designating grades—Acre, Tapajos, Madeira, and so on. Since the best trees and the best rubbers from them come from the upper reaches of the Amazon River, it has been natural for the trade to call these products "up-river." So "up-river fine pará" is the highest grade known, except "beni," which is the best of the up-river grades.

Men somehow are never satisfied. No sooner was wild rubber known than suggestions came to plant the trees. Dr. James Howison, an English surgeon at Pullopinang, in 1789 discovered a vine giving a milk that possessed the properties of the South American caoutchouc. He wrote about it in 1800: "Should it ever be deemed an object to attempt plantations of the elastic-gum vine in Bengal, I would recommend the foot of the Chittagong, Rajmahal, and Bauglipore Hills, as situations where there is every probability of succeeding, being very similar in soil and climate to the places of its growth on Prince of Wales' Island." Howison thus originated the plantation idea.

Later Thomas Hancock, in 1834, expressed in the "Gardener's Chronical" the probability of cultivating the best kind of caoutchouc-bearing plant of the East and West Indies. The supply at that time—two to three tons weekly—did not seem great enough! It came to England in poor condition, wet, sticky, and dirty.

Fortunately, in the early sixties one man saw a vision of the future and carried it out. Henry A. Wickham of London had spent several years in the Brazilian forests. A man of keen mind, intrepid force of character, and vision, he studied the rubber-trees and went so far as to plant trees on the Tapajos Plateau in Brazil. He posted himself thoroughly on the botany, the method of growth, soils, water supplies, and every other possible question connected with the *Hevéa* tree. He proposed to London that seeds from the *Hevéa brasiliensis* tree be gathered and planted for the production of cultivated rubber-trees. Others had tried it but failed; they had chosen the wrong species. Markham had sent Collins to investigate. Cross had brought back *Castilloa* seedlings; but the plants never thrived, and the rubber gained was of low grade. Sir Joseph Hooker, then director of Kew Botanic Gardens, believed in Wickham's plan and interested Sir Clements Markham of the India Office. Luckily, Wickham was given the responsibility of making the experiment, and by rare good fortune he was left unhampered by instructions. We must commend the English for one thing; when once their minds are made up, they see a thing through.

Setting out again then for Brazil, Wickham went immediately to the territory on the Tapajos Plateau, well up the Amazon River, where he had been considering a plantation enterprise. He writes a romantic story of his experiences. Singularly, discouraging circumstances were turned into success by an accident. While he was in the district, word came to him of the arrival of the steamship *Amazonas*, Captain Murray at the helm, which was the first of the new "Inman line of Steamships—Liverpool to the Alto-Amazon direct." A few days later the information arrived that this fine steamship, through a mix-up, had been abandoned by the supercargoes and left on the captain's hands, with nothing to take back for the return voyage to Liverpool.

Wickham was nothing if not an opportunist. He had neither cash nor credit. The seed was just ripening on the trees. But he boldly wrote to Captain Murray, chartered the ship on behalf of the Government of India, and made an appointment to meet him at the junction of the Tapajos and Amazon rivers. Here he was in the jungle, with an impatient captain waiting at port on an empty steamship. Jumping into an Indian canoe, he paddled up the Tapajos, a dangerous trip, particularly in that season, and struck back into the woods where he knew the full-grown *Hevéa* trees to be. Out of seventeen varieties, he chose seeds from the black or best grade of the tree. Accompanied by Indians he daily went through the forests and packed pannier baskets with loads of seed. It was a delicate operation, for the seed is rich in a heavy oil that quickly becomes rancid, a condition that destroys the power of germination. With remarkable astuteness he did what no other had done—packed the seed to avoid decay. Once on board the steamer he went to the city of Pará, from which port clearance papers were necessary before he could go to sea with his cargo.

Wickham says in his narrative: "It was perfectly certain in my mind that if the authorities guessed the purpose of what I had on board, we should be detained under the plea of instructions from the Central Government at Rio, if not interdicted altogether." Any such delay would have rendered his seeds useless. He had, however, a friend in the person of Consul Green, who entered into the spirit of the occasion and made a special call with him upon the chief of that district. They represented that they had "exceedingly delicate botanical specimens specially designed for delivery to Her Britannic Majesty's own Royal Gardens at Kew." This seems to have been impressive; and, after the usual complimentary interview in the best Portuguese manner, they were permitted to clear port.

On the voyage Wickham took exceeding care of his precious seeds. During June, 1876, he arrived in England. A special train was sent down to meet him at Liverpool, and the seven thousand young seeds were promptly planted in the Botanical Gardens at Kew. A fortnight later they had sprouted. Then an equally great problem confronted the experimenters, for no plans had been made to send the shoots to any of the English colonies. They were originally intended for southern Borneo; but because of the depression in business at the time, the government forestry appropriation had been decreased. Governments cut down the amount for research in those days as now. As a result of this decrease, the seeds were sent to the Eastern Tropic Botanical Gardens in Ceylon. Thus the plantation industry was started. Wickham was knighted in recognition of these services.

In 1877 twenty-two trees started in Ceylon were sent to Singapore in the Straits Settlements south of the Malay Peninsula. Some were planted in Singapore gardens and the rest taken to Perak. A few of these original trees are still standing. One of them is said to be the biggest plantation tree in girth yet recorded.

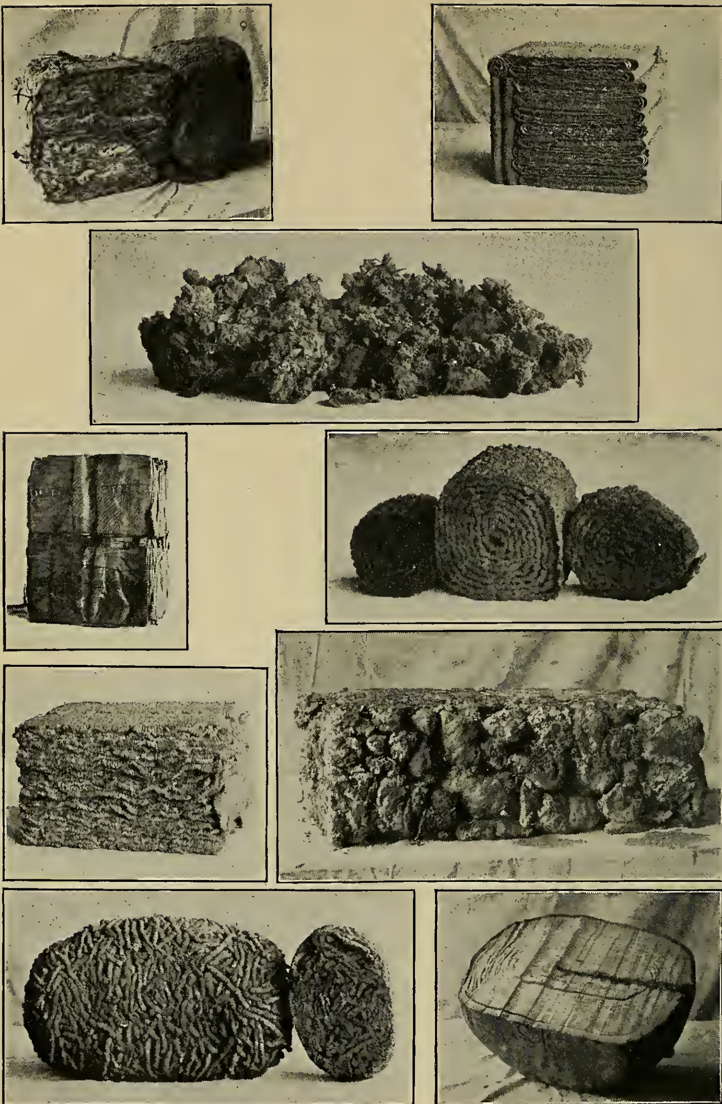
They bore fruit in Singapore first in 1881, and seed was sent to Borneo and Malaya. Because they had been making good profits from the growing of tea, the planters in Ceylon did not take hold of rubber planting with the same aggressiveness as did the planters of Malaya. But in Malaya, backed by financial interests in Europe and tired of the struggle to make a living out of coffee, rubber appealed to them, and they planted trees wherever possible. The first trees of the Ceylon plantation bloomed in 1881 at Heneratgoda, sixteen miles from Colombo. That year the first experiment in tapping began. Problems of how to tap and when to tap, of how many trees to plant to the acre, of the diseases of trees and methods of treatment, and of the proper handling of latex, have filled volumes of literature. It is, in a marked degree, due to the enterprise of the English and Dutch scientists and business men that the plantation industry has succeeded and has become so tremendously important in the world's markets.

From the wilds of Brazil to the cleanliness and uniformity of the plantations of the East necessitates a change of picture. Here the trees are laid out in orchards as even, regular, and well cultivated as apple orchards. There are little Chinese and native rubber farms and big ones, owned by corporations with headquarters in London, Amsterdam, and America. On the plantations the health of the workers is taken care of. Because there is not labor enough in these districts, it has become necessary to bring in coolies from China and India. In order to make the conditions as comfortable for them as their natural state of living requires, the health, the food, and the life of these people are watched, and the result has been economy in operation and increase in production.

To start a plantation, the jungle must be cleared in a location where drainage and soil are right. It is a long, expensive task to prepare land for the reception of the rubber-tree sprouts, which are set out in rows, usually about one hundred to two hundred to an acre. Then begins the important problem of exterminating weeds, which in these moist, tropical regions grow at a discouraging rate.

The tapping of a rubber-tree is an art that requires a delicate touch and a sure hand. By tapping is meant the cutting of the tree so that the latex will flow freely in a clean, uncontaminated condition, into a properly placed cup. Scientists spend their time in improving the yields by processes of tapping at proper intervals, by care of the trees, by selecting seeds for future plantations from those that give the greatest yield of rubber. Rubber-trees are being scientifically bred and trained, like cows, to give greater quantities of milk. A diagonal cut extending one third or one quarter of the way around the tree is one of the best of many methods. This is made with a razor-sharp knife of special construction, whose blade is so thin that twenty tappings may be made side by side in one inch of bark. If the cut be not sufficiently deep, the full quantity of latex is not obtained; if the cut be too deep, the tree is injured. Tapping is therefore so important that only a skilled laborer is permitted to do it. Because the latex is found in milk ducts, it is necessary to tap a tree daily. These glands seem to rebuild themselves after a few days' rest. By noon, when he has tapped 450 trees, the tapper's work is finished; at eight or eight-thirty in the morning, the work of collecting the latex from the little cups begins. Usually on the large plantations metal milk cans are used; and when the collector has filled his cans, he takes them to a collecting shed where his latex is weighed.

The plantations are milk factories. Here, cleanliness is as necessary as in a dairy. Rubber milk is



Courtesy of The B. F. Goodrich Co.

SEVERAL GRADES OF PLANTATION-GROWN AND WILD RUBBER

CAUCHO BALL — AMBER BLANKET CREPE

PLANTATION TREE SCRAP

SMOKED SHEETS — ROLL BROWN CREPE

PALE CREPE — UP-RIVER COARSE PARA

CONGO — UP-RIVER FINE PARA

even something like cow's milk. Both contain finely divided particles suspended in water; but in one case it is 3 to 5 per cent. of fat and in the other 25 to 35 per cent. of rubber. The farmer centrifuges milk and gets cream, but milk separators do not work on *Hevéa* latex. Since the rubber will not rise as a cream, the planters add acetic acid to it to congeal or coagulate it.

On large plantations, the first operation is to strain the latex carefully in order to free it from dirt and from the curds or flocks that have been formed during transportation. Into appointed vats of correct size the latex is then poured, and with it is intimately mixed a dilute solution of acetic acid. This causes immediate coagulation into a mass of soft, white dough. The acid must be added within twenty-four hours, or spontaneous coagulation will set in, caused probably by the rapid action of bacteria that seem to sour the rubber milk just as bacteria sour cow's milk. After this soft, white dough has formed, it is put into a machine which tears it up into small pieces and presses out the excess of water and chemicals. It then goes through a washing machine, where it is washed with clean, filtered water; during this process it gradually hardens by the simple matting together of the rubber particles that had previously existed in the latex. On the larger plantations, it is usually coagulated in bulk, either in a big tank or in glazed earthenware jars of 200 to 250 quarts capacity.

In order to produce the light yellow crepe rubber, there is mixed with the acetic acid a small quantity of what the chemist knows as sodium bisulphite. The rubber comes from the rolls of the washer in a rough irregular sheet. This wet rubber is hung in dry rooms, like clothes on a line. Before it is dry, the rubber is white from the presence of water. From the dry room, the sodium bisulphite having bleached it, it emerges pale yellow in color. We call it "pale crepe."

The Amazon fine pará smells smoky, like ham. So older rubber men thought smoked rubber to be the best. The planters met the demand for the smoked product with the grade known as "smoked sheets." To make this, the method of coagulation is essentially the same, but without the sodium bisulphite. The coagulum is then rolled between washing rolls. When clean, it is passed between rollers that have been cut in such a way as to produce a pattern known usually as "ribs" upon the soft, wet mass. Less time is required in washing and handling smoked sheets than in producing crepe, but there is danger that all the impurities and serum are not removed.

The Rubber Growers' Association of Great Britain, and similar associations among the Dutch, have worked out methods to produce "even size, even weight, even thickness" of sheets. After the rolled sheets with the pattern or ribs come from the mills, they are hung up to dry. Then they are smoked in a smoke-house, much as we smoke hams. Great care is taken that the smoking be uniform, that it be not too hot, and that the color be regular; for by irregularity of handling the smoked sheets comes a large variety of defects that grade down quality. There are ten or a dozen different types of smoked sheets produced by different conditions of coagulating and smoking. There are bubbly sheets, moldy sheets, tacky sheets, dark colors, and light colors. To the farmer, milk is milk and cream is cream; he disposes of it all in one grade. The problem is not so simple for the rubber planter. Besides pale crepe and smoked sheets, there are clots in the strainers, bark scrap, and cup film, which are often worked together and called "compo."

The natives, too, on their little farms grow rubber-trees. They, however, follow the simple plan of pouring latex into pans, permitting it to evaporate until it has coagulated. Then they roll it up with a sort of rolling pin to squeeze the extra water out, and hang it on the fence to dry. This process yields a softer product, one that is wet, somewhat oxidized, and not of a high quality. The enterprising Chinamen trade rice and clothing for the rubber produced by these natives, and take it to central stations, where it is washed and dried. We call it "amber sheets," which are rated according to color.

One might think the rubber planter to have finished when he takes his sheet from the dry room. This is far from the case; for then a number of different forces begin to act upon it. Because sunlight causes rapid oxidation, the rubber must be kept from it; because heat causes a chemical change that renders rubber less useful, it must be kept as cool as possible. Care must be taken in packing and storage. Bacteria affect the rubber. Oil from machines produces soft spots. If it is packed in the rain or if it is not properly dried, mold develops on it; and some mold is deleterious. The proper kind of boxes in which to pack the rubber has been the subject of much study; for if the box, which holds about two hundred pounds and is approximately cubical in shape, be weak and break, the rubber may be contaminated with chips. Chips in inner tubes of automobile tires might affect one's good humor.

A glance at the map will show you the areas from which plantation rubber chiefly comes. The vicinity of the Malay Straits seems to offer that peculiar combination of soil, climate, and labor around which the successful development of the plantations has grown. From the little experimental trees set out in Ceylon, there was not a great or rapid development until the automobile brought a demand for rubber tires. This demand induced further planting. Statistics show that in 1900 there were four long tons of plantation rubber recorded, with 26,750 tons of wild rubber from Brazil and 27,136 tons from the rest of the world, or a total of 53,890 tons. For the first time in the history of rubber it had a statistical position that marked it as permanent and large enough a product to warrant the attention of the world. The industry then rapidly grew, so that in 1907 one thousand tons of plantation rubber are recorded, with 38,000 of wild rubber from Brazil and 30,000 tons from the rest of the world. In the same year, there were a total of 506,550 acres of ground under rubber cultivation. The automobile in those years became a potent factor, and the demand for tires rapidly increased. Consequently predictions of the optimists became realized: in 1909, plantation rubber had jumped to 3600 tons and wild rubber to a total of about 66,000

MAP OF THE WORLD TO SHOW SOURCES OF RUBBER AND COTTON USED IN RUBBER GOODS MANUFACTURE tons. The area under cultivation had grown to 861,000 acres.

Then occurred the famous and spectacular "rubber boom" that has gone down into history like the many speculative entanglements. Never has there been a more memorable year in the history of rubber than that of 1910. Men went as wild in England during this period of over-speculation as they did at the time of the South Sea Bubble or of the tulip mania in Holland. Our statistics show that crude rubber prices varied from a low point of about forty cents in the year 1878 to a high one of $3.12 a pound in New York in April, 1910. During those exciting days in London, investors even paid as much as 4600 per cent. premium for shares in rubber plantations. Speculators who knew little of rubber besieged bank doors when the list of a new company was opened. Waitresses, hair-dressers, elevator-boys speculated and made, at least on paper, money enough to retire to the ranks of the "bloated bondholders." Then came the break, and rubber prices have steadily declined ever since.

The stimulus to planting, however, was permanent, the total area under cultivation rapidly increasing, until in 1915 it had reached 2,293,000 acres, and in the next five years, 3,020,750 acres. The production of plantation rubber likewise kept increasing, as did the production of Brazilian and other wild rubber, but less rapidly. As a result, in 1915 there were 107,860 tons of plantation rubber, 37,220 tons of Brazilian, and the rest of the world yielded only 13,616 tons. In 1920 the plantations put into the market 304,816 tons, Brazil had fallen to 30,790, and the remainder of the world, to 8125 tons. Seventy-five per cent. of all this rubber came to America, and about 70 per cent. went into tires manufactured here and elsewhere. The far-sighted planter had won.

During the boom of 1919 and the depression of 1920 we again notice rubber's elasticity. For while millions were made in the boom of 1910, millions were lost in the depression of 1920. In this depression, over-production played the star part. After the World War the demand for automobile tires and rubber products rapidly increased; the supply of crude rubber increased in about the same ratio. But with the depression, the planters were in a difficult situation. The larger number of estates were owned by the English, who consequently felt the slump most keenly. Singapore, instead of Pará or Manáos, had become the world's shipping center, with London the world's rubber financial center. The end of December, 1921, showed a total acreage under cultivation in British Malaya of 1,760,000 acres; in the Dutch East Indies of 875,000 acres; in Ceylon of 410,000 acres; and in the other countries of 276,000 acres, making a total of 3,321,000 acres. The total amount in bearing and still solvent amounted to approximately 2,200,000 acres. These estates gave an average yield of 316 pounds to the acre, so that the production in 1920 was 309,100 tons, The demand for use could not possibly be more than 180,000 tons. With a visible supply of well over 300,000 tons, there was little hope for a profitable market. Since a selling price of eightpence per pound was under the cost of production, strenuous efforts were required to maintain the solvency of the rubber plantation companies.

The real needs of the plantation industry may be summed up thus: Prices must be sufficiently low to maintain the economic balance of supply and demand; cheaper production must come from efficient and economical management. These needs met, if world-business conditions be sound and normal, the plantation industry will keep alive, growing, and successful. From the rapidity with which unattended estates in the tropics become overrun by weeds, there is, though, a serious condition confronting the plantation industry and the world's use of rubber. The maintenance of a rubber plantation in good bearing condition requires labor to be expended in removing weeds and treating tree disease, regardless of any tapping or profitable output. When there is no money to be realized, or so little that what is realized is less than the cost of production, it is natural to let young orchards lie unattended. The result is an outgrowth of weeds which rapidly chokes the young trees. The care and money that have been spent in clearing the jungle are thus lost, and years will be required to bring many thousands of these acres back into good condition.

It is still too early to prophesy the extent of the labor problem in the Malay Straits. Every estate is cutting down its labor. Coolies are returning to India or China. Emigration has become greater than immigration. When production is required, it will take a long time and an expensive process to recruit these coolies again and train them for the work. On large estates and on small ones the cost of production, however, must be brought down low enough to permit profits to be made at prevailing prices.

I have thus far spoken but little of the wild rubber produced outside South America; and but little need be said, in view of its declining quantity. Rubber has been produced in Africa. The qualities were as variable as the climate and the peoples of that great country. The majority of processes for obtaining rubber from the latex were crude in the extreme. Much of it was obtained by spontaneous coagulation on standing, some by heating of the latex, and some by the use of juices from trees and vines. Foul smelling, it all needed washing; and the rubber man soon learned to recognize the grade of rubber by the odor.

Experiments have been tried in the Philippine Islands, where it has been found that the *Ceará* tree will grow rapidly and come into bearing under cultivation in from three to ten years. Crop conditions are favorable in the southern part of the Philippines outside of the typhoon belt, but no forward strides have been made. Development probably is retarded by the laws prohibiting a corporation from engaging in cultivation or control of more than twenty-five hundred acres of land. The Far East has the start, therefore, in plantation rubber production, and it is doubtful if any other country will for many years catch up with it.

There is one country, though, in which rubber has had a spectacular rise and fall; namely, Mexico. In 1852 Dr. J. M. Bigelow discovered a plant in the form of a small shrub that contained rubber in the wood. It was called *guayule* by the Mexican peon. No utilization of it, however, except by natives had been made until 1888, when a company went to Mexico and obtained a large quantity of the shrub, from which to extract the rubber. Later, the methods of extraction were developed to the point where the industry became a large commercial enterprise with many millions of dollars invested in it. Large supplies of the shrub were used, many thousand tons of the product being employed in the rubber industry. But the rise in volume of the plantation grades, the decrease in the cost of those grades, and the political conditions in Mexico have led to a gradual decrease of *guayule* in the markets.

Booms in the industry have led also to a study of every possible plant from which rubber might be obtained. In late years surveys have been made of western North American shrubs; even the Carnegie Institution and the University of California have published documents giving the rubber content of some species. The work was originally undertaken as a war measure for emergency supplies. Energetic Americans studied about 225 species of western North American plants, which they grouped into two classes: one in which rubber occurs in solid particles, as in the *Chrysothamnus;* the other in which it occurs in sap, as in the milkweed and Indian hemp. They seem convinced that if natural rubber is ever produced in the United States in commercial quantities, it will come from plants the maceration of which will result in the isolation of small quantites of rubber from much extraneous material. The cultivation will require large areas, and therefore cheap land. But the belief is that these plants can be profitably handled only by machinery, and that they will yield, in addition to the rubber obtained, paper pulp or by-products of value. The investigators seem to think that the desert milkweed promises most. However, the quantity of rubber seems to vary largely, ranging from about 1 per cent. up to 8 per cent. in the stem and leaves. This project, I think, may be left as something for future consideration, but not of particular moment to us at the present time.

Much has been written about synthetic rubber, and there was a time when the chemists of the world seemed to feel that Old Mother Nature could be pushed out of commission so far as rubber was concerned. Because every rubber chemist has been taught how the Germans succeeded in making indigo from coal-tar, every chemist has been led to believe that if he be but diligent enough he will find it possible to make any substance known in nature by the method of synthetic organic chemistry. The "race for rubber" was a merry one while it lasted, but Nature won. To be sure, she was aided by intrepid Englishmen and Dutchmen, so that it is probably safer to say that in the race between chemistry and the planters, the planters won. Grades of synthetic rubber were produced in some quantity in Germany during the war. Although this material could be vulcanized, artificial rubber, by whatever means made, has, up to the present time, never been produced in quality of a finished product equal to that of Mother Nature's first attempt.

There are some cousins of rubber. Three of these are of marked importance: gutta-percha, balata, and chicle. Gutta-percha has high electrical resistance, and is easy to handle in factory production. This has given it great importance in the manufacture of submarine cables, in which it is used as an insulating material of permanent nature.

The chief use of balata is somewhat the same as that of gutta-percha; although in the form of the adhesive layers between plies of fabric in belting, it has come to have a considerable commercial value. Used in the covers of golf-balls, gutta-percha and balata have found much use of a daily and intimate character.

Chewing-gum is of interest to us, since the base that gives it its resilient properties when masticated, is chicle. Chicle is a resilient gum derived from a milky latex. The bulk of the world's supply comes from Mexico and British Honduras, although there is another variety exploited in Colombia that is softer and less valuable.

Chicle seems to play a pretty large part in our lives when one considers that 9,859,000 pounds were imported in the year 1920. Virtually the total amount of these importations is utilized by the American chewing-gum industry, the value or manufactured output of which in 1920 represented a retail business of $100,000,000.

CHAPTER VI

RECLAIMING WASTE

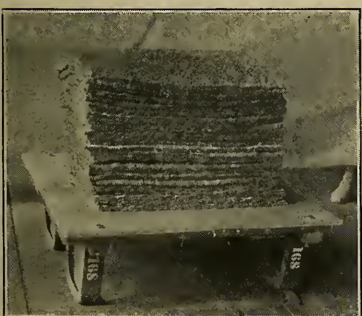
America is supposed to be a wasteful nation. The lumberman has from the beginning of our occupation of this country followed pretty generally the practice of skimming the cream. Out of the millions of cubic feet of wood in the forests an appallingly small percentage of it is finally worked up into useful products. Contrariwise, almost all of the old iron is collected and remelted; the steel industry utilizes its waste products.

There is a difference between the old or scrap products and the by-products from industry. Many industries produce substances other than the chief ones, which are sold to advantage. The dye industry is built upon coal-tar, a by-product in the manufacture of coke. Coke is necessary to steel manufacture, but steel has no use for tar.

The rubber industry has few by-products. It does, though, have its scrap products, The treads of tires wear down, the soles of shoes become thin, but both articles still contain a large proportion of vulcanized rubber. By getting rid of the sulphur, can we recover the rubber? Here lies an attractive problem for chemists and inventors. Because the shoes, tires, hose, belting, water-bottles, and other types of rubber goods are partly oxidized, somewhat hardened, broken, and

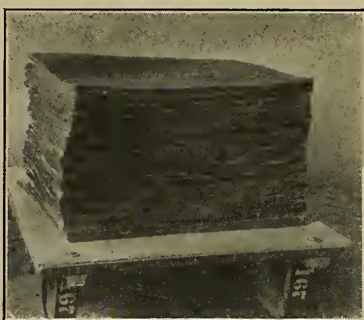
Courtesy of The Philadelphia Rubber Works Co.

VULCANIZED RUBBER SCRAP IN THE YARD OF THE RECLAIMING FACTORY



Courtesy of The Philadelphia Rubber Works Co.

RECLAIMED AUTOMOBILE TIRES



Courtesy of The Philadelphia Rubber Works Co.

RECLAIMED RUBBER BOOTS AND SHOES

impregnated with sand, the enterprise is difficult. Where the tire has rusted against the metal rim, it contains cakes of hard rust. The scrap-pile is certainly unattractive.

At the beginning of this scrap industry, your old tire case is sold to the dealer at about half a cent a pound. He throws it into his back yard. After he has accumulated enough of them, a junk dealer comes along and buys these old tires from him. What fun it used to be to gather old junk and trade with the peddler! In the back country he was an integral part of life. He came about with his load of pots, kettles, pans, and brooms, and traded with us for the old rags, old gum shoes, and other used-up products, which he, as in the present day, sorted according to grades that he knew would have more or less market value. Finally the junk was shipped to the dealer who handled larger quantities; he, in turn, sold it to the factories, where it could be worked up into new products. In the same way our old hose, our tires, and our rubberized shoes are collected now. The business of buying rubber scrap and selling it to the reclaiming mill is one of considerable proportions.

In a consideration of what to do to bring this rubber into usable condition, we are at once faced with a fundamental fact: most rubber articles contain cotton fabric in some form, others contain wool, and a few, linen. It is a relatively small proportion of the total tonnage that is free from fabric of any kind. Now, this fabric is weakened by the service it has undergone: in many cases, it has been wet and is partly decayed. It therefore has little value as fabric or as cotton. In any event, whether it is good or bad, the fundamental problem is to separate the vulcanized rubber from it. The first operation necessary before these old articles can be put through any process, is to free them from foreign materials, such as sand and metals. Rubber mixtures must be clean and free from any hard materials.

Consequently, in the reclaiming factory all material is first sorted into classes, such as tires, shoes, and hose. After sorting, each of them is finely ground. In the course of this fine grinding, which consists of two or three separate steps, the tire is passed over screens and over a piece of apparatus known as a magnetic separator. Here the slow-moving ground mixture of vulcanized rubber and fabric is allowed to drop in close proximity to a magnet, which deflects the iron particles, causing them to fall off by themselves, and freeing the rubber from the metal.

The next step is one that has to do primarily with the removal of fabric. In the old days, each little rubber factory utilized what scrap came to it in its own way. It was difficult, if not impossible, to remove fabric except by the so-called mechanical method. This removal was accomplished by grinding the rubber and blowing the fabric in finely-divided form out of the mass by means of an air-blast. The rubber was then subjected to the action of live steam at relatively high heat; the resulting product became known as "shoddy." This process left much to be desired. In the first place, because more or less ground rubber adhered to the particles of cotton and were blown away with it, the yield was low. In the second place, some of the fiber always remained with the rubber and accordingly made its appearance in the finished product. In other words, the "shoddy" was not clean, and it was not much more than a filler.

The first attempts at the use of old rubber are said to have been made many years ago. From 1865 to 1870 but few people used old rubber. One company sent old shoes to the women in the country, who tore them apart by hand. They were paid by the pound for all clean rubber that could be stripped from the cloth in the shoes. At this time Austin Day of Ansonia, Connecticut, commenced to grind rubber, using at first car springs and afterward old shoes.

Since in 1871 there was a demand for rubber free of fiber, E. H. Clapp hit upon the method of subjecting the ground material to an air-blast, the process separating fiber and rubber. For several years this method was used. A number of men, though, tried to free the rubber from fiber more completely. Much secrecy surrounded factory practice. Rubber men, like snails, preferred their shells; therefore who really discovered first the acid process may never be known. But it takes more than dreams and secret chambers to bring about commercial results.

Lieutenant-Colonel Chapman Mitchell, a younger brother of the eminent physician and author, S. Weir Mitchell, after the Civil War went into the sugar business with Harrison, Havemeyer & Co., in Philadelphia. He had a keen perception. Accosted in the street one day by a friend, he was handed some uncured mackintosh clippings. Could he get the rubber back without injury? He saw a future and experimented, and a new industry in the reclamation of rubber waste was born. This was in the early eighties. The finely ground mixture of rubber and cotton was immersed in dilute sulphuric acid and steam was blown into it through lead pipes, the steam warming it to the temperature which permitted the acid to attack and destroy the cotton. As the chemist would say, his process hydrolyzed the cellulose into a form soluble in water. After the cotton was destroyed, the entire mass was removed into a wooden circular tub or washer with a large rotating wooden wheel in the middle, so designed as to permit the wheel to churn the mixture in water. After it was partially washed in this big vat, the entire mass was allowed to flow down an inclined wooden chute called a riffler, which contained cross-pieces or baffles about two to four inches in height and spaced about a foot apart. The heavy particles of sand subsequently removed, would collect against these slats; while the rubber would run on down the riffler into a settling tank. This was a sort of adaptation of the metallurgical ore-washing methods.

After this washing process the rubber was in a condition of relative fineness, although it was still not fit for use; for it was firm, tough, vulcanized rubber, free from cotton. The acid process part of it, therefore, was simply a cotton remover. Consequently, the rubber men conceived the idea of placing the rubber in trays, in a large open cylindrical tank, about six feet in diameter and twenty-five feet long, made of heavy boiler-plates and known as a devulcanizer. When the rubber was put in these trays or placed in the devulcanizer in mass, steam was forced into the tank. The rubber was heated usually to a temperature around 300° Fahrenheit and for a length of time depending upon the type of scrap to be heated. Frequently oils, to assist in the process, were mixed with the vulcanized rubber before placing it in the devulcanizer. The action of the high temperature served to soften the rubber. There was no removal of sulphur: in point of fact, vulcanization went on a little further; but in the presence of steam and oil, the rubber became plastic enough to permit its final mixture with fresh rubber. In time, devulcanizing usually lasted about twenty-four hours. After devulcanization the rubber was removed, dried in air driers, massed on a mixing mill, and thus prepared for reworking.

An acid process from which nothing ever came had been patented in 1863 by C. H. Hayward and D. E. Hayward of Massachusetts. Colonel Mitchell, however, made the process work, and continued in the invention of apparatus until 1889. He instituted a commercially efficient process and organized an industry; for his company, the Philadelphia Rubber Works, was the first commercial enterprise which had exclusively for its purpose the recovery of rubber in the form of the usable product that we call reclaimed rubber.

Because the Mitchell method was particularly applicable to the treatment of scrap in a relatively low state of vulcanization and containing no free or uncombined sulphur, it was effective with old boots and shoes. The soundness of the process is evidenced in the fact that even to-day it is still the standard method of treating boot and shoe scrap. But since hose, belting, and tire scrap are more highly vulcanized and in addition contain varying but always appreciable quantities of free sulphur, this method leaves much to be desired. It was not until the development of the Marks process, the patent for which was issued in 1899, that it was possible to obtain an acceptable product on the devulcanization of these grades of scrap. Before this date, mechanical scraps and tires were of virtually no commercial value.

Arthur H. Marks invented what we to-day know as the alkali process for reclaiming, the most advanced step that had been taken or that has since been taken in making old scrap useful in rubber mixtures. His process consisted in subjecting the ground rubber waste when submerged in a dilute alkaline solution, as for example a 3 per cent. solution of caustic soda, to the action of heat at a temperature from 344° to 370° Farenheit for about twenty hours, while the entire mass was contained in a closed vessel. The finely divided waste being placed in a large horizontal tank within which paddles or other stirring apparatus rotated, the ground rubber with its cotton fiber was constantly agitated in the presence of the caustic soda solution, heat being supplied from a hollow jacket outside the inner container. After about twenty hours of heating, the entire mass was "blown off," as the practical men say, into a large washing vat, where it was washed in running water, the overflow being screened to prevent the reclaimed rubber from running away. The cotton, made into water-soluble or hydrolyzed form, was washed out. The usual processes for removing metals and sand by the magnetic separator and the riffler were carried out; and finally, the mass being dried by warm air on large screens, it was worked into sheets on mills similar to the mixing mills.

Marks's first application for a patent was rejected. But samples were shown in May, 1889, to the examiner, who recognized that something different had been produced—at least, something different from the product of the Hoffer process of ordinary boiling in caustic soda solution, for the plasticity of the rubber had been restored. In the Marks process the combined sulphur is not removed, but a change has taken place. A certain relation of the combination of sulphur and rubber constitutes vulcanized rubber, a material that is tough and elastic, not plastic. After vulcanized rubber has gone through the Marks process, this toughness disappears and plasticity returns; some fundamental change has occurred.

By this process, reclaimed rubber, for the first time, came to be, under the same conditions, similar in character to crude rubber. It was plastic on the rolls; the combining ingredients would absorb readily; it would vulcanize easily with sulphur. It over-vulcanized and under-vulcanized as crude rubber did.

The differences between the reclaimed rubber from the acid and from the alkali processes are great. Reclaimed rubber that has simply been made soft by heatin, as in the acid process, possesses two great disadvantages: small traces of acid, which cause rapid deterioration, now and then are left in the rubber; the tensile strength and other physical properties are poor. The alkali-reclaimed rubber is strong. It mixes well with crude rubber. For many purposes, it possesses all the necessary properties of crude rubber; for other purposes, it is vastly better than crude rubber. Owing to a slight alkaline character that adds to the length of life of the rubber mixture, it has an advantage. Thus has developed *reclaimed rubber,* no longer shoddy.

Chemists and inventors, trying to reverse the vulcanization process, and attempting to split off the sulphur atoms in the vulcanized rubber molecules, called the process "devulcanization."

One could scarcely wade through the mass of patent literature. There have been many hundred patents taken out on different modifications of the alkali process alone. Numerous other substances have been and still are used in connection with it, to soften and give other valuable properties to the resulting mixture. But the basic principle has never been modified and is to-day the one process by which the greatest tonnages of rubber scrap are reclaimed and made usable.

Extremely interesting are the methods by which men have attempted to dissolve vulcanized rubber in various solvents in order to remove the sulphur. I have in front of me a list of 156 different substances that have been tried, either to dissolve or withdraw the sulphur; they have all failed, and to-day the removal of sulphur from vulcanized rubber is probably one of the great unsolved problems in the rubber industry. Perhaps some of these processes do definitely take the sulphur out; but when the sulphur is all removed, the substance left is not rubber but an oil. Rubber is so complex, its affinity for sulphur is so strong, that any known reagent powerful enough to remove the combined sulphur makes the rubber unfit for commercial use.

The development of the Marks process resulted in a large increase in the use of reclaimed rubber by rubber manufacturers. By research in the last twenty years and by perfecting a product that performs a definite function in the rubber compound, the reclaiming industry has eliminated shoddy. Reclaimed rubber has brought about a saving in mixing time and costs and also a decrease in the time of cure. That its use is fundamental in the manufacture of rubber goods has been clearly demonstrated in the last year by the fact that the production of reclaimed rubber has been in approximately direct ratio to the production of the classes of goods in which it has been used. The industry to-day rests upon the Mitchell patent and the Marks patent. Scores of other patents have been granted, but the processes have lacked some essential feature; either they were too expensive, or the agent used caused the rubber to deteriorate, or the resultant product was not so good as that already on the market. This does not mean, though, that future developments may not be as revolutionary and sound as the two patents already mentioned.

For the year 1921 the amount of crude rubber used in the United States was 345,599,000 pounds, and of reclaimed rubber, 76,508,000 pounds. It is an article of tremendous importance and necessity in our economy. There is no question of its value; articles made from it age well. Like any other material used in this complex and intricate industry, though, reclaimed rubber is one that requires a knowledge of it and of the purpose for which the resulting article is intended, in order to make its use justified. Even raw rubber must be used with some degree of care.

Reclaimed rubber, therefore, plays a large and valuable part. Just stiff enough when in an unvulcanized condition, it makes manufacturing of many articles more easy. Reclaimed rubber is not used where the maximum tensile strengths are required, any more than pure crude rubber alone is used where toughness or resistance to abrasion are required. For the tough, resisting service in a rubber heel, in footwear, in rubber bumpers, in wire insulation, in carriage cloth, reclaimed rubber serves, and serves well.

Many people seem to feel, usually without a knowledge of the facts, that reclaimed rubber is not a valuable material for use in rubber mixtures. If it were not used, there would be a tremendous waste that rubber users should not sustain.

If this little story frees the reader's mind from any idea that reclaimed rubber is something inferior, it would be well. Reclaimed rubber is not inferior; it is just different. It is true that one can make inferior products from the best of materials; therefore in the handling of reclaimed rubber, intelligence is required. That during the period of low-priced crude rubber so large a tonnage of reclaimed rubber has been used is one of the best arguments in favor of its value and quality.

The utilization of scrap rubber through reclaiming is an economic achievement.

CHAPTER VII

THE CHEMISTRY OF RUBBER MIXTURES

This is a chapter of details. But chemistry is a science of details, of little things, of explanations.

In Malaya we could go into the orchard and gather a quart of milk from a rubber-tree, and then bring it back to the laboratory and ask the chemist to look it over. True to the habits of his kind, he would say, "I know what that is, and how it is put together." He would know only some facts and theorize on the rest.

As it runs out of the trees, the latex is a milky fluid consisting of water in which are suspended minute globules of rubber. These globules are solid, not liquid. Very fine in subdivision, they measure from five ten-thousandths to three ten-thousandths of a millimeter. It is stated that they are so numerous that one gallon of latex contains more than two hundred billion of them. If we were to lay out these little globules side by side, we should find that those in one gallon would make a minute rubber thread 372 miles long. When observed under the microscope, they seem to be somewhat irregular in shape. Since they are solid, we term the latex a suspension of solid particles. If the rubber were liquid, we should call the latex an emulsion. Milk as it comes from the cow is an emulsion.

When the chemist analyzes the latex, he discovers it to contain on the average 28 per cent. of the chemically pure rubber; resins, which are substances soluble in the chemical known as acetone, 2 per cent.; mineral substance from 0.3 to 0.7 per cent.; components containing nitrogen, which the chemist calls by the general name of proteins, 1 to 2 per cent.; sugars dissolved in the water of the latex, 1.1 to 2.3 per cent.; and water, about 60 per cent. From the latex may be obtained 30 to 35 per cent. of commercial raw rubber, which contains various of these substances.

Proteins or nitrogen substances play an important part in the latex. Modern chemistry has learned how small quantites of them assist in the formation of emulsions and suspensions because they seem to prevent the separation of the emulsified substance from the water. When you buy cod-liver oil as a medicine, as most people do at one time or other, you see a nice white emulsion. It would be quite possible for the druggist to make you an emulsion of cod-liver oil by the simple process of shaking together the oil and water; but, on standing in the bottle, the oil would separate in a layer by itself. Physicians have found it wise to give cod-liver oil finely divided with water in the form of an emulsion, because it digests readily. In order to keep the preparation, therefore, from separating into two layers, casein is added to it, which has the peculiar property of protecting the globules of oil and keeping them away from each other.

Nature has prepared for us a suspension in which she has put in a substance, namely, the protein, that permits a high degree of dispersion of these fine particles and prevents their rapid coalescence into a layer separate from the water. The substances that play this part in preventing the coalescence of suspended or emulsified globules are known as protective colloids. Different rubber-trees seem to have different protective colloids. Because the latex of the *Hevéa* tree is very stable, the rubber from it does not tend to separate or float to the surface in the form of cream. The latex of the African trees and the latex from the Central American trees seem to have in them different protective colloids; for, on standing, the rubber floats to the top.

A gallon of latex weighs 8.17 pounds and contains from 2.45 to 2.85 pounds of raw rubber. To supply the world with 250,000 long tons of rubber requires, therefore, in the neighborhood of 224 million gallons of latex. The difference in composition between rubber latex and milk is striking, for the cow has nothing like the efficiency in production of the substance most desired from it, namely the fat, cow's milk showing only 3 to 6 per cent. of butter fat. These two milks, the vegetable milk and the animal milk are, therefore, radically different.

On the plantations, it has become necessary to handle latex as rapidly as possible,—in any event, to limit to certain reasonable and well-known lengths the time between its collection at the tree and its coagulation in the shed or factory, because as soon as it comes into the air from the tree it begins to decompose and to be acted upon by bacteria. Coagulation, the change that is required chemically in the latex, is the alteration of the protective colloid. The addition of acids changes the latex in such a way that the proteins are no longer able to prevent the globules of rubber from running together. The first step in the chemical change of latex is to add acetic acid in dilute solution. It is used in dilute solution because the quantity of protective colloid is small and but little acid is required to alter it. Strictly speaking from the chemical point of view, the nature of its alteration is unknown. It is evident, though, that acetic and other acids will cause coagulation.

We know that when latex is allowed to stand it gradually becomes acid from the action of bacteria on the proteins; just as when a glue and water solution is allowed to stand, it changes to acids through the action of bacteria and fungus growth. By any kind of coagulation, though, the rubber itself is not changed; the little particles that were held apart in the water solution simply mass together.

If latex is allowed to coagulate spontaneously, a disagreeable odor develops, which persists until vulcanization. When coagulation occurs by acetic acid, however, the rubber is odorless. Although other acids, such as formic acid and sulphuric acid, have been used, more than 95 per cent. of the raw rubber is now prepared on the plantations by the use of acetic acid. It in no way injures the quality of the raw rubber.

Let us now turn to the raw rubber itself and examine the facts that chemists have learned regarding its characteristics and properties. The first and most important one is the variety of substances contained in it. Rubber itself, free from these substances, is a hydrocarbon. An interpretation of this chemical term means that it is composed of only the chemical elements carbon and hydrogen. Raw rubber contains from 92 to 94 per cent. of the rubber hydrocarbon. Besides this, it contains moisture, mineral substances, resins,—which are simply a variety of chemical individuals soluble in acetone,—and the proteins. The composition is about the same as that of the latex, with the water and the ingredients dissolved in the water, or serum, removed.

In the laboratory the chemist, who with beaker and combustion furnace analyzes the hydrocarbon, finds it to be made of five carbon and eight hydrogen atoms. But there are several other hydrocarbons that show the same constituents on analysis. The rubber hydrocarbon is a distinct one. Therefore he has come to believe that several of these C_5H_8 groups are united physically (he says "polymerized"), and he expresses the composition $(C_5H_8)_x$.

But the chemist is a singular fellow. He has learned that the terpenes, of which turpentine is one, have a composition $C_{10}H_{16}$. So he calls rubber $(C_{10}H_{16})$. Among his technical friends, he goes further and draws a picture of the hydrocarbon, in which the exact relation of each element to the other is shown. Since the chemist loves these pictures, we shall leave them to him. They belong to the most intricate field of organic chemistry, and the rubber structure to the most intricate of them all.

Rubber may be made artificially by heating the oil "isoprene." The chemical process, which consists in the addition of one molecule to another, forming a succession of these groups linked together into a ring of uncertain dimensions, we call "polymerization." How far the chemical composition, the state of polymerization, or the state of aggregation of the polymerized masses, affects the properties of crude rubber as we know them, and how far the hydrocarbons from trees of various ages differ chemically and physically, are all unknown phases of an interesting problem. We do not know the part played by mineral substances or the exact condition of the nitrogenous matter, although the proteins have a most important influence upon the characteristics of the rubber.

The other substances in raw rubber after coagulation are not deleterious impurities. They are of wonderful advantage by assisting in resistance to oxidation and by helping in vulcanization.

To determine the percentage of acetone-soluble matter, much study has been done by some chemists in the analysis of rubber. Rubber from different botanical species varies largely in resins. The plantation rubber coming from the *Hevéa* tree seems to produce the smallest amount of any. The *Ceará* rubber, the *Ficus* rubber, that is, those from Central America and Africa, on extraction in acetone yield resinous matter as high as 7 to 10 per cent. The *guayule* rubber shows 20 per cent. of a liquid resin. Lower grades, such as the scrap, the rubber that has fallen upon the ground, and those grades that have been allowed to dry in the bright, hot sunlight, seem to have decomposed a little; as a result, the amount of substance to be extracted by acetone has increased. The rubber resins are highly complex, and whether they are the original source of rubber in the tree or whether they have been produced from the rubber we do not know. Probably to-day the "acetone extract" is the one reasonably reliable means of determining the botanical origin of different grades, and the fresh from the deteriorated rubber; although the control of quality in a finished article can be carried on irrespective of the origin of the rubber. The amount of resin extracted by acetone is not, as some have believed, a guide to the quality of a vulcanized rubber mixture.

A chemical property of the rubber hydrocarbon is unsaturation. It adds directly halogens, halogen acids, sulphur, and sulphur chloride, as well as certain other substances.

The story of synthetic rubber has been much discussed. Artificial rubber is well-known. During the World War much work was done upon it in Germany, where considerable quantities were produced; but it was not the same hydrocarbon as that derived from the tree. It was a close relative, known as methyl rubber. But the tires and other soft rubber articles made from it were decidedly inferior in service. It was, however, valuable in hard rubber or ebonite.

After its coagulation, one can think of rubber as a body made up of innumerable round globules of rubber in the form of a sort of microscopic mass of fine shot, each of which is surrounded by a thin film of protective colloid, the protein substance. Thus, raw rubber has a structure. It is not like glass, which is homogeneous; not like leather, which is a mass of fibers; or like wood, which is a mass of short, thick fibers.

The probability of this structure is interestingly proved by the action of rubber when it is softened or masticated, as we call it, on a mixing mill. If our theory be correct, some of the toughness of rubber in its raw state is due to the harder nature of the surrounding protective colloid. The use of this term, protective colloid, when one is speaking of rubber in the mass is not exact; for it really is a protective colloid only when the rubber is dispersed through the latex. Nevertheless it still surrounds the particles of rubber. These proteins are probably stiff like glue; because when masticated on a mixing mill, the rubber becomes softer from the breaking up of a certain amount of this structure. After prolonged mastication, it is not so tough as before.

The rubber, when mixed, is passed through a machine known as a calender in such a way that it issues in the form of a thin sheet. Even after vulcanization, the rubber is found to show a difference in strength in the direction of the passage through the calender from that at right angles to it. For years the rubber man has observed this property, which is known as "grain." It is quite possible that the little rubber particles are stretched during the process of calendering, so that we may imagine them in the form of elongated fibers very minute in size, rather than as little spheres. Since they probably overlap each other in somewhat the same way as fibers of cotton during the twisting of cotton fiber into thread, one may readily picture them a series of little rubber threads, naturally tougher in the direction in which the fibers have been stretched.

In another way we have proved that there is a structure in rubber, which structure is changed and broken by the process of mastication. Raw rubber, in a sense, does not dissolve in solvents. One may say, rather, that the solvents dissolve in rubber. If a piece of rubber is allowed to stand several hours, for instance, in benzol, in gasoline, or in carbon bisulphide, it swells to several times its original size. The solvent has, therefore, penetrated and dissolved in the rubber. When, however, in the regular course of cement making, the rubber is beaten or stirred so that mechanical action is applied upon it, a cement is obtained which is really a distribution of the swollen and softened rubber in the balance of the solvent that has been used; that is, a colloidal solution has been obtained. The difference between a colloidal solution and a true solution lies in this fact; a true solution, such as salt in water, is one in which the solid has passed into the liquid in such a way that the properties of the solution are homogenous.

When we make this colloidal solution in benzol, using only 2 per cent. of rubber that has never been passed through between the rolls of a mixing mill, and compare that with a liquid of the same strength but which has been softened or masticated by a mixing mill for about twenty minutes, we observe a distinct difference. The solution that contained unmasticated rubber is thicker and more viscous than that containing the masticated rubber. This has led to a belief in raw rubber structure, which structure has been broken down by mastication, so that the little films of protein are broken up and distributed into the rubber mass. Just what the structure is, what it means, and how to change it, are problems yet to be solved by the research chemist.

After all, what is vulcanization? Ever since the discovery of the process, chemists have worked upon this question. There are numerous theories. One thing we do know, however, that sulphur in some way actually combines with the rubber molecule. Rubber has an affinity for sulphur; and once it has taken sulphur on, there is no divorce court known that can separate them. Probably divorces never leave the parties thereto in just the same mental state; therefore, while by drastic chemical methods sulphur has been removed from rubber, the rubber is never the same in physical properties as it was before its union with sulphur. When only about 2 per cent. by weight of sulphur is added to rubber, it serves to produce a soft, strong, stretchy composition. During a study of the basic principles of vulcanization, when a sample of rubber containing 10 per cent. of sulphur was heated even for a long period of time, all the sulphur did not combine. Some of it remained as free sulphur. Investigators analyzed samples regularly over a period of several hours, and found that the sulphur combined with the rubber steadily. There is no chemical compound formed during the vulcanization of soft rubber; the process is continuous. The amount of sulphur that enters into combination with rubber increases with time and rise of temperature; when the time and temperature are constant, the amount of sulphur entering into combination with rubber is dependent upon the quantity of sulphur originally present.

Once it was believed that sulphur did not combine with rubber until the temperature had passed the melting point of sulphur; but this was definitely disproved a few years ago by a chemist who permitted a mixture of rubber and sulphur to stand at relatively low temperatures, one sample at 122° Fahrenheit, over periods of days up to eighty. He found the same regular combination of sulphur with the rubber. So vulcanization does go on at ordinary temperatures, but slowly.

When small amounts of about 3 per cent of sulphur are combined, as we say, with rubber there results the soft rubber of commerce. During the time of heating, while the essential process of vulcanization occurs, all the sulphur is not combined; there is an excess called "free sulphur." Shortly after the rubber is removed from the mold at the end of the vulcanization, the color at the surface is that of the mixture itself. When the rubber stands for a little while, however, an interesting change takes place; for this excess sulphur, or "free sulphur," begins to crystalize and separate itself from the rubber. Probably dissolved in the rubber during vulcanization, on cooling and standing it separates. At the surface, we find it coming out in the form of a gray powder called "bloom."

Essentially all rubber articles show bloom, or "sulphuring up," on the surface. To be sure, there are some of them such as boots and shoes and colored water-bottles wherein a freedom from this gray powder is desired. It is very difficult for the rubber chemist so to design his composition that bloom will not occur. In doing this, in order to combine all the sulphur, he uses the minimum quantity and vulcanizes for as long a time as quality permits. Even then, there is a small quantity of uncombined sulphur that may, under particular conditions, come to the surface as bloom. The sulphur crystallizes also inside the mixture. A sheet of rubber cut after standing twenty-four hours shows under a microscope beautiful crystals of sulphur. The photograph shows this internal crystallization. Bloom, though, does no harm. In point of fact, up to the limit of our knowledge at the moment, the strongest, toughest articles show bloom. Some day, however, we may find means of overcoming it; although it is not deleterious. It is singular, too, how sulphur, which was a yellow powder mixed into the rubber in the beginning, comes out on the surface as a gray one.

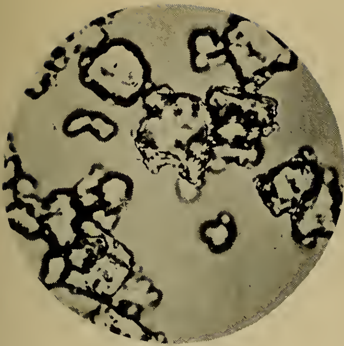
Sulphur is one of those interesting chemical elements that seems to have the power of existing, like *Dr. Jekyll* and *Mr. Hyde,* in more than one form. The chemist calls them allotropic forms. Interested in what the form is, the crystallographer finds that each is a different crystal, with edges and faces variant. The rubber man finds the yellow sulphur that he originally mixed comes out on the surface as a gray bloom; the casual notice of that change is about the extent of his interest.

The time and temperature of vulcanization are the two necessary outside factors giving the proper quality to the rubber composition. The rubber man must observe these in just about the way the cook must observe the time and temperature of cooking different cakes. When the young housewife puts the wrong substances or the incorrect proportions into her biscuits, she bakes soggy ones. If she leaves them in the oven too short a time, they are underdone. Likewise, if the rubber man removes his mixture from the press and the mold too soon, he finds the rubber to be weak, somewhat sticky, or, as he calls it, "undercured." If he leaves it in the right length of time (there is a large leeway usually), he finds it strong, not tacky, and resilient. If he leaves it in too long, it becomes like overdone roast beef, dry. On breaking, it is found to be short, that is, it breaks at a shorter elongation than it should. He calls it "overcured," or he says it is burned. By long, sad experience, he has also learned that it does not age well, but gradually becomes harder and harder, taking on oxygen from the air with much greater rapidity when over-cured than when either under or correctly cured. The time and temperature of cure for each composition, or the adjustment of the composition to cure at a time and temperature for some factory practice, is one of the most essential of the rubber chemist's duties.

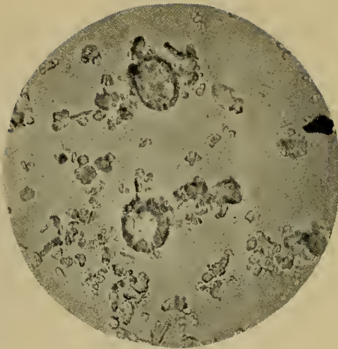
There are wide and, to the manufacturer and consumer, vitally important differences in physical properties between under-cured, properly cured, and over-cured rubber articles. Still we have as yet only theories of a general character to explain the nature of these products of vulcanization. The amount of combined sulphur, when expressed as a percentage figure in terms of rubber as 100 per cent., is known as the coefficient of vulcanization. No chemical individual of the rubber hydrocarbon and sulphur has been isolated from soft, vulcanized rubber mixtures.

When a large excess of sulphur is used in a mixture, addition goes on up to a maximum of 32 per cent. of combined sulphur; and there results the only chemical compound that yet has been isolated—a mono-sulphide C_5H_8S, or, as usually written, $C_{10}H_{16}S_2$. It is, in the laboratory, a brown, dry powder. In the factory and in commerce we know it as hard rubber or ebonite, used in battery jars, sheets, fountain-pens, and the like. It is highly resistant to the action of chemicals. Around hard rubber has developed a sort of separate industry, to be discussed in a later chapter. It is a rubber industry, to be sure, but an industry wherein stiffness, strength, freedom from action of chemicals, and a high degree of resistance to penetration by electrical charges are required.

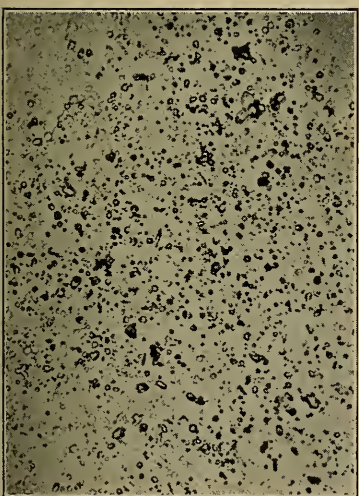
Many discussions have arisen between two camps of chemists; those who expound the sulphur absorption theory of Ostwald and those who stand by a chemical theory. The great rubber chemist Weber was an exponent of the chemical theory. Chemists to-day adhere to a combination of a chemical and physical theory as most reasonable for the explanation of vulcanization. The fact that no compounds have yet been isolated in the soft rubber range of vulcanization is no reason for us to believe that a purely physical theory alone will account for it. Carl Otto Weber will ever remain in the minds of rubber chemists as the most notable leader. Born in 1860, of German-Scotch ancestry, he studied chemistry in Germany and migrated to England, where for some years he was a managing chemist in a rubber factory. A prolific contributor to technical literature, an indefatigable research chemist,



BARYTES

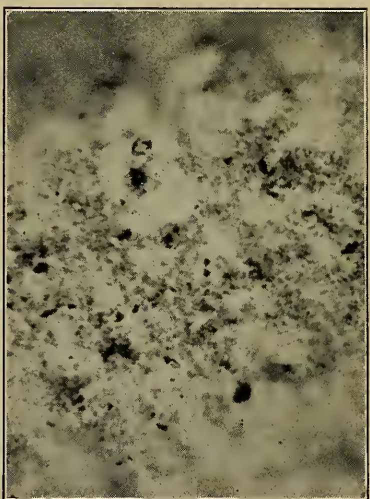


WHITING



Courtesy of The New Jersey Zinc Co.

ZINC OXIDE



CARBON BLACK

PHOTOMICROGRAPH OF BARYTES, ZINC OXIDE, WHITING, AND CARBON BLACK, COMMONLY USED IN RUBBER MIXTURES. MAGNIFIED 1500 DIAMETERS

he became a leader in things rubber. He finally came to America, where he died in 1905. Weber may truly be called the father of rubber chemistry.

Besides the one described, there are other methods of vulcanization. Shortly after a knowledge of sulphur or "hot" vulcanization was obtained, Alexander Parkes, a chemist of Birmingham, England, having seen the result of Hancock's work and his patent specifications, immediately went to work and tried the effect upon raw rubber of all the compounds of sulphur that he knew. At length, in 1846, he succeeded in obtaining a vulcanized rubber by immersing a sheet of raw rubber in a mixture of 100 parts carbon bisulphide in which had been dissolved two and one half parts of sulphur chloride. After immersing it for about one and a half minutes to three minutes and drying it, he found his material to be stronger than it had been and resistant to heat and cold. Thus the discovery of vulcanization by a different method was made known.

Chemists have found by further study the significant fact that sulphur chloride, which is expressed chemically S_2Cl_2, like sulphur, combines with the rubber molecule. Even though the results are essentially the same as in the first process, because of the highly corrosive character of sulphur chloride, the use of this material has been limited to combination with raw rubber into which no other substance has been mixed. But that discovery has been important to you; since you probably use it when sitting in the dentist's chair, as the rubber dam to keep saliva from moistening the cavities that have been opened by the dentist is one of its products. The rubber is cured, however, at low temperature; that is, the ordinary room temperature. No more is known of the real chemistry of this process so far as soft rubber is concerned than is known of the hot or pure sulphur vulcanization. We do know that when an excess of sulphur chloride is used, a chemical compound approximating $(C_{10}H_{16})S_2Cl_2$ is obtained. This is a dry powder with no valuable properties. It corresponds chemically to the product obtained in hard rubber.

In recent years two new processes of vulcanization have been developed. One of them was first discovered by a Russian named Ostromislensky, who discovered how certain complicated organic compositions, derivatives of coal-tar, when mixed with rubber and heated, cause a stiffening, an increase in strength, and a resistance to temperature change quite similar to that obtained when sulphur is used. He has not, however, succeeded in producing any substances that have the tensile strength given by sulphur during vulcanization. The process is interesting from a chemical point of view. It may lead us ultimately to a clearer knowledge of what vulcanization is, although the field is a large one and will probably take years for a complete solution of its problems.

Within the last few years an Englishman, S. J. Peachey, patented a method of vulcanization at ordinary temperatures. When crude rubber in a form such as sheets, clothing, etc., is treated with sulphur dioxide gas, it is rapidly absorbed into the rubber much as vapor of solvents is absorbed. When this absorption is complete, the rubber is saturated with hydrogen sulphide. These two gases interact, with the formation of sulphur in a very active or, as the chemist calls it, nascent condition. It is so active, in fact, that it adds itself to rubber very easily at room temperatures, giving thus a process of vulcanization that is different from any of the others, although the basic principle is that of addition of sulphur to rubber. These processes are being worked out in England and, to a degree, in this country; but they have not yet become a large factor in our rubber markets.

The most striking advance in the chemistry of vulcanization has been made with the use of organic accelerators. The first inorganic accelerator was white lead, used by Goodyear in 1839. The chemistry of this type of accelerator, so far as known up to recent years, was that of the old idea of the carrier. Serving to attach to itself sulphur, and then letting go of it, white lead gave the sulphur to the rubber in a shorter time than the rubber could take it up alone. Without knowing exactly the condition in which the sulphur was when given to the rubber by white lead, the chemist supposed, in any event, that the sulphur was made more active by the use of this catalyst.

With the coming of the organic accelerator, many chemists have tried to find out exactly why it acts so rapidly. Despite the large number of these organic substances, the idea was prevalent for some years that only those containing nitrogen were sufficiently powerful for practical use. Thus, the derivatives of aniline, or, as it is known to the chemist, aminobenzene, were employed, and various more intricate modifications and derivatives of aniline. Lately, however, chemical compounds that contain sulphur have been employed.

These facts have led chemists to search for the cause. To make a long story sufficiently short, these investigators have learned that vulcanization occurs most actively when the accelerator first adds sulphur to itself, and then separates off the sulphur in a particularly active condition. The accelerator with its extra sulphur chemists call a polysulphide. It acts like a dump-cart—quickly loaded, quickly unloaded.

The real chemistry of the properties possessed by vulcanized rubber when in contact with oils such as benzol, gasolene, or heavier lubricating oils, is not known. Raw rubber absorbs these oils and swells; vulcanized rubber likewise absorbs them and swells. Some substances cause vulcanized rubber to swell more largely than others; and some cause vulcanized rubber to shrink. Methyl alchohol, wood alcohol, or grain alcohol will shrink vulcanized rubber slightly. Some substances produce no change. The derivative of benzol known as toluol swells vulcanized rubber slightly; benzol swells it to nearly double its size, but carbon bisulphide to more than double. But this swelling is the end of the effect; it is not possible by heating or by any other method to make vulcanized rubber into a colloidal solution. Oiled roads, therefore, are not particularly good for tires.

In an earlier chapter we have considered powders and their effect in rubber mixtures. Why do these substances act as they do? It is a most interesting question, and one that is probably not yet wholly solved. Let the microscope tell its story. An examination of the photomicrograph of zinc oxide and some other substances used in compounds shows these substances to be very small. It is doubtful whether the ultimate particle of carbon-black has ever been seen under the microscope. It is probable that the larger particles shown are aggregations, and that even the smaller ones may be minute aggregations. When the microscopist measures these, he observes as closely as he can the particle-size expressed in diameters, as though these little particles were spherical in shape. The diameter of carbon-black is less than two ten-thousandths of a millimeter; that of zinc oxide is about five ten-thousandths. Other dry pigments are all larger in size. Not only do the photographs show the particles of carbon-black and zinc oxide to be finer in size than those of the barytes, but they vary in structure and do not seem to have the sharp angles and faces evident in the barytes. Here the chemist has made good use of the microscope, as you see in the photographs.

These finer-grained materials may be classed in two groups: finely divided colloidal particles and all others. Colloidal particles are those of gas-black, zinc oxide, lithopone, some grades of clay, magnesium carbonate, and many others. The "all others" include barytes, asbestine, whiting, and a large number of mineral substances. There is no clear line of division between these groups, except in the process of manufacture, the size, and the specific action in a rubber mixture. After all, rubber, as the consumer gets it, is not a simple mixture of rubber, sulphur, accelerator, zinc oxide, and carbon-black; but, to meet the demands of numerous physical properties required for service in the form of shoes, adhesive layers, treads, and belt covers, other materials must be used. We have found in recent years how these materials serve practical purposes and are not simply cheapening fillers. In point of fact, many powders now cost more than crude rubber. The rule-of-thumb methods are gone from the leading laboratories, but the variables are so extended that the service test has become the final criterion of the value of any mixture.

While we have developed research laboratories to show us why, development departments to show us how, testing machinery to give us results, we, nevertheless, are constantly faced with the question: Will rubber age? Rubber is a perishable product. For any purpose, a knowledge of the rate of deterioration is most advantageous, because the problem is a vital one to manufacturer and consumer. Heat, light, oxygen, and sulphur play their parts in the tragedy; but, as yet, no definite theory to account for the varied rate of aging has been proposed. In the vast majority of cases, too rapid decay is due to over-cure of the mixture, or improper conditions of storage. Differing in practice from that of the old days, chemists have determined means of testing the rate of aging. Various types of apparatus have been developed, until to-day it is possible within a space of two weeks to predict fairly confidently the length of life of any given composition; at least, the prediction can be made by comparison with compositions of a known length of life.

All rubber goods should be stored in the dark and kept as cool as possible. Both these factors are under the control of the user. Even though the rubber chemist makes his compositions the best he can, it still is necessary for the consumer to coöperate with him by keeping away these two active forces, heat and light, if he, the consumer, desires to maintain his rubber products for the maximum time. How long should they remain strong and serviceable? That depends upon storage conditions, because over-cure has pretty generally disappeared. In hot climates one should expect trouble; under temperate and cold conditions, very little.

CHAPTER VIII

THE BICYCLE TIRE

When Nancy Hanks in 1892 trotted a mile in 2:04 and clipped over four seconds from the best previous record, she not only established a mark for horse racing, but she earned a place in the hall of rubber fame. For the first time in history, pneumatic-tired wheels were used successfully on vehicles other than bicycles. She drew the bicycle-wheeled sulky. Her performance announced to the world that pneumatic tires on wheels were speedy. In a few months the steel tires disappeared from sulkies and the solid tires from bicycles.

As the forerunner of the automobile, the bicycle expressed a human desire for faster and more comfortable transportation. The history of the bicycle began in Germany in 1816, with the first vehicle upon which man rode and propelled himself. A year or so later, the old dandy-horse or hobby-horse was developed in England and introduced into America. The bone-shaker (a descriptive name), driven by the feet alone, and steered by hand, was exhibited in Paris in 1865. It was a two-wheel velocipede with foot cranks and two wooden wheels equipped with iron tires. For several years this was quite popular, but it was too uncomfortable to serve for long.

About 1870 C. K. Bradford suggested rubber tires, and so for a time solid, round tires were used. By 1877 the tire had evidently given sufficient relief from discomfort to warrant the organization of the Pope Manufacturing Co., to make bicycles with solid rubber tires. Riders shook themselves upon these until 1888, when John Boyd Dunlop of England, in an attempt to satisfy the cravings of his small boy, invented a type of tire that was the first practical application of the pneumatic tire. He had, to be sure, been antedated in principle, as he himself admits, by several inventors, particularly Robert W. Thomson in his idea of a carriage wheel as early as 1845. Thomson, an Englishman, wished to make carriages easier to draw, noiseless, and more comfortable. He made the first single-tube tire of several plies of canvas covered with rubber—"sulphurized India rubber and each fold connected to the one below it by a solution of India rubber." He blew it up with air. The affair was crude, but the inventor was far ahead of his time.

Dunlop, a veterinary surgeon in Belfast, Ireland, unlike Thomson, brought out his idea opportunely; but it might have been neglected, except for the foresight of Du Cros, prominent enthusiast in Irish racing. Du Cros organized the Dunlop Co., doing much to make the Dunlop tire practicable. This is another one of these instances where mere invention has not signified application. Many inventors are so far ahead of their times that their work falls into the discard; and it remains for others really to develop the ideas and put them on the market in form for real use and service. That inventor who fits his work to an immediate need and combines it with business acumen and manufacturing facilities is he who makes the greatest success. From Dunlop down to the present, the bicycle tire has been continually improved, filling the changing needs of service.

This first Dunlop tire was an outer casing of several plies of rubberized canvas, with means of inflation. Bound about each of the wheels of a tricycle owned by a young son of the inventor, it was held to the rim by wrappings of tape. Thus the bicycle tire came into being, to fill the needs of youth. It was called the "pudding tire" and was generally ridiculed. It was, however, faster on the road and more resilient than the solid tires of that day. The patents granted resulted in the formation then of one of the world's most important tire companies, the Dunlop Pneumatic Tyre Co., Limited, of England. Living until October 23, 1921, Dunlop came to see his work and the company which bore his name a tremendous success, and to see his invention used on millions of bicycles and automobiles.

Tape wrappings to hold a tire on a felloe did not last long enough. To improve them, there came several inventors; among them, Pardon W. Tillinghast, in 1892, with a perfected single-tube tire, a valve, and a method of attaching the tire to the rim. He had vulcanized into the form of an annular ring, an inner tube, a supporting layer of fabric, and an outer wear-resisting cover. He endeavored to improve Dunlop's tire, because he thought the tube would chafe against the casing. His invention was put on the market under the name of the Hartford Tire, manufactured by the Hartford Rubber Co.

It is stated that the pneumatic tire factory of George R. Bidwell Cycle Co., of New York City, in April, 1891, turned out the first pneumatic tires on this side of the Atlantic.

Probably the one other patent of most interest is that of Thomas B. Jeffery of Chicago, who in 1892 developed an improvement in form of a specially designed clincher tire of a double-tube character. He worked out new means of securing the tire to the wheel, of diminishing danger of puncture, and of preventing a leakage of air that would occur with a puncture. Even though the prevention of leakage was not highly successful, the idea of a clincher rim was quickly taken up in coöperation with a Mr. Gormully. The Gormully and Jeffrey tire, or the G. & J., as it was called, was for many years one of the most prominent and widely used types of bicycle tires. In fact, upon this clincher rim principle as almost simultaneously developed in France, the original pneumatic tires for automobiles were based. Morgan & Wright of Detroit also invented modifications of value.

In these years, the bicycle became increasingly popular, so much so in fact that many a rubber company making tires may be said to owe its survival in the panic of 1893 to the popularity of this means of locomotion. Tire making progressed rapidly in Europe simultaneously with development in America.

In England in 1893 the original pneumatic tire made by the Pneumatic Tyre and Booth's Cycle Agency, Limited, and commonly known as the "Dunlop" from the name of the inventor, holds the place of honor. Not only this, but the patents had been admitted by nearly all the tire makers; and these were paying royalty. The 1893 pattern consisted of an air tube and an outer cover backed with strong canvas. Through the edges of this canvas continuous wire rings passed. These rings were smaller in circumference than the edge of the rim, but greater than the center; and when the tire was inflated, they rested midway between the two and could not slip off. The tire was fast, comfortable, and tough. Then there was the Scott tire; and next came the Michelin tire, which was secured to a nearly flat rim by steel rings. The Seddon tire was another pattern. Another group of tires may be described as the clincher variety, the cover being secured to the rim by the pressure of the air. The clincher, made by the North British Rubber Co., was the originator of this class. There were several others.

The Philadelphia Cycle Show in February, 1893, marked a turning point of moment in tire history, for there the first cord tire was shown. The inventor was John F. Palmer of Chicago, and the manufacturer, the B. F. Goodrich Co., of Akron. He attempted to embody a principle that secured the closure of any ordinary puncture that might occur in the tread. But it did not close punctures. Have we ever seen a tire that did?

Bicycles were soon everywhere. Bicycle racing became a sport of parts. In Europe, where the automobile development has not progressed in proportion to population so rapidly as in this country, the bicycle is to-day seen upon the public road to a very much greater degree than here. In France in 1921 there were over 4,000,000 bicycles; in England, about 5,000,000; and in America about 5,000,000.

The bicycle tire of the single-tube variety is made to-day in largest numbers in America; in Europe the double-tube predominates. A bicycle tire in the United States is simply a tube, round in section and circular to fit the wheel, made of several layers of light fabric, proportioned to the degree of load that it must carry, with an inside layer of rubber to hold air, an outside layer of rubber to resist abrasion, and layers of rubber between the plies of cotton to hold them together, and the whole thing vulcanized in one process.

If we were to go over into the bicycle tire department of any of the several manufacturers, we should find a process about like this: Frictioned and coated fabric to make up the plies giving strength to the tire has been previously prepared in the calendar room, where compounds are used that experience has proved good for the purpose. The rubber inner tube is laid upon the bias-cut fabric. These layers are as long as the circumference of the tire and as wide as the length around the section of it. A little extra is used to overlap or splice the edges and ends. The workman now overlaps and sticks the edges of tube and fabric together from end to end around a short, curved, hickory form, while the fabric lies upon a sheet-iron drum. Then he attaches the valve-stem, the form is pulled out, and the opening closed. The outside rubber parts, tread and side wall, are applied in sheet form, after which process a drum a little larger is pulled over the now formed tire, and air is blown into it to press it between the drums. The outer drum by a quick motion is pushed along the inner, an action which serves to roll the inflated tire between the two drums and thus force all parts to stick together.

The unvulcanized tire is formed in the same shape and size in which it comes into the market. It is taken to the vulcanizing or curing room, where it is laid in a two-part mold or doughnut of metal that has been hollowed to the exact size of the outside of the tire, the valve projecting out through an opening into the hole in the doughnut. The top of the mold having been laid on, the mold is put into a hydraulic press, where pressure upon the mold closes it. Steam is then applied inside the tire, inflating it against the resistance of the heated mold and causing the rubber to flow into the markings that give form to the tread. Because of the heat of the steam inside and the heat of the mold from the steam in the press plates outside, the rubber composition quickly vulcanizes.

This is the simple method of making a bicycle tire composed of square-woven fabric. There are, however, bicycle tires of cord construction. The first cord tire, the Palmer cord bicycle tire, showed so much greater resiliency than the square-woven fabric bicycle tire that many a race was won by means of it. It was an expensive tire to build, for it was before the days of the conception of a loom-prepared fabric made of cord. Nowadays, cord bicycle tires are made from the same type of fabric, although lighter in weight, that we use in automobile cord pneumatic tires.

There are several different weights: there are those made of heavy fabric, suitable for all commercial and utility purposes; there are medium-weight tires, which should be the choice of the average rider who uses his machine for general purposes; and there are the light-weight tires for the man who wishes to go at the highest speed or to enter races.

Here, the quality of rubber and the construction of the fabric make great differences in the resiliency and speed. As in the case of all articles, the rubber chemist designs his compositions each for a particular purpose; thus the tread is carefully worked out to give resistance to abrasion, and the friction or layers of rubber which hold the plies of fabric together are designed to do that particular thing during the life of the tire.

The bicycle has come into our lives to stay. It is a light, convenient little machine, which transports people easily and quickly and at the same time gives them some exercise.

But as the boy, so may the man become. The bicycle tire prepared the way for the automobile tire. It set men thinking, too, about good roads. We owe much to Colonel Alfred A. Pope, who in 1893 sent out to the newspapers a circular letter urging the people of the country to petition Congress for the establishment of a Road Department and Institute of Road Engineering. He was the pioneer in this country for good roads. If the bicycle tire did nothing else it stimulated highway construction.

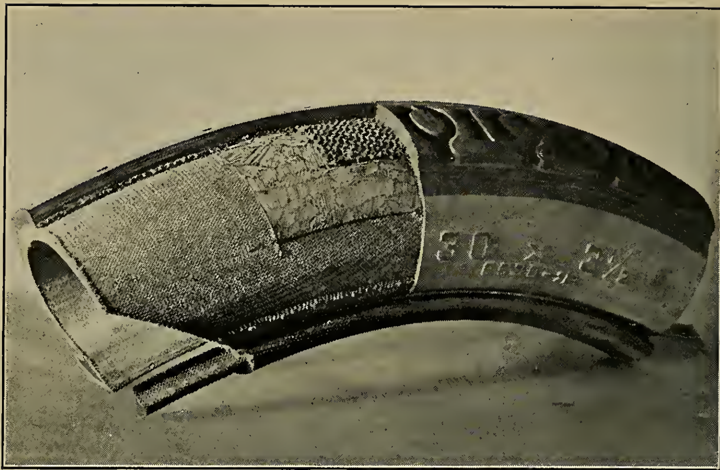
CHAPTER IX

THE PNEUMATIC AUTOMOBILE TIRE

In China there was a horseless vehicle before 1600. Vehicles propelled by foot and hand were known in Europe in the seventeenth century. A French physician made a mechanical vehicle in 1710. Carriages with sails were early known in England. The period from 1800 to 1835 was a vastly busy one for steam engineers, and about that time the steam vehicle became fairly well established in England.

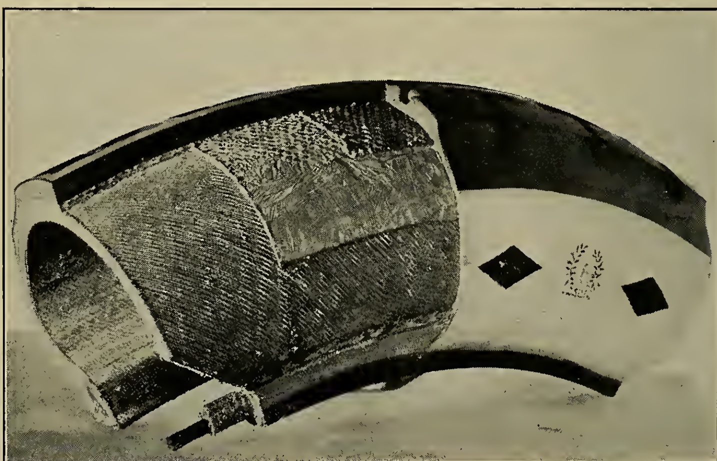
The old Hancock steam carriage of England, called "the infant," making regular trips between London and Stratford, was a forerunner of the modern interurban passenger bus. To its inventor probably should be given the distinction of making the first passenger automobile in the world, because he manufactured for himself a steam phaëton, used extensively about London, that was equipped with seats for three persons.

Upon the internal combustion engine and the experiments of Daimler, Benz, and Selden the automotive industry to-day really rests. All the first cars, and particularly the steam ones, lacked strength and sturdiness; they jarred themselves to pieces in a comparatively short time after being put into service. To be sure, the metals were not so good as



Courtesy of The B. F. Goodrich Co.

FABRIC TIRE DISSECTED



Courtesy of The B. F. Goodrich Co.

CORD TIRE DISSECTED

those of to-day, for modern metallurgy is of relatively recent development; but the main difficulty lay in the vibration caused by bad roads and lack of cushioning. True, the use of rubber for cushioning vehicles had been planned by Thomas Hancock in England. That, though, was before the days of vulcanization; consequently his idea had no real value. It was therefore the discovery of the art of vulcanizing rubber and the making of tires from it that made possible the extended development of the automobile.

In 1896 there were but four gasolene automobiles in the United States: the Duryea, the Ford, the Haynes, American cars, and the imported Benz. They were all experimental machines; there was no market, and it was 1898 before the first bona-fide sale was consummated. Alexander Winton, who ranks almost with the pioneers from the point of view of experimentation, sold a one-cylinder Winton automobile; he received payment for it and shipped the car April 1, 1898. Curious old things, they would make as much of a sensation on the road to-day as they did then, but for quite a different reason.

The next time one of your tires blows out or is otherwise incapacitated for service, you might find it interesting if, instead of passing it on to the junk dealer, you would spend an hour in an examination of its construction. Whether your tire be "cord" or "square-woven fabric," cut a two-inch section out of it with a sharp knife from tread to bead, so that the edges will be smooth. Then saw the bead in two with a hack-saw. There are three necessary parts of a tire: the casing, the tube, and the rim. By common consent the casing is called the tire.

Without regard to the refinements of tire design, which may differ slightly with tires made by different manufacturing companies, one observes several parts, each of which is essential to the use and the serviceability of the tire. The bead, which is the part in immediate contact with the rim, serves to hold the tire in place; without a bead or stiff part at the base of the tire, it would, under the strain of driving, quickly separate itself from the rim. In the early days drivers had many harrowing experiences with badly designed, primitive rims and beads that came off, left the car, and ran on ahead as though to point the way. In general use there are two types of beads: one, the clincher; the other, the straight bead. The clincher bead was the first type and is hook-like at the base. In America it is the common type in three and three and one half inch sizes. In Europe it is still largely used in all sizes. Later development found in the straight bead a better type, which, by virtue of the metal strips within the bead, is inextensible; it cannot slip over the rim when expanded under air pressure.

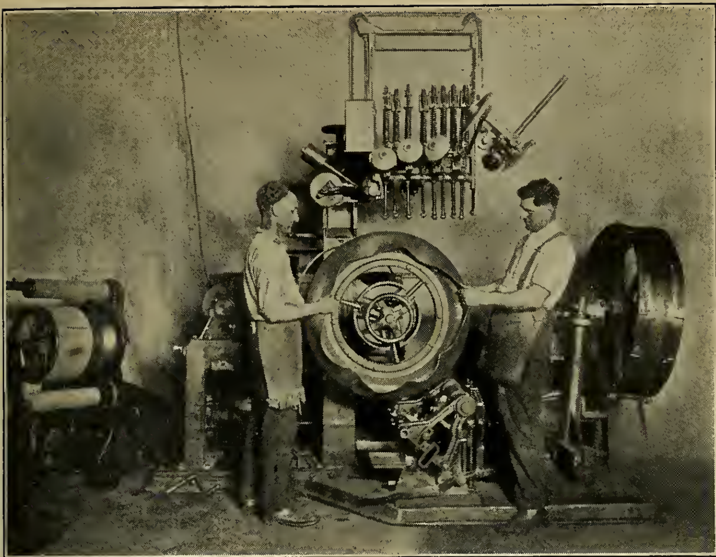
The straight bead or straight side tire has proved itself by tests and experience to be the best one in construction and service. This type of tire, other things being equal, lasts longer than any other; for the stresses and strains set up in the fabric, which is the next basic element of tire construction, are less irregular when the plies are folded around a straight bead than when they are curved as sharply as in the clincher type. Europeans will come after a time to the more convenient demountable rim with its straight side tire.

In a tire, we depend not alone upon the bead but also upon fabric. There are many niceties in the construction of cotton thread and the weaving of it into both square-woven fabric and cord fabric. Particularly must the cloth be processed in the rubber factory in such a way as to allow each layer or ply to work harmoniously under the bendings incident to service. When a thirty-two by four inch cord tire is inflated to sixty pounds of air pressure, there is exerted within it an outward force of thirty tons. When loaded to twelve hundred pounds, it is pressed in nearly three quarters of an inch; and every time the wheel revolves, each part of the tire is deflected by that amount. It is constantly bent back and forth in service. Wire bent this way quickly breaks; but the fabric bends over six million times in each ten thousand miles.

The remarkable increase in tire service during the last five years, is due to the scientific adjustment of the threads that make up the fabric and cord, as well as to the greater resistance of the rubber layers to flexion and heat. This rubber layer called "friction and coat" holds the plies of fabric together and at the same time keeps them apart so that they cannot rub against each other; it is another of the essential elements in tire construction. The fabric moves over very small distances, yet sufficiently to develop heat. This rubber must serve as a permanent lubricant; not temporarily, like the oil that is put in between the leaves of springs or into the transmission or the differential housing, for that can be changed every few hundred miles, but permanently, because the rubber in the layers between the cords is put in at the time of manufacture and stays there until the tire is gone. There is no other substance yet found that will remain so permanent as vulcanized rubber under the heat and bending. But the cotton is equally important with rubber; it is the backbone of the tire.

The fabric of the so-called square-woven type is manufactured by those operations generally used for ordinary cotton cloth. That is to say, the fibers are twisted into yarn and the yarn into threads, and the threads are then woven into cloth upon a loom. The threads are of the same size, shape, and twist; one set known as "warp" is interwoven with another set called "filling," and each runs under and over the one adjacent to it. Because as the tire bends, these interlocked threads wear against each other, the fabric tire gives a shorter mileage than the cord tire. A study of a tire section or of a piece of fabric shows this wavy condition.

The cord tire is made from thread fabric. The warp is constructed of cords of the right number of fibres, twisted to the proper size and woven on a loom with relatively few filling threads of a light nature to hold the cords together in manufacture. Usually there are only five filling threads in two inches of cord fabric. During frictioning, the warp threads straighten out into approximately parallel lines, no one of which is in contact with its adjacent partner. In the cord tire each cord or layer of cords is separated from every other by rubber; in the fabric tire each thread overlaps the one adjacent to it. These are the fundamental



Courtesy of The B. F. Goodrich Co.

LAYING ON THREAD FABRIC IN BUILDING A CORD TIRE AT THE TIRE BUILDING MACHINE

Courtesy of The Fisk Rubber Co.

TIRES READY FOR THE VULCANIZERS, IN THE VULCANIZER ROOM

differences between cord and fabric tires. The repeated flexing a tire is subjected to is one of the elements of wear, indeed a major element, which cotton resists and other materials do not.

In various parts of the tire there are several different weaves used. The breaker fabric with its peculiar construction permits the strength and the resistance to motion necessary to maintain the tread upon the closely woven body-fabric. The thinner, smaller weaves, in lapping the bead, play a most important part in the quality of the ultimate product; but, in themselves, they are relatively simple, both in grade of cotton fiber and method of weave.

The tire designer must select his cotton, for the cotton fiber or staple varies greatly in length. The diameter of one fiber is so small that if you were to lay two thousand of them side by side, they would measure only one inch. Tiny and fragile as they are, these fibers, when properly chosen with respect to length and twisted together, become, like other communities, strong in numbers. In a thirty by three and one half inch cord tire there are over 1700 miles of fiber if placed end to end; but in a cord tire thirty-five by five there are more than 5700 miles. The builder's choice of fibers of the proper length gives strength and service to the tire fabric. Yet, as is the case with men in the army, it is not necessarily the largest ones that we depend upon for the most work. Fibers vary in length up to one and three quarters inches.

How important a part is played by organization! In the case of the tire, the fibers are organized by cotton-mill operations into fabric and then built up by the rubber maker into a tire, to the end that each ply, each thread, and each fiber work in unison. The manufacturer who is able so to control his millions of little staples that they will act as one is the Marshal Foch of tire service. When tires are run under-inflated or overloaded, the harmony of this organization is disturbed by a sort of mass attack on one sector, which throws too much strain on the inside plies. As a consequence, breaking begins.

In tread design a cue is taken from Mother Nature, who grows tough skin on the bottom of a dog's foot and furthermore cushions it by pads of soft flesh. The tread of the tire is the wearing surface, a tough composition; but under it is a yielding foundation, soft, flexible, and snappy.

The black tread has been evolved after a painstaking, intricate study, and the chemists have worked long and diligently in their laboratories to produce such a highly resilient rubber mixture. When tested on machines built for the purpose against the abrasive action of carborundum, these treads outwear dry leather by about two and one half times; with both materials wet, they outwear leather more than ten times. An interesting test was run some years ago to compare sheet-iron and several rubber compositions. This black rubber mixture resisted the action of a powerful sand blast three times as long as iron. The black rubber tread composition, therefore, on a pneumatic tire is the material most resistant to road abrasion that the chemist in his laboratory has been able to produce.

A tire is not a tire until it has air in it. The inner tube has one purpose—to hold air. Although there have been various attempts to substitute other things than air (and far be it from me to condemn research in this direction), thus far no substance with which to support the tire has been found equal to air. It is the most easily obtained; it is the most springy substance known; and its only weakness is the ease with which it escapes through a very small hole. Despite the study of puncture-proofing and the substitution of other substances, none of them has met with sufficient popular service to call it important to the tire industry.

The tube, made of a very extensible rubber mixture, is the simplest part of a tire. Stretch a piece of an old one. Notice how the part next to the tread has deteriorated from the heat, and yet the part next to the rim is still strong. In designing tube thicknesses and sizes, tire designers try to choose the correct thickness, length, and diameter to permit the tube to run many miles beyond the distance that the casing will run. A trick here lies in the design, in the compounding, and in the type of vulcanization, which gives to the tube such resistance to heat that it does not become weakened or assume a permanently large size, a condition making it impossible to put the tube back into another casing after the original one has been used up.

The flap of the straight-side tire is a little article that is often overlooked. It is a piece of formed fabric and rubber used only in straight-side tires, for the purpose of preventing this soft rubber tube from forcing itself down underneath the bead. Many of the troubles of motorists are due to the flap, which, during the hasty application of the tire, flap, and tube upon the rim, is displaced, folded, or broken. The result is that, instead of protecting the tube, the flap becomes a means by which the tube is pinched and quickly broken through.

The one great aim of the tire designer is to build a perfectly balanced product, so made that its parts work in unison. After all, one of two things happens to give an end to a tire; either the tread wears through or the fabric breaks under repeated bending. There are, however, occasions when the tread wears unduly before the fabric has really run its life, and where the fabric breaks before the tread has been used up. The constant aim of the tire designer is to attain this perfect balance; to build his tire like the "one-hoss shay."

The earlier designs of pneumatic tires followed the principles then known for bicycle tires. Indeed, much parallel invention was under way in the early nineties.

The histories of bicycle and of automobile tires are closely interwoven. Fundamental principles were pretty generally worked out for the bicycle before the coming of the automobile. Really, Daimler's first machine was a sort of motor-cycle. Being a little skeptical of the pneumatic, these first motor-car builders experimented with many varieties of solid and cushion tires; but as none of them was satisfactory, they turned to the pneumatic, adopting the single-tube bicycle tire. Although the single-tube tire was fairly satisfactory, it would not stand up under the heavier and faster cars. The tires were then made much heavier and larger than they are to-day; some manufacturers found that to keep pace with the increasing size, weight, and speed of the automobile, it became necessary to produce a tire built to withstand vastly greater stresses. Farwell, in his "Story of the Tire" (1912), says: "The makers now [about 1900] turned back to the original Dunlop clincher detachable tires as more suited to their needs and began to develop a distinct type of automobile tire. The wired-on or Dunlop tire, which was developed into the straight-side tire of the present day, was enlarged and strengthened and put upon the market by its makers, the Hartford Rubber Company. At about the same time the B. F. Goodrich Company brought out their Goodrich clincher, which was the first American tire of this type to be made for automobile service.

"In November, 1900, at the first exclusive Automobile Show held in the 'Gardens' there were 33 automobile makers and eight tire exhibitors, nearly all showing single tube pneumatic and solid tires. During the next two years most of the manufacturers dropped the single-tube and were making double detachable tires only." The automobile shows of then and now appear strikingly different.

We must not pass over these early names without giving credit to Michelin et Cie., the earliest French rubber manufacturers, who had the honor of first applying the pneumatic tire to the automobile. Because the first broad use of the automobile was in France, and the manufacturers there felt the necessity for protecting the mechanism of the car from road shocks, this development came about.

Hard to apply and still harder to replace, these old tires were clumsy things as a rule. They were difficult to inflate with any means at hand in those days. They gave relatively little service, and were hard to change.

The history of the cord tire has been somewhat obscured. John F. Palmer patented it for bicycles in America in 1892. He took his patents to England, where the new tires were so much faster in bicycle racing that the officials handicapped the riders who used them. It was a gift of free advertising which led to the prompt adoption by all riders and the extended use of the "Palmer Tyre" made by Mr. C. H. Gray at the India Rubber Works, Silvertown, near London.

Mr. Thomas Sloper, however, in 1891 had conceived the cord idea and filed a provisional specification in the British Patent Office. Manufacturers would not listen to him when he sought their interest with his germ of a great idea. So the final specification was not filed, and the aggressive Palmer captured the English market.

Palmer adapted his principle to the automobile tire in 1895 but his web tire failed. His all-warp fabric with fine weft threads, however, was the forerunner and basis of the thread fabric today contained in essentially all cord tires. Sloper was employed by Mr. C. H. Gray, who foresaw the value of the idea for automobiles and developed a successful cord tire, called the Palmer Tyre, which was later taken to America and made by the Diamond Rubber Co. and the B. F. Goodrich Co., with many improvements, as the Silvertown Cord Tire.

How ideas travel! The cord idea began in America, went to England a bicycle tire, and returned grown-up into the automobile tire.

But the English tire contained two plies of heavy cord, like rope. To attain simplicity of manufacture, Americans took the lead again. The Morgan and Wright Co. (U. S. Tire Co.) and the Goodyear Tire and Rubber Co. almost simultaneously came forth with tires made of woven thread fabric. It was not a success at first. When the tires came to be inflated upon a bag during cure, and the methods improved, the nearly perfect cord tires as we know them were the result.

Let us take a trip into the factory and see how a tire is made. The compound for the tread, which has been mixed in the mill-room, is delivered into another room; the beads are formed in still a different part of the factory; and the side walls, which have been rolled out on the sheeting calenders, go into still a different room: it is a huge plant in all, turning out thirty-thousand tires every day, fifteen miles of them rolling out every twenty-four hours. The tire factory is, to say the least, a lively place.

A visitor finds a seeming confusion of men, machinery, fabric, and rubber, with tires the outcome. It is not easy to picture the making of a tire, for each part is made in a different part of the plant and assembled at the building machine. Cord fabric is frictioned and coated with a resilient compound on the three-roll calenders of the calender room. Here the steel wipes or frictions rubber around the threads. All cotton in a tire mill is called fabric.

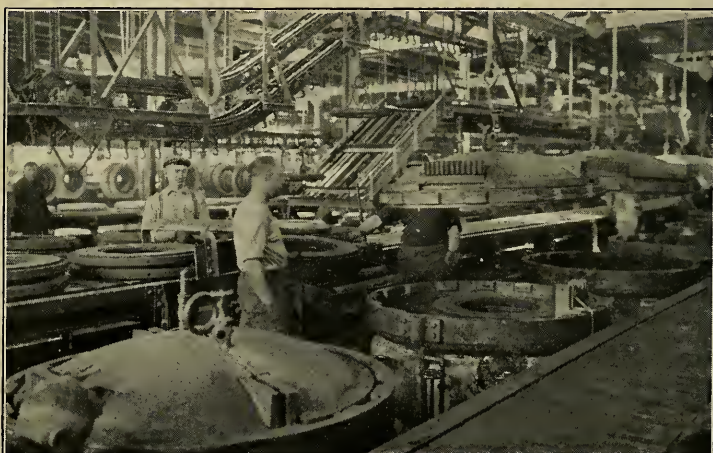
Since the threads of the fabric run at an angle of about forty-five degrees to the circumference of the tire, the fabric must be cut on the bias. And so large, heavy rolls of this rubberized fabric are conveyed by the truck system into the bias cutting room, where they are carried through rapidly operating bias cutters that shear off certain widths. Operators roll them up, keeping plain fabric, known as "liners," between them, so that the adjacent layers of unvulcanized rubber may not stick to itself and make the building of the tire impossible. These bias blocks are then conveyed to a table where workmen overlap the edges, using the proper width for the different sizes and different plies. After being thus spliced, they are rolled up into bundles, each separated by liners, in the proper length to make a given number of tires of a certain size. The same cutting to width and length of the breaker fabric is done in different places, as is the cutting of the side-wall sheet rubber.

The tread rubber is carried to the tread-forming room, where the rubber is softened on a warming-up mill and squirted through the die of a tubing machine, coming out of this die at a definite thickness and width for each different size of tire. In some factories these treads are formed on a calender, and in some by a tubing machine; but, in any event, the exact width and thickness at each point is controlled by measurement. The operations are conducted by skilled men, to make certain that the exact weight, necessary not only for economy but for quality, is gained.

Meanwhile, by an operation that would take a chapter in itself to describe fully, the bead is prepared. If it is a rubber bead, it has been formed on a tubing ma-

Courtesy of The Fisk Rubber Co.

PLACING THE UNVULCANIZED TIRE IN THE MOLD



Courtesy of The Fisk Rubber Co.

FILLING THE VULCANIZERS WITH THE MOLDS

chine and pressed in a hot mold to a defined size, with a layer of fabric around it.

At the building machine, one sees the operators fit in the proper place a metal core. This core is designed to be of the size that is correct for the inside of the tire, depending upon the process by which it is to be made. If it is a fabric tire, which is finally to be finished in a mold, this core is of exactly the size; if it is a cord tire, however, the core is a little smaller, for the mold operation in making a cord tire consists of stretching it, while being vulcanized, upon an air- or water-bag. According to the construction of the tire, the plies of canvas are wound on this core by a machine in the order in which they have been laid up by those who spliced the bias strips together. The operator places the end of the canvas roll carefully upon the core, and sets the machine in motion. The tackiness of the rubber makes it stick to the metal; and the fabric is stretched at exactly the necessary tension as it is wound on the core. Meanwhile, rollers are pressed by weights or springs upon the fabric in order to join the plies to each other firmly. Half the fabric previously having been put on the machine, the earlier formed bead is applied on top of it, in the right position and very accurately adjusted. Then in the building the bead is wrapped about by the body plies. After the necessary plies have thus been built up, and the previously formed combination of tread, breaker-fabric, and cushion have been laid on and rolled down under pressure, the tire is taken to what is known as a finishing stand. Here the side walls are applied and the tire inspected.

To gain accuracy and speed, much nice inventive work has been done in the making of tire-building machinery. Machine-built tires are more precise and uniform than those built by hand. Before the tire is modeled to its approximate shape and ready for the final step of molding, there are a number of operations to be performed by these machines. If it be a fabric tire, the operators who work on the finishing stand lift it to a rack on a truck. If it be a cord tire, on the other hand, it is sent to a stripping table, where the core is removed, the tire is dusted on the inside, and an air-bag or a water-bag of heavy, thick rubber, which has been previously painted with soapstone solution to prevent it from curing to the fabric, is inserted.

If it be a fabric tire, it then must go down to the vulcanizing room, where there are long rows of heaters. The tire is trucked to these heaters; and a mold, in two halves, is brought by a powerful conveyor, in front of the workmen, who lift the tire and its core and place it in the lower half of this mold. The mold has been designed so that it is of exactly the exterior shape that the tire is to have when finished, including all the lettering and other features. As the tire travels along a metal belt, the top half of the mold comes down from an automatic conveyor that has carried it out of the way above the operators, and is carefully guided into place on the tire. The mold gaps open, for the tire in this form does not fit it exactly. In the mold are the protuberances that form the depressions in the tread design and hold the tire away from the mold until pressure forces it into place.

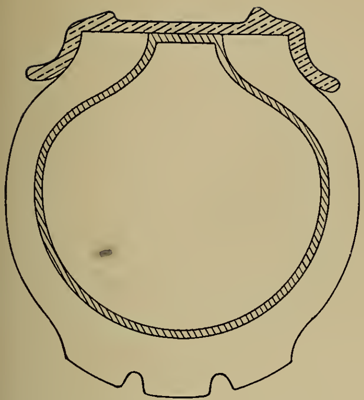
Carried away on the automatic conveyor, the tire, together with many others, is loaded into the shell of the vulcanizer, in the bottom of which is a plate or platen, which, before the mold was filled, rested in a position nearly at the top of the heater. This platen is fixed upon a plunger moved by water pressure in a cylinder below. The lowering is done by simply pushing the molds down a short inclined plane upon the platen, until there has been made a stack of twenty to twenty-five molds in the heater. After this, the cover is placed on this open vulcanizer; by a simple device it is locked in place so that no steam can escape. The molds are then forced together by hydraulic pressure and the soft rubber takes the form of the mold, after which process steam is applied and the vulcanization is begun.

Great accuracy has been gained in recent years from the use of automatic, temperature-controlling instruments by which an operator has to turn but one valve to maintain an exact temperature during the desired time. At the end of the time, it automatically turns the heat off and gives a signal by which the operators know that the vulcanizer is ready to be discharged. In the discharge the hydraulic ram raises the molds to a height where the men can pull them by a rope and a winch upon the traveling conveyor, along which they are carried. The two halves of each mold are separated, the tire removed, and the mold again filled. These are to the production man beautiful operations that give rapidity and accuracy to the vulcanization of tires.

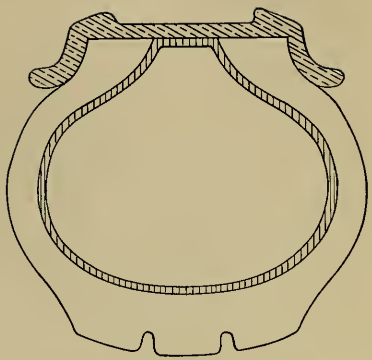
In the case of a cord tire, a somewhat different process is used; for, as stated, an air- or water-bag is placed in the tire. The tire is then put in the lower half of the mold; the upper half is lowered on it. Air or water connections are made to proper pipes. When the tire is in the vulcanizer, hot water is forced into the water-bag in order to stretch the tire and drive it by internal pressure against the mold. The object desired in cord tire vulcanizing, is so to design and mold tires that the fabric will not be displaced.

After vulcanization, the casing is lifted from the mold, removed from the core or water-bag, and sent to the inspection room, where it is coated on the inside with mica paint to prevent the inner tube from sticking to it. Then it is wrapped for distribution.

The manufacture of inner tubes is very simple when compared with the manufacture of the tire case. The tube, with the exception of the reinforcement around the valve, is made of one composition, sheeted on a sheeting calender to the proper thickness to make a tube of a given size. This sheeted rubber is then transferred from the central calender room to the tube department, having been previously cut to a width desired for each size. Then it is unrolled and separated from the liner upon a zinc-topped table, where it is cut to a definite length, corresponding to the length of the tube for each particular size. Carefully, it is rolled upon a former or mandrel, which is simply an iron pipe carefully polished and of the correct diameter to give the inside size of the tube. In some factories the tube is formed on a tubing machine, in which case it is extruded from the die of the machine, round in section. Then it is cut to the length required; after which process it is carefully stretched upon the man-

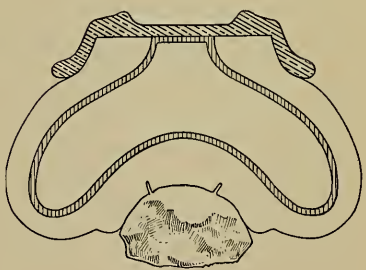


NO LOAD, INFLATED WITH 60 POUNDS PER SQUARE INCH AIR PRESSURE



NORMAL LOAD OF 850 POUNDS, INFLATED WITH 60 POUNDS PER SQUARE INCH AIR PRESSURE

OVERLOADED 41%, NAMELY TO A TOTAL OF 1200 POUNDS, INFLATED WITH 60 POUNDS PER SQUARE INCH AIR PRESSURE



EFFECT WHEN OVERLOADED TIRE INFLATED WITH 60 POUNDS PER SQUARE INCH AIR PRESSURE IS RUN OVER A STONE

drel. Once, however, upon the mandrel, whether sheeted or extruded, it is wrapped with fabric.

After this operation, it is stacked on trucks, the units being separated by iron plates at the end; and the truck-load of mandrels with their rubber tubes upon them are pushed into long horizontal vulcanizers, the doors closed, and steam turned in. Sometimes the valve-pad reinforcement, which is a combination of rubber and fabric cut to an oval shape, is applied before vulcanizing; at others it is applied after vulcanizing. At the end of the time of vulcanization, the tubes are stripped from the mandrel by the simple process of blowing air between the tube and the mandrel. Taken to another room the tubes have, by a skilfully used bit of apparatus, the two ends buffed, cemented, and vulcanized together. From here, the tubes are sent to a table where the valve stem is applied, if it has not been applied, as in some plants, before the splicing operation. They are then inspected in water for leaks, and packed for shipment.

How should we take care of a tire? The principle developed in the field of engineering of only loading a beam to within a reasonable factor of safety applies here. If you build a house, you make certain that the beams underneath your floor are large enough to carry many times the greatest load that you ever expect to assemble upon that floor. Look at the picture of a tire section under no load, normal load, and overload. The inside of the tire has become flattened with overload or under-inflation, conditions really affecting the tire in the same way; and the inside layers or plies, slightly shorter than the outside layers from bead to bead, then carry too great a proportion of the load. As a result, when that tire is driven over a stone, it is liable to take a shape that seriously distorts it. And, too, because of greater internal friction, the amount of heat is increased. Hence, the fabric weakens, the rubber deteriorates rapidly, and the little fibers one by one begin to break; until some day, when least expected, one of the plies will break through. Then, instead of a six- or eight-ply tire, there will be only five or six. As in the case of a rope with one strand broken, the load becomes excessive for the other strands; and some time thereafter they will break down with the usual blow-out. A tire is really a suspension-bridge, the cords being fixed at the two beads and shaped by air pressure.. The air is not much compressed during service, but it is required in order to maintain the cords under the necessary tension and to permit them to work in the most natural way.

Of the total power of the motor in an automobile, part is absorbed in the mechanism of the car and the remainder, estimated to be more than 80 per cent., is transmitted to the rear tires to be expended in pushing the machine against the wind, up hill, and against other resistances. Driving over bricks and bumps, dodging around automobiles at the side of the road, our tires are subjected to power as well as dead load and to sudden changes in strain: These jerks, bumps, and cuts by rough stones on the road's edge, that let water into the fabric, are the killing forces that destroy tires. If tires were treated as most of our property is, we should carefully examine them month by month. The older ones should be shifted from the position of greatest work, namely, the rear, to the front; for we should think of them as old faithful horses gradually to be retired to easier jobs, while the younger ones are called upon to carry the heaviest burdens.

How much work does a tire do? If one thirty-two by four inch tire on the rear wheel of a car carrying a load of fifteen hundred pounds runs ten thousand miles up a 4.4 per cent. grade, the work it has to do, engineers tell us, is 2026 horse-power hours. This is equivalent to lifting more than four billion pounds of stone up one foot. The computation, to be sure, assumes the tire to be on the up-grade all the way; but if it goes up-grade only one quarter of the time, the work done would lift the Washington Monument about twelve feet. When your tire goes one hundred miles, it does as much work as you would do if you shoveled 220 tons of coal into your second-story window. During such a job you would perspire pretty freely; the tire heats, too. We have learned by experiment that when this four-inch tire was run for an hour at twenty miles per hour, the temperature of the tire just under the tread had increased 37½ degrees; at forty miles an hour, the increase was 75 degrees. In the hot days with the thermometer ninety-five degrees in the shade, and 110 degrees on the road surface, imagine the tire heated to 180 degrees, or nearly enough to boil water. Is it any wonder that the rubber wears rapidly then? These figures of temperature show that the motorist has considerable to fear if he rides at excessive speed in hot weather, or if he permits his air inflation to be reduced to the point where there is maximum flexing and consequently increased rise in temperature. Regardless of that, rubber tires resist just such wear to a greater degree than any other known structure.

Motoring is not wholly a matter of engines and chassis. "Bone-shaker" vehicles are gone forever. To the pneumatic tire may be given credit for the astounding growth of the automobile, for it has permitted both speed and comfort.

CHAPTER X

TRANSPORTATION BY TRUCK

Transportation is a mighty word. Indeed, civilization measures its scope and development by its efficiency in moving men and materials. The change from the days when each household was self-sustaining and all life was agricultural is a history of transportation. The Neanderthal man killed his meat in the forest and carried it to his cave. He lived from day to day. The barter principle of trade was given up only as transportation made possible the movement of commodities from distant fields of origin to centers of use. Banks, warehouses, and exchange systems depend upon movements of goods over the world's highways.

After human effort came the ox-team, after that the horse-drawn wagon, then the railroad, and finally the improved highway for motor transportation. In fact, if one looks over the world as it is now, he finds each of these ancient and modern methods of movement realized in different parts of it. The measure of the intelligence of peoples, in any event the standard by which they are rated in the family of nations, is pretty largely that of the efficiency of their transportation systems. The famines in China illustrate how vital highways are in modern life; for there were provinces filled with starving people, and but a few short miles away, as we in the United States measure distance, there was plenty of food; yet the lack of highways made it impossible to move the food to those who needed it most.

Our great railways are main lines of travel, requiring secondary lines with fast and prompt service to feed them with the products of the soil and industry. For this purpose the motor-truck, developed during the last two decades, constitutes at once the most spectacular and efficient means. The tourist does not enjoy the crowded thoroughfare; his horn too often fails to stir the truck driver ahead to yield half of the pavement. Yet the very freight the truck carries means the prosperity that makes touring possible.

The motor-truck takes its value from certain characteristics that may be termed fundamental. It can move goods at relatively high speed; its power is sufficient to permit its carrying loads of any size to meet the demands of industrial and commercial enterprise. It is adaptable, more so than any other known vehicle, to various service requirements. The milk-truck in early dawn rushes its supply from the farm dairies to the centers from which babies are fed; dirt from excavations for sky-scrapers is hauled away in dump-trucks; the department-store delivers its merchandise for miles into the country. Through the efficiency of the truck, regularity of service is habitual, although still the condition of roads affects seriously the movement and life of the vehicles. There is, to be sure, some difference of opinion among students of motor transportation as to how far the range of trucking may be considered efficient. The railroad, however, is the main line and the motor-truck the feeder, or the rapid means of communication between adjacent industries or cities. Motor transportation is economical, for the cost per ton mile has been reduced to a point making the extension and use of trucks possible. Probably the truck will never be able to compete with the railroad on long hauls.

Recent years have witnessed a striking change and development in the use of the truck, for it has come to be a serious competitor of the trolley-car. Both the bus and the street-car have their definite places; each has its advantages. I would not wish to say that either will displace the other. The motor omnibus systems in New York, London, and Paris as well enough known to support a conception that they would not be conducted upon so extended a scale were not the cost of transportation low and the profits unmistakable. Freedom of movement; ability to follow the lines of growth of the community and so give service where the laying of tracks for trolley-cars would be highly expensive; avoiding obstacles, as in the case of parades, fires, or temporary obstructions—this fundamental principle of flexibility, without doubt, renders the motor-bus a means of passenger transportation that has come to stay and that will develop in the future. Recently some busses have been run on rails, but they are still in an experimental form. There is no one of these different types of motor-trucks, busses, or cars in which rubber or the rubber tire in one form or another is not an essential. Indeed, a feature of the latest addition to this family is the cushion driving wheel of the rail car, in which, underneath the usual steel wheel and protected from the weather by side flanges, is a special rubber cushion to give comfort to the rider. The rubber tire, therefore, is a commodity without which it is doubtful if any of these transportation schemes would serve.

From the time when Sir Isaac Newton, in 1680, suggested the steam-driven wagon, down through the years, attempts have been made to revolutionize transportation by self-propelled vehicles. The early disappointments and failures of the steam wagon in its various forms were due to the lack of a soft cushion to smooth out road inequalities and to reduce vibration. Probably for this reason more than any other, these early rapid-transit enthusiasts came to the invention of the solid road-bed and the smooth rails that we associate with the railroad. The first plan to avoid shocks was to cushion the wheels with tires of solid rubber. The idea of air in a tire was a later development. The electric vehicle pioneered by Colonel A. L. Riker in 1898 was one of the earliest truck developments, although the steam truck was more fully worked out in England and the gasolene internal combustion engine was developed in France and America. One still sees on the English streets steam-driven trucks. For all of these heavy services the solid motor tire, which was a natural offshoot of the solid carriage tire, has proved to be the most logical medium by which cushioning, long life, and efficiency can be gained. The solid tire differs from the pneumatic tire, which is so vital to passenger-car transportation, in being rubber all the way through.

The inventor of the original solid rubber tire is unknown. The history of tires in England seems to give credit to Thomas Hancock who, in his book written in 1856, suggests solid rubber tires to relieve vibration. They were, however, manufactured before 1856, for the records show the firm of Charles Mackintosh & Co., to have manufactured such tires for vehicles as early as 1846. Hancock says: "These tires are about an inch and a half wide and one and a quarter thick. Wheels shod with them make no noise and they greatly relieve concussion of pavements and rough roads; they have lately been patronized by Her Majesty." But because of their sticky qualities and the property of softening readily with heat, these early tires gave a relatively short service. There is a patent on record in England, granted to Thomas Smith in 1845, the principle of which was spokes set within a felloe of metal in a trough-like form, the open part being outward and containing a tire. No mention, however, is made of rubber in connection with this patent. During 1856, in England, M. Coles Fuller brought out a combination solid tire composed of cloth, canvas, or other fibrous materials.

The first introduction of solid tires for cabs in London was in 1861, but difficulties were experienced in attaching the rubber to the wheels. In 1863 N. H. Carmont took out a patent for holding the metal part of the tires on the felloe with a dovetailed section to receive the rubber tires, which were grooved to fit the channel. Later, another company, known as the Noiseless Tyre Co., was formed to furnish tires for the Shrewsbury Cab Co., the first firm to introduce the use of solid rubber tires in England. Upon the invention of the bicycle in England in 1867, it was found necessary to relieve the vibrations of the old "boneshaker"; and solid rubber tires were manufactured that were cemented into a groove in the rim of the machine. These tires were followed in 1879 by cushion tires, which, although no larger in diameter, possessed increased resiliency produced by a small hole running through the center. They were specially devised for what was then known as the "safety" machine, which followed the old high bicycle.

The introduction of the motor-bus in England necessitated a further departure with regard to rubber tires. Not only were pneumatic tires out of the question, but it was found impossible to retain solid rubber in the rim when the weight of some six or seven tons was imposed upon it. Therefore, it was necessary to vulcanize some sort of a retaining band in the bed of the rubber. Now, it is a very difficult matter to unite thoroughly a non-yielding body like steel with an elastic body of the nature of rubber. In time, this has been effected. So metal rings of various sections were used for this purpose, and detachable rims enabled these ring sections to be fitted on the felloe of the wheel. But the Scotland Yard authorities prohibited the use of sectional tires for use on public vehicles in England; and this action, to some extent, checked the development of this class of tire.

The Shrewsbury & Talbot tire, the trade name of the Carmont tire, was introduced into New York. It at once gained approval, and it remained until later development drove it from the market. It is interesting how the point of view of the public has changed in the last fifty years, for the early solid tire offered the public in 1856 by the Boston Belting Co., was received with the unfailing skepticism then ready for anything in the nature of an innovation. Because rubber wheels made no noise, they were considered detrimental to the safety of pedestrians; and the inventors were deterred from taking out patents by the authorities, who warned the manufacturers that vehicles equipped with such tires were a menace to public safety. We even find the rubber sole and the rubber heel catalogued under the name of "sneakers," even though the safety and comfort of the user, as well as economy, are increased by their use.

The most practical development of the solid tire for carriage purposes was one invented by Arthur W. Grant, later known as the Kelly-Springfield tire, which probably more than any other one invention led to the popularity of rubber on horse-drawn vehicles. The rubber was held in place on the wheel by means of longitudinal wires running through the tire and forming circles of smaller circumference than the rim flanges. Built of long-lived rubber mixtures, this tire was capable of positive attachment in the channel or rim. A little later the tire was modified by the so-called "side-wire" carriage tire, invented by James A. Swinehart of Akron, in which the wires were passed outside the rubber body.

The automobile has so completely dominated the field that the horse-drawn vehicle has become only a means of wagon transportation, and the internal wire or any other type of carriage tire has essentially disappeared. We need not, therefore, describe the numerous other methods of holding a piece of solid vulcanized rubber on a wheel for carriage purposes.

After years of development and trial, the solid truck tire of to-day has come down to us in one form: a steel base upon which is a layer of hard rubber, and, upon that, the mass of soft rubber giving comfort, cushioning, and resistance to wear. The function of the motor-truck tire is to provide traction for the wheels, and, as a protection to the mechanism of the truck and load upon it, to cushion them. The first idea of the metal-base tire came from Europe—a steel band grooved in the form of dovetails. Into these grooves was forced a layer of rubber mixture that would become hard rubber on vulcanization. This served as a stiff base impossible to remove from the steel, although chemically not united with it. Before vulcanization of the hard rubber, a layer of a resilient tread composition was applied, and the whole vulcanized in a mold under pressure, so as to form the shape desired. Thus was developed the wireless tire introduced into the market in 1909. To-day the steel-base tire is universally used on motor-trucks and is called the truck tire.

The steel base on which this solid truck tire is built is a continuous band of channel-steel, the lower surface of which is smooth and the surface between the flanges machined with a series of circumferential slots that in cross-section have the appearance of dovetailed depressions. Because accuracy of measurement is important, that they fit the wheels, the manufacture of these bases is a specialized process in steel mills. They must also be made to fit exactly into the metal molds after the tire is on them, during the vulcanization process. In the course of manufacture, the surface of the steel is roughened by numerous corrugations. In some factories fine, sharp, flint-sand is blown against the base with a powerful air-blast; in others, it is copperplated; in others, it is treated with acid to pit the surface with an infinite number of fine depressions. The purpose of this work is to give a surface to which the hard rubber mixture may hold in innumerable little points of attachment, these points making the security of the hard rubber base certain.

In the operation of manufacture in the rubber mill, after the metal base is thus cleaned, in order to fill these little depressions with a hard rubber composition, it is coated with cement. After drying, this base or permanent band is mounted upon a horizontal shaft placed in front of a special calender. The hard rubber compound containing an amount of sulphur approximating 32 per cent. by weight of the crude rubber has previously been mixed in the mixing room. The numerous other ingredients are chiefly those materials that serve to vulcanize it simultaneously with the wearing part. This hard rubber compound is softened and passed through the rolls of the calender, which form a sheet of unvulcanized hard rubber mixture, the precise width of that part of the base between the flanges. When the proper amount adheres to this steel band, the base, with its layer of unvulcanized hard rubber, is taken to another calender, where a continuous sheet of a soft rubber mixture is run, until the right thickness, depending upon the size of the tire, is rolled up upon it. At this point, the calendering operation is stopped, and the tire is removed from the support of the wheel. Rectangular in section, it then is taken to the trimming machine, where the excess of soft rubber is removed. By this process the shape in section of the tire is made as nearly as possible to conform to the shape desired after vulcanization.

The soft or wearing rubber may be applied to the hard rubber base by another process. First it is softened upon a warming-up mill. After softening it the workmen feed it into the opening in a heavy tubing machine, where it is forced by great pressure through a die. From the die the rubber issues as a long, solid mass. The die is the shape in section that the finished tire is expected to be. Different sized tires—four-inch, five-inch, six-inch, seven-inch, etc.,—require dies corresponding approximately to the size desired. The mass of rubber is forced through this die until a strip a little longer than the circumference of the tire has been passed out of the machine. It is then cut off and laid away to cool. Finally, when ready for building up on the hard rubber base that has been run on the calender, this mass of soft rubber is roughened on the surface where it will be in contact with the hard rubber. After being carefully cemented with a rubber cement and dried, it is placed in what is known as an up-setting machine capable of handling accurately and easily as much as 150 to 300 pounds. This long mass of rubber is there applied carefully to the hard rubber; and after preliminary pressing and the fitting together of the two ends, it is in the approximate form in which it will issue from the mold.

By either of these two processes, the calendering process or tubing-machine process, we have a steel base with a hard rubber layer upon it, and upon that the mass of soft rubber of the size and form of the final truck tire.

This tire is then taken to the vulcanizing or curing room, ready for the final operation of vulcanizing. The vulcanizing process is similar in principle to that used with a pneumatic tire; that is, the doughnuts, with their tires in them, are placed upon a movable plate or platen held at the top of a hollow, cylindrical shell known as the "heater" or "vulcanizer." By mechanical devices the molds are pushed on top of the plate, the plate is lowered by letting out a little water through the hydraulic mechanism, and another mold is placed on top of the first. The tires then are pressed by hydraulic pressure into the exact shape and conformation of the inside of the moulds. When the steam is turned into the vulcanizer around the molds, the vulcanizing operation begins.

There is probably no part of rubber operation that requires greater care in manufacture than this one of vulcanizing or curing a solid tire. Not only are we dealing here with rubber that is to be vulcanized, but with a thick mass of rubber. The thermal conductivity of rubber is very low; in other words, it is a very good heat-insulating material. Furthermore, various compounds are different in their resistance to the passage of heat through them. It requires from one to two hours to bring the temperature of the center of an ordinary-sized solid tire up to that of vulcanization. For this reason, solid-tire curing temperatures have usually been kept relatively low and the time of vulcanization relatively long.

After the vulcanization is completed, cold water in some plants is run into the heater and allowed to remain long enough to cool the mass of metal and rubber. The control of steam has been maintained by automatic temperature-controlling apparatus, the materials have been carefully examined, and every possible precaution necessary to insure uniformity of one of the most delicate products made has been taken—a product that is submitted to tremendous variations in service. After the tire comes from the mould, it is inspected, the little extra amount of rubber that has flowed out of the mold and which is known as rind, or overflow, is cut off, and the tire is ready for sale.

The solid tire of the permanent-band type is then ready to be applied to the wheel, and much of its service depends upon proper application. To apply the tire, the wheel is removed from the truck and laid upon a heavy press operated by hydraulic power. The tire, which fits the felloe band of the wheel tightly, is placed in position; then the two plates are brought together, the action forcing the band or base of the tire upon the wheel. The process usually requires a pressure of twenty tons—in any event, far more pressure than any tire will ever be subjected to in service.

There have been several types of demountable tires made which are capable of application in a garage or on the road; but they are gradually disappearing because they work loose. Since the tire itself is so heavy, one or two men can scarcely apply it while the wheel is still on the truck. Therefore, the permanent band-

Photo by Underwood & Underwood

A FREIGHT TRUCK

Courtesy of The White Motor Co.

ONE OF THE TRACKLESS TROLLEYS

pressed-on type has come to be the most largely used truck tire.

We see some wheels equipped with two tires in the rear; these tires or "duals" have a wide use because two tires radiate the heat more readily than one. Since there is not so heavy a mass of rubber to absorb the heat, there is consequently not so much difficulty of radiation. And there seems to be a somewhat greater gasolene efficiency from the truck when there is a relatively small amount of rubber in actual contact with the road. Skidding, too, is reduced by the dual tire; and since the units are relatively small, it is possible for a fleet of trucks to carry the same size of tires in front and in rear, using them singly on the front wheels and in pairs on the rear ones. The large single tire, however, has its field; and it would be scarcely wise to say that any one type of tire, single, dual, or any other, has an unlimited field of usefulness.

The solid tire is probably subject to more abuse than any other rubber article, loaded as it often is to double the amount the tests have proved advisable. Run at speeds by which a high degree of heat is generated, the mass of rubber being unable to radiate its heat so easily as a pneumatic tire, truck tires have been known to absorb heat until the temperature inside them has become so great that the rubber decomposed with a generation of gases, and the tires blew out. In all the data that have been gained about blow-outs it is a safe statement that they rarely occur except when the overload of the truck is so high that it is beyond the ability of tires to stand it. This raises one of the vital questions for the truck user;

namely, the relation of size of tire to the load he expects to carry. Despite all arguments to the contrary, it is economy for him in the long run, whether he uses one make of tire or another, to put on his truck that tire proportioned in size to the loads that he wishes to carry, to the speed the truck will stand or the law allows, and to the road conditions. By so doing, he will gain a service before the tire is broken down that will make additional cost for the larger tire an economy rather than an expense.

Non-skid devices on solid tires, such as chains, cause some trouble, and there is a certain amount of confusion among users about them. While on the pneumatic tire the chain is capable of movement, on the solid tire there usually is but one place where it sets itself against the rubber. Proved from the days of the internal wire, it is true that wherever rubber comes in contact with an inflexible body, such as metal, it will wear out rapidly. Thus the chain wears out the solid tire at its points of contact. This has led the manufacturers to develop non-skid tires, which have served to hinder slipping upon wet pavement, snow, or ice. There is still a great field, however, for improvement in devices which will resist the slipping tendency and yet in no way injure the product.

Many trucks are equipped with large pneumatic cord tires, some of them as much as nine inches in sectional diameter. These extra large ones have found their way into extended practical use, although the six-inch, seven-inch, and eight-inch tires are the usual sizes. The fundamental advantages resulting from the use of pneumatic tires on trucks are cushioning and traction greater than can be obtained from the solid tire. The cushioning ability of a pneumatic tire, when not inflated too highly, is about four times that of a solid tire of the same carrying capacity. As a result, the operation of the truck is faster, with consequent economy of operation; there is less injury to a fragile load, for the riding is easier; but there is grave danger from blow-outs and punctures. Generally, pneumatic tires have been used only on the smaller trucks, namely, those up to three tons in carrying capacity; for the four and five-ton trucks the solid tire still leads.

Technical men still discuss the practicability of pneumatic tires on trucks. There are delays caused by the changing of tires even when demountable rims are used. Since the rim and the tire are heavy, and the rim is generally rusted on, the time required to make a change is often a serious matter. Furthermore, the air pressure carried, from ninety pounds in a six-inch size up to 130 pounds in the nine-inch size, is much higher than for the smaller tires. Most garages are not equipped with pumps capable of maintaining these higher pressures. And, too, the center of gravity of the trucks is raised, for the pneumatic tire is higher than the solid tire. This has led to a few accidents when blow-outs have occurred and trucks have toppled over on the road. As a rule though, such difficulties have not been numerous; and the pneumatic tire on trucks is probably here to stay. Such beautiful products are these big pneumatic tires that it is always a pity when a puncture does occur, to see them ruined before the truck can be stopped.

Although some wonderful long-distance hauling from the rubber metropolis, Akron, to Boston and to San Francisco has been done on trucks equipped with pneumatic tires, experience differs. Many seem to believe that the pneumatic tire spares the trucks numerous jars and strains; and, therefore, the truck itself can be made lighter. But, and this is important, if the truck be spared jars, it is because of the air-cushion. Because these cord tires contain eight to sixteen plies of cord fabric, they are stiff. To attain long life for them enough air pressure must be used to avoid too much flexing with consequent cord breaking. The compressibility and elasticity of air enables the tire to absorb jars; therefore, when air pressure is high, the tire is hard—indeed, more so than a solid tire. Then the purpose is defeated. Highway engineers realize that when the pneumatic tire is inflated as it should be, the pressure to the square inch of road contact is the same regardless of the load carried, and is based entirely on the necessary inflation pressure. If in obtaining wider area of contact the inflation pressure is reduced, the tire will become unduly flattened—a condition which will lead to rapid deterioration. To balance low air pressure for softness against high pressure for mileage is not possible in large pneumatic tires.

The solid tire, being made completely of rubber, bulges out under load, because it cannot be compressed, but it is sufficiently plastic to flow. If you place a pencil with the soft eraser upright on the desk and push it downward, the eraser will bulge at the sides; it is not compressed but is displaced. A rubber tire oozes out in the same way; and as it spreads on the pavement, this so-called traction wave flows around continually through various sections of the tire and causes internal action. The designers, however, have so arranged the shape of the tire that even if it does flow, only internal heat results, which, if the tire is used properly with respect to the load carried, does not become sufficiently excessive to have a serious effect upon its life. Since there is no danger from punctures, cuts, and so on, the average mileage of the solid tire is greater than that of the pneumatic tire.

Of recent years, a new idea has been expressed in the building of tires that combine the softness of the pneumatic under low inflation and the length of life of the solid. Resilient solid tires capable of service under heavy trucks will solve the truck tire problem; for these permit speed, ease of riding, freedom from changes on the road, and longer mileage than is possible from the large pneumatic. This type is the truck tire of the future.

In truck transportation heavy loads are demanded. Can the roads stand the pressure? A road is, after all, nothing more or less than a hard layer of material, brick, concrete, macadam, upon native soil. If this layer is made thick enough, heavy loads may be carried over it without danger of breaking through. But when, as has been the case in too many instances, the highway engineers have simply floated a thin layer of brick and concrete upon clay without drainage to remove water, the trucks have actually broken through. Increased speed of a vehicle tremendously increases the impact that its wheels make on the roadway where there is any unevenness. However, the answer to the maintenance of roads probably lies less in a limitation either of the type of tire or of the width of contact with the road than in road construction. Roads should be heavy enough to carry the future motor transport.

Since motor transportation on highways is here to stay, would it not be wise to build roads of a width to carry two streams of traffic with safety; of a construction sufficiently deep to carry increased tonnages at low cost per ton-mile; with a drainage system to carry off the water? Roads should permit permanence and flexibility to the development of motor transportation. Even as they are, streams of trucks carry goods and people over hundreds of routes.

Statistics may be dry, but they stimulate the imagination. In the economics of truck use, railroad men recognize the advantage of the motor-truck in short branch-line operation, trap-car service, suburban distribution, terminal distribution, and the utilization of outlying yards in lieu of yards in congested districts. In the handling of food supplies from farm to city the radius has been extended by about fifty miles, a matter of vital moment for milk and other perishables, which serves to save time for the farmer and to reduce the cost of living. Education is affected. Consolidated schools in country communities, with the improvements thereby obvious, have been made possible through the speed and safety of the motor-bus for the transportation of children. This use is rapidly growing.

The extent to which motor-truck haulage has progressed is well set forth in a census by the United

States Bureau of Public Roads for the eastbound traffic only on the Boston Post Road at the New York-Connecticut line in October, 1921, which shows nearly every type of commodity and many million tons being carried. For such transportation the total number of public express lines is probably about one thousand, says the National Automobile Chamber of Commerce; and a Senate committee has estimated the annual motor-truck tonnage hauled in the United States over the highways at 1,438,000,000 tons. In the motor-bus field 108 cities were using motor-bus lines at the beginning of 1922.

But truck tires contribute to the esthetic as well as the economic welfare of a nation. In England, the char-a-banc is changing the life of its people. No longer are the delightful, picturesque little places inaccessible. The railroad is never a good tourist route. The highways, hedge-lined, are beautiful. A trip from London between the rows of brilliant rhododendrons down to Salisbury, the winding road along Runnymede, leaves memories never to be forgotten. Where the automobile has shown these beauties of England to hundreds, the char-a banc carries thousands. The English people are discovering England, and they are doing it on truck tires.

CHAPTER XI

WATER-PROOF FOOTWEAR AND CLOTHING

Men, like cats, abhor wet feet. No substance, however, was successfully made into a water-proof shoe until rubber came to be used for that purpose. The South American Indians were the pioneer rubber shoe makers of the world. Pouring the latex from trees on their feet, they permitted it to dry; it became an unvulcanized, water-proof "rubber," as we should call it, or a "galosh" as it would be called in England, exactly fitted to the foot. Since it was doubtless uncomfortable to hold feet over a flame to dry the milk, the Indians made clay lasts or forms of the shape and size of the foot, each constructing his own. Over these they poured latex, to be evaporated in the smoke of a palm-nut fire.

The first rubber shoes worn in this country came from South America in 1820—a pair of very elaborate, gilded rubbers, which a Boston sea-captain brought home as a curiosity. The first serious importation for selling purposes was made five years later. At that time, Salem, Massachusetts, one of the most aggressive business centers, exported to South America maple lasts, to which the natives took very kindly. Dipped shoes, about equally thick in all parts, were the only kind that proved serviceable up to the time of Goodyear's discovery of vulcanization. In shape, the first American shoes were simply overshoes.

The first lot of these Amazon India rubber shoes made of pure gum was sold in Boston in 1825 by Thomas Wales. These were made to fit a shoe of any size: there were no rights or lefts; they stretched over the leather shoes.

The first domestic vulcanized rubber shoe was made by Goodyear in 1840. The L. Candee Shoe Factory at Hampden, Connecticut, was organized in 1845, under licenses of the Goodyear patent. Then came the Goodyear India Rubber Manufacturing Co. at Naugatuck. The demand became so great that by 1860 there were 1,200,000 pairs of rubber shoes made in this country.

In the late fifties a new overshoe came into vogue, which, with various modifications, was the arctic, invented and patented by T. C. Wales. It consisted of a shoe with a layer of rubber between a cloth outside and a cloth lining.

The rubber boot is an American product, there being no record that any rubber boot was imported from South American countries. Nathaniel Hayward introduced the hard heel in the forties; and from that day to this the rubber boot has been a popular article.

The lumbermen's shoe is an outgrowth of the old women's buskin made in the fifties—a laced shoe lined with Canton flannel and made to wear directly over the stocking.

George Watkinson, then president of the old Colchester Rubber Co., wrote: "In 1860 there were only eight companies making rubber shoes in this country.

They took precedence as follows: Hayward, Ford (or Meyer), New Brunswick, Newark, Candee, Naugatuck, Boston Rubber Shoe Company, Providence (or National). We had three styles of boots, the 'Hip,' the 'Knee' or 'Cavalry' and the 'Short.' Shoes were simply 'overs,' 'buskins,' 'three-strap sandals,' 'one-strap sandals,' and 'Jessie sandals.' The arctic was just come into use at the Naugatuck Company under the Wales patent, which was however not sustained, and every one went into the making of arctics."

Thus has developed over the years one of the most intricate phases of the entire rubber industry; for if one looks to-day into the catalogues of the many large institutions that make rubber boots and shoes, he finds them classed something like this: There are "boots," viz., as we know them, boots that come to the knee or to the hip, loved by the small boy in the spring; there are the "miners," a water-proof boot particularly employed because of the heavy work on ore or stone that it must resist; there are the "dull shoes," the "lumbermen's," usually a leather or a woolen top shoe coming nearly to the knee, with only the bottom part around the foot made of rubber; there are the "artics" and the "gaiters"; and finally there is that miscellaneous group classified as "light goods."

In order to give some idea of the extent of these styles and sizes, the catalogues have been analyzed of four leading rubber manufacturers, viz., the B. F. Goodrich Co. at Akron, Ohio; the Mishawaka Woolen Co. at Mishawaka, Indiana; the Hood Rubber Co. at Watertown, Massachusetts; and the United States Rubber Co. in several different factories. The analysis shows that the styles and sizes made by these four companies when added together give a table that is astonishing in its intricacy:

Classification	Number of Styles
Boots	7,953
Miners	850
Dull Shoes	4,616
Lumbermen	6,027
Arctics	7,953
Gaiters	8,358
Light Goods	41,930
Total	77,687

Thus there are 77,687 varieties of shoes and boots of all kinds made by four companies alone. Each of these styles and sizes is here computed as a pair, and consequently the number of individual shoes, each different, reaches the astonishing total 155,374. These figures give some idea of the tremendous intricacy involved; the problem of manufacturing, warehousing, inventory, etc., is so vast that out of the total rubber industry in all its phases it is probable that the boot and shoe end of it is the most complicated. Figures for 1919 show there were 9,208,000 pairs of rubber boots made, and 66,195,000 pairs of rubber shoes and overshoes, or a total of 75,403,000 pairs. These had a value of $90,780,000.

Light shoes, as we call them in the rubber industry, are generally known as rubbers; they are the lightweight rubber overshoe that we put on to protect water-absorbing leather shoes on a rainy day. When buying rubbers, a customer of the older generation usually had laid before him by the clerk a pair pulled out of a drawer containing a heterogeneous assortment, each two tied together with red string. A rubber shoe was stretched over the leather shoe; there was no question of fit.

As this clumsy, ill-fitting shoe, formerly known as the "gum shoe," often peddled about the country in market baskets, has been replaced by its stylish modern successor, wrapped in tissue-paper and packed in a neatly labeled carton reposing on the shelf of the dealer with all the dignity of a leather shoe, there has come a significant change in the rubber shoe industry. Now it is necessary to use craftsmanship; and the rubber shoe last designer, who determines styles, is an important factor. While he is little heard of, he affects the appearance of the feet of the nation about as Paris affects the appearance of women's dresses. Since styles of leather shoes are so numerous, the rubber designer must gather his ideas from the leather shoe trade, attending the style shows, determining what the leather shoe changes are going to be, and adapting his rubber shoe accordingly. He tries to fit as many different styles of leather shoes as possible.

The first step the designer takes is planning the last. A last is nothing but a wooden form, sometimes an aluminum one, of the size and shape for the particular style and size that is to be made. There are the high heels of the Louis type, the medium or Cuban heel, the low heel, the long vamp, the short vamp, the high instep, and the low instep. After he has grouped all these styles together, he selects those which possess the most points in common. The shoe of each group most closely typical of the lot is then worked up in wood into a composite model last. This last is one upon which a leather shoe would not be made; it is larger, for the rubber shoe must fit over the leather shoe. Then begins the work of an artist. The designer must trace the outline of the bottom to get what he knows as the bottom pattern, and then he must work up each step in the rubber, taking care of two points: the style and the effect of wrinkling and bending, in order that all parts of the shoe work together in action. When the last is finally designed and tested so that the shoe made from it is found to fit exactly, and the style is right in the best judgment both of the last designer and the manufacturer of shoes, the manufacture begins.

The manufacture of light shoes employs the fundamental principles by which heavy boots, arctics, gaiters, and other types are made; for these all differ only in detail. Shoes are made of rubber mixtures and cotton fabric, or rubber mixtures and woolen fabric, since warmth in winter is important, particularly in the arctics which have become so popular. In its essentials, the rubber shoe industry consists of a process by which the rubber mixture, sheeted to the proper thickness, assembled with fabric, and cut into the proper form, is laid by skilled workmen piece by piece upon the last, so that in its unvulcanized condition there is formed a perfect rubber shoe with all the markings, the corrugations of the sole, the band around the top, that make up the finished shoe. In a rubber shoe factory, one is impressed by its intricacy; there seem to be many different hand operations. Each of these, however, is essential; and all parts come together in the making-room from different preparation rooms.

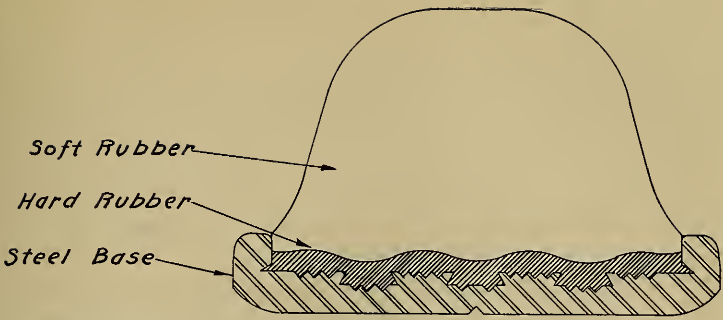
The rubber compounder who makes up the formulas for the different compositions has, after years of experience in this oldest of the divisions of the rubber industry, found that certain mixtures give maximum service. Since appearance plays a large part, he has found himself limited. Rubber shoes, as a whole, contain only small percentages of sulphur, to avoid bloom.

In the plant, the operations start with a soling calender. The compound, which contains rubber and the various strengthening and coloring pigments, will have been mixed in the mill room in the way in which all rubber mixtures are made. It is then taken to the calender room, where it is warmed on the warming mill and fed into a four-roll, small-sized, rubber shoe calender. The idea of the four-roll calender is to permit the use of an embossing roll, for the three-roll calendars used in larger articles deliver the sheet of rubber smooth on each side. Big rolls are housed in heavy framework; and naturally, were they to be removed at any time, it would be a long, difficult operation. Therefore these soling calenders have been made small in size, capable of delivering a long sheet of composition in width a little greater than the maximum length of the sole for any large-sized rubber shoe. Different styles for different purposes require slightly different markings on the bottom. If you will examine your shoe, you will find the grade numbers, the name of the maker, and little variations in the corrugations, indicating different styles and shapes. Upon the fourth roll has been cut by an artisan the depressions which will produce these raised conformations on the sole, and the rubber is embossed by this roller as the sheet passes between it and the adjacent one. To permit different types of impressions, there are usually several of these embossed rolls. By means of easy locking devices, and since it is small, the embossing roll may be removed readily and another one substituted.

The sole is one of the fundamental parts sheeted on the calender to the required thickness. As it runs out in a long strip, workmen cut it up in sheets of the proper length and put it in "books," which consist of boards with sheets of cloth attached on one side to prevent the layers of rubber from sticking together. In another, but slightly larger calender, may be running at the same time the thin sheet of the "upper" compound. This thin sheet will have marked upon it by the embossing roll the outline of the upper, the outside part of the shoe that goes around the foot above the sole. In still another calender may be running simultaneously cloth, wool, or cotton of the particular weave needed, upon which is being laid friction, the soft rubber composition forced into the interstices of the threads. The fabric may also be coated. Here we have the sole, the upper, and the fabric parts. I have not mentioned the various other small but important parts that go to make up the shoe: the little trimmings, the reinforcing parts or stays, the insole, the heel, all of which are made in different rooms, for various purposes. Since there are many parts and many sizes of each shoe, there must be many workmen and many machines.

Only the three fundamentals—sole, fabric, and upper—are here considered. These pass from the calender room to the various preparation rooms where skilled workmen, or in some cases machines, cut out these several parts into the particular shape required. Finally, these numerous compositions and shapes are assembled in the making-room in accordance with a "ticket" or plan previously made. A given number of shoes a day requires a large number of parts. The making of the ticket in the shoe factory is an important operation of management. This ticket must show at each step in the operation the proper quantity or number of each part for each type of shoe, so that hour by hour and day by day the parts will come to the making-room in the necessary amounts, with no delay to the shoemakers. In one of these large, well-lighted making-rooms, you will find lasts in number and sizes specified by the ticket.

The shoemaker's one duty is to lay upon the last in the proper order these different parts. Since the insole is next to the foot, or leather shoe, as the case may be, while the fabric that is to serve as the strengthener lies at the bottom between the insole and the outsole, the first operation is that of laying the insole upon the bottom of the last. Outside of that is placed the fabric lining and reinforcing pieces. Then the upper is applied and rolled down, so that it exactly and tightly fits the last. There it is stuck definitely to the other parts and set to the height and points of shape that the designer has intended. Finally the out-



Courtesy of The B. F. Goodrich Co.

PARTS OF A SOLID TIRE

Courtesy of The B. F. Goodrich Co.

A LADY'S SLIPPER, MADE IN THE MODERN RUBBER FACTORY

Courtesy of The B. F. Goodrich Company

A RUBBER SHOE MADE ON THE AMAZON

sole is laid on and rolled down, usually a layer of cement having been put upon it that it may stick tightly to its adjacent rubber. The outsole is carefully forced by a roller in the hands of this skilled operator around the edge and over the upper, the operation making a neat outside binding. Each type of shoe is constructed a little differently, and yet here lies the crux of the whole thing: the bringing together of these different-shaped rubber pieces upon a previously designed last, with the shoe thereby formed definitely to the shape intended.

After they have been formed upon lasts, these light-weight rubbers are put upon trucks and pushed out of the making-room into another room where several at a time are dipped into a bath of a special varnish, the purpose of which is to give the rubber shoe the high polish that is so desirable. Any grade of varnish would not accomplish the desired purpose; for it might come out of the vulcanizer with a motley colored sheen or dull. Years of experience have developed this varnish to withstand heat and the action of sulphur without change of color.

After they are varnished, the shoes, still on their lasts, are returned to the racks on the big truck and are pushed through another room into the vulcanizer. This vulcanizer is, in reality, a large room containing steam coils that serve to heat the air in the room, the hot air in turn supplying the heat to the rubbers and so vulcanizing them. Thus the rubber shoe is vulcanized in what we call dry heat, that is, in hot air, by a carefully regulated temperature over a period of several hours. When this time is completed, the trucks are pushed down into the inspection room. Here the shoes are removed from the lasts, inspected, and sorted; the excess of fabric and rubber around the top of the shoe is carefully cut off by skilled trimmers; and the rubbers are packed into boxes ready for shipment to the shoe store.

If we were to follow through the manufacture of heavy boots, lumbermen's or arctics, we should discover essentially the same principles, though carried out on a heavier and larger scale. Where in the light shoe, for instance, there is around the rubber upper only one ply of fabric, in the heavy boots there are two plies near the top, graduated to as many as seven plies near the bottom, with reinforcing layers of rubber. And while the sole of a light rubber may contain two plies of fabric and be only a matter of five thirty-seconds of an inch thick, the sole of a heavy boot usually is strengthened by a thick, tough insole and several other plies of fabric, being often half an inch thick.

Furthermore, in the vulcanization of different types of boots, there are several methods; for one of the fundamentals in vulcanizing such heavy articles is to create enough pressure to avoid the development of air bubbles and blisters. Therefore, different processes are used to give a pressure sufficient to hold the layers against the last tightly enough so that blisters will not be created. In the boot, design or balance of parts plays an even greater rôle in service than is the case with ordinary rubbers, for it is subjected to excessive wear.

Why are some shoes white, some red, and some black? There is a good reason for the majority of them being black; it is the history of the industry. We are willing to have black, because black is so consistent a color of leather shoes and is so natural a one to our eyes. We seem not to care for variegated colors upon our feet. However, the manufacturer's one aim has been to find those things which give service, regardless of what they might be, where they might come from, or what they might look like. He makes a definite study of special types of service. In the use of boots, he must consider the cold weather of the North and the hot climate of the South. He must consider the fisherman who shovels herring, fills baskets with cod, or stands in the canning factories of the Pacific Coast day by day in slime and oil. Here a boot must withstand a particular condition and give a long wear. He must also consider the miner who, in the copper-mines, works in acid water containing copper salts; he must remember the lumberman snagging his foot-covering as he fells the giant trees in the forest; a hole may mean a frozen foot—perhaps death. All these varieties of service are studied in the little office of the designer of rubber boots and shoes. In the effort to develop service qualities under such difficult conditions, there have come to be different colors in rubber shoes. The color itself, however, has been secondary. They could be, nearly any color of the spectrum wished by the consumer.

On the tennis-court the players move quickly to and fro; the school children to play basket-ball crowd the gymnasiums; with sure feet, they jump and run on the airy, soft-soled tennis-shoes. Tennis-shoes constitute a considerable part of the use of rubber as foot covering, for in 1919 there were 19,896,000 pairs of these canvas shoes with rubber soles.

The fundamental principles of manufacture are essentially the same as with rubbers, except that instead of a rubber upper there is a canvas upper.

Apparently Walter B. Manny, in 1891, first suggested the use of rubber heels. In the last ten years, and particularly during the last five years, the use of rubber heels on leather shoes has grown to astonishing proportions. They are resilient and soft enough to take away the effect of the blow of the foot as the heel strikes the pavement, removing therefore considerable jar from the body and giving comfort to the wearer. They are longer in life than leather. Therefore we find that an industry which was too small to be reported in the census of 1914 had grown in 1919 to the extent of 138,468,769 pairs of rubber heels and a value of $14,238,000, a development which could not have taken place unless these heels possessed definite value to the wearer.

What becomes of these rubber heels? The Census Bureau answers the question and propounds another when it says that the production of leather shoes in the year 1919 totaled 275,357,206 pairs. Thus, about half the leather shoes are equipped with rubber heels. Why? Because, while the shoemakers are in the leather business, when the wearers come to know the health and comfort to be derived from rubber heels, every one will demand and receive them on his leather shoes.

The manufacture of rubber heels is typical of that of other molded rubber goods. The rubber mixture is sheeted out in about the thickness of the heel. Unvulcanized blanks are stamped out of this sheet by dies in a power-driven punch press. The raw heels are inserted into molds, which consist of either two or three pieces, design plate, form plate, and cover. Molds have raised lettering or designs engraved in the plate. In place of the necessary holes for nails or screws, steel pins of corresponding shape are screwed in. Design and form plates are provided with guide-pins, so that the heel form fits with the lower plate. The thickness of the form plate corresponds with the thickness of the heel. Before the hot molds are filled, they are brushed with a solution of soap to prevent the rubber after vulcanization from adhering to the steel.

The vulcanization of rubber heels is effected in hollow-plate presses like those used in the laboratory, except that they are larger. So that an equal pressure may be applied upon the molds, the platens must be parallel to each other. The presses are used in batteries of a dozen or more, the steam in each of which is automatically controlled. After the vulcanized heels are removed from the molds, the rind is trimmed off. The resulting rubber heel is to the human foot what the pneumatic tire is to the automobile.

The modern rubber sole is an achievement of rubber compounding and manufacture. Nearly all the mixtures have in them a certain percentage of wool, cotton, or leather fiber mixed with the rubber and vulcanized. The compound is mixed in the usual way in the mixing mills, sheeted on the sheeting calenders to a correct degree of thickness, cut out to the approximate shape of the finished sole, and vulcanized in a sole mold of the usual character, for the necessary time and at the proper temperature, the mold being held together by hydraulic pressure. There are various kinds of unusual types, such as soles with inserts of strands of stout cord under the ball of the foot and at the heel; there are special ones with knurlings or corrugations on the soles, although these are not widely used.

No sooner had crude rubber come into the European markets than every practical man who worked upon it tried to make garments. The old English stage-coaches had outside top-seats; and since England is so rainy a country, it was natural for the men who traveled from Manchester to London, desiring to keep themselves dry and warm, to study how this new substance could be used for the purpose.

Many attempts were made in the years after 1790; but it remained for Charles Mackintosh of Manchester to find it possible to "dissolve," as he called it, rubber in coal-tar naphtha, to apply it to cloth for waterproofing purposes, and out of the cloth to make a garment. This was the first practical rubberized garment made; it was named from the inventor "Mackintosh," a word that has come into the English vocabulary. That great pioneer of the rubber industry, Thomas Hancock, became a business partner of Mackintosh in 1833, and much of his study had to do with attempts to improve the rain-coat. Indeed, the first practical application of the Parkes method of cold vulcanization of rubber by the use of sulphur chloride in a solvent was the vulcanizing of the rubber which had been applied as a thin layer of composition upon the surface of these cloths.

Emory Rider, who died May 24, 1884, worked with Goodyear in Springfield, Massachusetts. He is said to have been the first to vulcanize clothing, and he underwent extraordinary trials for want of suitable mechanical means for the vulcanization of large pieces of goods.

So important was the use of rain-coats considered during the World War that there was a total purchase of ponchos, rain-coats, and slickers by the Government amounting to ten million garments and costing more than forty-six million dollars. It is an industry to-day of infinite variety, largely, however, in respect to the styles of garments and the colors and weaves of cloth required. Man in his garments seems to wish variety, and women extensive variety, so that there are various hues, shades, weights, thicknesses, and weaves of rubberized garments. Generally speaking, manufacturers make them in three classes: there are single-texture fabrics, with one layer of fabric and a layer of rubber on the inside; there are double-texture fabrics, with two layers of cloth stuck together by a layer of rubber between them; and there are fabrics with a layer of rubber on the outside.

In the process of manufacture, after the choice of the proper composition, which depends considerably upon the quality and service which the particular coat is supposed to render, and upon the choice of the fabric, the rubberizing of the cloth, so far as single-texture and double-texture cloth is concerned, is done by application to the cloth of rubber in the form of cement. We still follow the original method in principle that was worked out a hundred years ago. A spreading-machine, as it is termed, is a simple apparatus looking like a long table, at one end of which is a roll; above this roll is a metal sheet known as a knife or a doctor blade. This knife, by careful adjustment, is set down close to the fabric, which has laid upon it a certain amount of rubber cement that has been previously prepared by churning the mixed composition in gasolene. As the cloth then passes between the roll and the knife, a thin layer of cement is laid upon the cloth. In its travels the cloth passes to the top of the long table, which really consists of a series of pipes or steam plates into which steam is forced; the heat generated thereby evaporates the solvent. Then the cloth is rolled up with fabric next to each concentric layer to prevent its sticking to the adjacent layer.

The operation is repeated until the proper thickness of rubber is built upon the cloth, when it is, in the case of single-texture garments, passed on to the vulcanizing-room to be vulcanized. In the case of double-texture garments, the layer of cement is placed upon one side of each of two layers of fabric, and these two are then unrolled through a doubling-machine, consisting of two metal rolls under high pressure, which force the two layers of fabric together rubber to rubber, so that they stick. As the cloth issues from the doubling-machine, it is rolled up and passed on to the vulcanizing room.

With single-texture garments either one of two processes of vulcanization may be used. The original

Parkes or sulphur chloride process is one of them. This is still much employed in Europe and more or less so in this country. In this process, the rubber side of the fabric by a continuous movement is carried in contact with a roller, the opposite side of which is turning half immersed in a weak solution of sulphur chloride in either benzine or carbon bisulphide. This gives a light, weak application of sulphur chloride to the rubber, so that on hanging festooned in a large room for a few hours, the rubber becomes vulcanized. In the case of the dry-heat method of cure, the fabric is festooned or hung across bars near the ceiling of a small room, the air in which is heated by steam coils on the bottom of the room. After a few hours the vulcanization is accomplished, and the fabric is removed, ready for subsequent operations. Double-texture fabric is usually dry-heat vulcanized. The rubber-surfaced fabric such as you see upon policemen and firemen for protection from water is sometimes made by the application of rubber from a spreading-machine, but more usually, I believe, by the application of a thin layer of rubber in the usual manner on a friction and coating calender, after which it is dry-heat vulcanized in the way that has been described. The result, regardless of the process or purposes for which it is intended, is rolls of cloth with rubber on one side or between two layers.

From such rubberized cloth, garments are made by manufacturing tailors by methods similar to those used by tailors everywhere. In building up the cloth into the garment, it is no longer sewed but is cemented together. After vulcanization of the cloth a second time in a dry-heat room, the seams adhere tightly enough to be effective in shedding water.

Protection from the weather is, and doubtless ever will be, an extensive use for rubber in the service of mankind. The mother sends her child to school with rubbers and rain-coat. The business man wears his sandals; the workman dresses in heavy garments and boots. Of vital value to health and comfort are rubber footwear and clothing.

CHAPTER XII

BROADENING THE FIELD OF SPORT

Sport requires quickness of mind and muscle. From earliest times, the snappiest substance was chosen for sports of different kinds. Long before rubber was discovered, ball tossing was indulged in. More than four thousand years ago, in the twelfth Egyptian dynasty, the throwing and catching of balls was known; and we find that the early artists sculptured human figures engaged in this sport. A leather-covered ball was used in the games on the Nile more than forty centuries ago, and one of these early specimens has a place in the British Museum.

Using a leather-covered sphere stuffed with hair, the Greeks played ball. One can imagine that not many home runs were batted with such a dead ball. The Greeks believed in symbolism, for they played this ball-tossing game primarily in spring, to typify the emerging into life of nature after the gloom of winter. Later the princes of Europe played the game, as probably many others did, who could afford either to make or to purchase the balls. But South American Indians had an advantage over the people of Europe, for the ball that they used was lively rubber; the game therefore was more interesting.

The American sport of base-ball, it is generally believed, was founded by the Knickerbocker Club of New

York in 1845. The earliest regulations, formulated in 1858, specified that the ball should be composed of India rubber and yarn, covered with leather. To-day the base-ball is built up around a rubber and cork core, weighing one ounce and properly vulcanized and molded in spherical form. Upon this is wound woolen yarn at a definite tension; the ball is covered with carefully tanned, selected, tough leather, sewed in the way that all Americans know. This combination of wool, rubber, and leather, which weighs between eight and eight and three-quarters ounces, is the thing the home run kings bat over the fence; it is what makes possible a game enjoyed by millions; it is the best-known article that contains rubber.

But this it not the only respect wherein rubber serves the great American game. In the old days, the intrepid catcher caught the ball or it hit him; but then the ball was pitched with less speed and fewer baffling curves than now. Later it became necessary for him to be armored with a body-protector made of rubber covered with fabric and blown up tight enough with air to absorb the shock should the ball strike it. There is many a catcher who has sent up a vote of thanks to rubber for protecting him against serious injury.

Let us turn now to another great and popular game. Base-ball is played by comparatively few but seen by thousands. Golf is played by thousands and seen by few. It is estimated that there are in this country more than 500,000 golf players, playing on about 2,500 courses. In the year 1921 there were very close to 7,200,000 golf-balls made and sold in this country. It has truly become a popular game.

There is considerable doubt just when and where the game of golf originated. Some authorities contend that the game is of Scotch origin; others say it began in Holland. Some believe the word "golf" is derived from the Teutonic word *Kolbe,* meaning club, or from the Dutch word *Kolf.* One thing, however, we do know; the game was in some form played in Scotland as early as 1353.

The first ball used was egg-shaped and made from beech wood; the club was carved from one piece of wood and shaped something like the present hockey club. The modern golfer, who loves the smooth green and the exactly spherical ball, to be sure of accuracy in putting, would indeed find himself lost in the attempt to putt an egg-shaped piece of wood with a hockey club. In those days there were no regular golf courses or any particular places of play. The players usually agreed on a starting-place and an objective. The contest was to determine which player could drive his ball to a certain object in the shortest time, and, in some contests, to arrive at a destination in the fewest number of strokes.

Since all games change and progress, it was not long before the wooden ball was superseded by one which was made of hard-pressed feathers with a leather cover, and which was but a little larger than the present ball. So far as skill in its hand sewing was concerned, the cover was a work of art. It is stated that so many feathers were packed into one of these small balls that if released they would more than fill an ordinary hat. Feather balls were used until 1848, when it was discovered that gutta-percha, a relative of rubber, could, under heat, be shaped in an iron mold to the form of a sphere. According to W. Dalrymple in "Golf Illustrated," of November 30, 1901, the real inventor of the "gutty" golf-ball, was the Rev. Robert A. Paterson, for many years principal of the Binghamton Ladies' College in New York State. In 1845 he rolled a lot of gutta-percha clippings into a ball, painted it, and used it on the links. One of the first Scotchmen to use this invention was William H. T. Peter.

Naturally, many experiments were made with the new ball. The introduction of it tended to make the game more popular and somewhat cheaper. The ball had kinks of its own, as we duffers think all golf-balls have, one of which was a tendency to "duck." Gradually it was found by the more persistent players that after a ball had been used a few times and been considerably bruised, the flight was better. Balls came to be made with marks on them, the scoring being done with a chisel or a hammer, and after a while with the mold itself. Although it took about six months properly to season a "gutty" ball, when produced, it was quite serviceable and distinctly economical; for it could, when worn, be remolded.

The game in the early days became so popular that an ordinance was introduced into the Scotch Parliament in 1457 decreeing that "futball and "golfe" were not to be played at some certain periods that were set apart for training in archery. During the four hundred years following, the game remained almost entirely in its native land. Even in 1875 the royal and ancient game had made very little progress south of Scotland. But in 1890 it took sudden and popular hold, and since then it has developed with great rapidity. Comparatively new in the United States, the first amateur championship games were played over the old St. Andrews Golf Course at Yonkers in 1894. The next year the first championship game was played under the auspices of the United Golf Club Association at the Newport Golf Club, Newport, Rhode Island.

The solid gutta-percha golf-ball, with various forms of marking, held its own until 1898, when a new idea in golf-ball manufacture, and one destined to prevail, was introduced by a resident of Cleveland, Ohio, Coburn Haskell. The story of this invention is of particular interest to me, for this manuscript was written not a hundred yards from the site of the old building, now torn down, in which the first thread-construction ball was wound. One evening Coburn Haskell was discussing various inventions with B. G. Work, then superintendent of the B. F. Goodrich Co. at Akron. In the course of the conversation, Work remarked to Haskell:

"Why don't you invent something?"

"What shall it be?" said he.

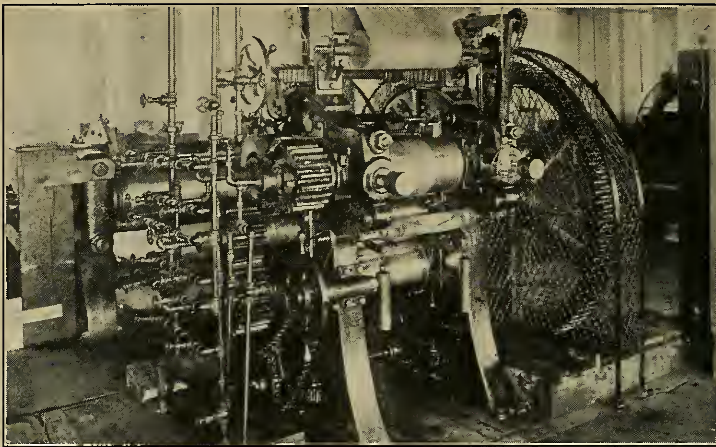
"You 're a great golf enthusiast," replied Work. "What we need for golf is a new type of golf-ball; more uniform and with a longer flight."

Haskell lay awake most of the night dreaming of golf-balls. The next morning he remarked to Work, "Why not make it up of rubber thread wound under tension?" That appealed to the practical genius of Work as a clever idea and one that was the answer to the question.

At that time the B. F. Goodrich Co. was engaged in the manufacture of rubber thread for suspenders, and several skeins of it were brought up to Work's office. There Haskell set himself to the task of winding a golf-ball. Imagine a man unused to skilled work attempting to wind many yards of rubber thread under tension into a spherical form! No sooner would the ball be partly wound than it would slip out of his fingers and fly away over the floor; then the work had to be done again. He gave it up at last, and some skilled girls were called in to wind the balls. The thread spheres were sent into the factory and covered with gutta-percha in a hollow mold. Haskell could scarcely wait for a train to Cleveland to try the ball on his golf course. He at once found it to be longer in drive and truer in putting. This original ball was composed of a gutta-percha core, upon which was wound thin rubber thread; the two substances were enclosed by a gutta-percha shell.

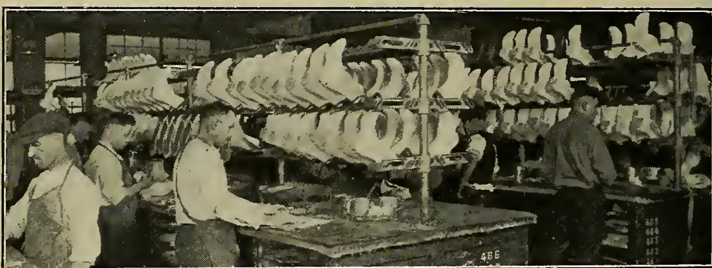
The new Haskell golf-ball met with much prejudice. Not until 1901 was the first important test given to it in amateur championship contests at Atlantic City. There twenty out of the twenty-four starters in the qualifying round used the new ball, among them W. J. Travis and C. B. McDonald. Travis managed to win the qualifying medal with it, turning in a score of 157 strokes and eventually winning the championship.

This ball increased the length of the player's shot, but it was difficult of control. It ducked. The first balls made were put out with shallow lines on the surface. Deeper grooves were soon applied; by them the difficulties with ducking were overcome. A short time



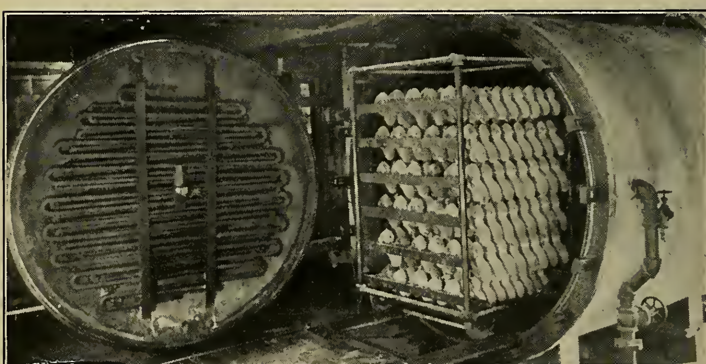
Courtesy of United States Rubber Co.

THE SOLING CALENDER



Courtesy of The B. F. Goodrich Co.

AT THE MAKE-UP TABLE



Courtesy of United States Rubber Co.

SHOE VULCANIZING

later the "bramble" or "pebble" surface marking was adopted, with further improvement in trueness of flight. Through its snappiness the new ball brought with it the necessity for lengthening all courses. Hits that were laid out for the average players were made to look ridiculous. Irons came into use where drivers and brassies had formerly done the work.

As time went on, longer and longer flights became possible from more and more scientific construction of the center and the cover of the golf-ball. Such rapid changes worried the officials of the golf associations who feared that the courses might be reduced to a mere drive and a putt. To curb the tendency toward excessive length of flight, for no man knows how far it might be possible to develop a golf-ball by means of the modern science of the rubber industry, the United States Golf Association and the Royal and Ancient Association of Great Britain joined together and agreed that the golf-ball must not exceed 1.62 ounces in weight or measure less than 1.62 inches in diameter. The styles of marking were left matters of choice.

The modern golf-ball is one of the most delicate, intricate, and scientific articles made by the rubber industry to-day. It is composed essentially of three main parts. The center or core contains a heavy material such as lead, to give proper weight and thus influence the length of drive, and is usually mixed into a soft mixture. If you examined the photograph of a section of a golf-ball that has been frozen and sawed in two, you would see how large a part is occupied by this core. Many substances, steel, hard rubber, soft doughs, stiff pigments, even liquids, are found in some of the many brands. Around it are layers of rubber thread of several sizes, widths, and thicknesses. This rubber thread is made of the finest rubber and sulphur composition that the chemist can produce. Around the thread is then molded a gutta-percha cover. Not only must the cover be as resistant as possible to the edge of an iron, but it must be soft enough during the molding operation under heat to amalgamate with the outside layers of thread. The markings on the cover are carefully designed; for if they are too deep the ball will soar, if too shallow the flight will be low, if none at all the ball will duck. Balls of the same weight and size, the same core construction, and the same thread tension, molded in the same way, will show different distances by several yards when the indentations in the cover are of different number, size, and depth.

The painting operation of a golf-ball is one of those intricacies necessary to its proper construction. A good golf-ball paint is not one that can be bought from any paint-shop; it must be chosen carefully. It is required to adhere to the gutta-percha cover even when the ball is distorted or when it is struck with the edge of an iron. It must therefore be flexible and resistant to blows. It must not change color in the sun; it must not crack; and it must not be so soft that it will slow down the ball on a sand green by picking up sand.

Perhaps one of the most important phases of its manufacture is the accuracy with which the core is made and the correctness with which the thread and other parts are applied, in order to make sure that the ball may be true to center. Only a truly spherical ball, with the center of gravity in the precise center, will give true flight and accuracy on the putting green.

In the long course of manufacturing development that has produced the modern golf-ball, there have been many processes perfected. The original Haskell patent described "a golf-ball comprising a core composed wholly or in part of rubber thread wound under high tension and a gutta-percha enclosing shell for the core of such thickness as to give it the required rigidity." This problem of winding thread under tension was no easy one. Therefore the invention of the winding machine was one of the most important steps in the development of the golf-ball as we know it, and today these better-than-human machines work rapidly and accurately.

The first stage in the manufacture of the golf-ball consists in the formation of the soft center. Upon this is wound a tape of vulcanized rubber. This core is then taken to the winding-machine; and upon it as a center there is wound the vulcanized rubber thread. A power-driven device does the winding. In the machine the ball center is revolved upon a variable axis that moves enough and at regular intervals so that the thread, which is carried around by the machine and unwound from a shuttle, is wound in different great circles upon the core and evenly distributed over the entire body of the ball. As it passes from the spool the thread is stretched and wound upon the golf-ball under an exactly regulated tension.

The flight of the golf-ball in play is partly dependent upon the degree of tension applied to the thread while being wound. The prevailing practice is to stretch it almost to the breaking-point. Rubber is a peculiar substance, in that it is easy to stretch a considerable distance, but more and more difficult to stretch slightly farther distances. In golf-ball manufacture the thread is put under that tension which brings it up to what may be called the difficultly stretchable part. This gives it the maximum practical tension. Some balls are wound under high tension and some under lower tension. The floaters and the more durable balls generally, so far as the cover is concerned, are wound under lighter tension; they thereby have less length of flight. Because the thread is placed upon the core under the maximum tension, the high-tension balls are harder, feel heavier under the blow, and travel greater distances. There are many different kinds of winding-machines, all of them, however, having for their purpose uniformity of tension and proper spherical shape.

After the golf-ball has been wound to its precise size and inspected to make certain of size, weight, and tension, it is taken to the molding-room, where the cover is applied. Several methods are used. By one of them these covers are first formed in two hollow hemispheres in a preliminary molding operation. The mold, which is made of metal, then has one of these hemispheres put into it, the rubber ball placed in that, the other hemisphere placed on top of it, and the top half of the mold applied. The mold is then put into a hydraulic press, heated with steam, and warmed. When the gutta-percha is soft, the halves of the mold are brought together by hydraulic pressure, the action forcing the soft gutta-percha into the outside layers of the thread and into the markings of the mold. After the proper time has elapsed, the steam is turned off; and, to cool the mold and the ball, water is then turned into the hollow plate, the cooling making it possible to remove the ball from the mold without injury. When hot, the cover is soft; when cold, it is hard and firm. After removing the ball from the mold, the operator cuts off the slight excess of cover squeezed out between the two halves of the mold.

The ball is then examined again for accuracy and is sent to the room where it is painted. It requires several coatings of paint before the right quantity is applied. After the ball is dried, the different colored paint is put into the lettering to indicate clearly the manufacturer's name and brand.

There are three characteristics that make the golf-ball what it is to-day. It must be constructed in a way to give under the proper blow of a club a long and true flight. Secondly, it must be sufficiently hard and heavy so that on a putting green a fairly firm tap of the club is required to give the putt direction and accuracy; for a light-weight ball is inaccurate on the green, and in the approach shot it will bound off the green if too light and snappy. Thirdly, the cover-resistance must be sufficient to make the ball durable under reasonably severe playing conditions.

The flight of a ball is influenced by several different conditions: the temperature of the air, the barometric pressure, the humidity of the air, and the wind velocity. Golfers as a rule find wind to be the only obvious condition that influences their play beyond, of course, their own muscles. A golf-ball is, therefore, very much in the position of a projectile to be fired from a cannon. In a recent interesting article by Innis Brown in "The American Golfer" a comparison is made between the effect of wind and air resistance upon golf-balls and cannon-balls. Temperature also plays a distinct part. In certain tests made in England, the same balls driven by the same mechancial device traveled on an average twelve yards further in May than in January. A considerable part of this flight was influenced not by temperature in so far as resistance of cold air on the ball is concerned, but by the effect of temperature on the rubber thread. Rubber thread is snappier in hot weather than in cold. Therefore the flight is longer in the hot weather than in cold.

The markings on the surface of the ball have been mentioned, for they influence flight very particularly. These influences have been studied in recent years by scientists, and it is now clear that different types of markings give different effects. Nothing flies well without some degree of spin; rifles are grooved in order to give spin to the projectile, which otherwise would wabble in flight. Arrows are given a directional character by a tail; even a kite is balanced in such a way that it maintains its flight, and the poorest-balanced kite is the one which wabbles the most. Each of these articles in the air must follow its nose, a difference in pressure being developed upon one end from that on the other.

So there is on a golf-ball a pressure greater at the bottom of the ball than at the top; thus the ball is acted upon by a force tending to make it move upward.

The difference between the pressure on the two sides of a golf-ball is proportional to the speed of the ball in flight multiplied by the velocity of the spin. When the golf-ball leaves the face of the driver in a well hit stroke, it travels at great speed. In front of the ball, the air is under considerable pressure; and from this point of extreme compression to the back of the ball, the air regains its normal density. Therefore, there is a disturbance in the atmosphere in the form of a tube of compressed air. As the ball travels forward, it creates in a constantly decreasing degree this tube of compressed air; and the air rushes around the ball, flowing in and out of the irregularities. These irregularities thus get a grip, so to speak, on the air; and the ball is steadied in a remarkable degree during its flight.

Recently measurements have been made to find out how much energy is imparted to a golf-ball by the blow of the club. In this test various golf-balls were dropped from different heights upon a heavy iron plate, which had been covered with a sheet of carbon-paper, so that the imprint of the flattened region of the ball was left on the paper. By the determination of the diameter and area, we learned how much the ball was flattened; and from this we computed the amount of energy required to distort the ball to that degree.

Measurements were also made of the flattening given to the ball by the blow of the driver in actual play. The club-head weighed fourteen ounces; its velocity was 203 feet a second; the energy of impact was computed to be sixty-five foot-pounds. By computation we found the velocity of the ball to be about

198 feet a second, and the energy stored in the ball as it left the club-head to amount to about sixty foot-pounds. This energy is equivalent to the amount of work one would have to do if he lifted sixty pounds one foot.

Some further studies were made to find out how much force would be required to burst a ball when the load is applied gradually. Is it possible for a powerful player striking the ball with accuracy actually to smash it? One of the standard makes of ball was placed between the flat steel plates on the head of a testing-machine and compressed. With a load of three thousand pounds applied to the ball, it flattened without breaking to the extent of more than half an inch. It required 3900 pounds of pressure to cause the ball to split open. In view of the fact that calculations show a sixty-five foot-pound force for the average club stroke, it is highly improbable that any person can burst the ball by a direct blow.

Why is it, then, that balls break? They are not broken; they are cut. The edges of mashies and other irons are sharp; and when this edge strikes the surface of the cover with the force of a heavy blow, the cover cuts. Some of the golf players in this country believe that their game would be much better if they used the same brand of ball favored by the accurate, heavy-hitting professional players. The most powerful one is the harder ball, for it contains thread so wound that it has the maximum return force. Being hard, this type of ball is readily cut when topped with an iron club. The reason for this can be demonstrated by a simple experiment. If you will place a sheet of paper upon a piece of glass or any hard surface and press upon it with a knife-blade, you will find that it cuts through very easily. If you put under it a wide rubber band and press the blade with the same force, you will observe that the paper does not cut, because the rubber band yields. The golf-ball with the most resistant cover is usually the one that is the softest wound, for the ball inside the cover yields under the force even of a cutting blow. This yielding gives durability to the cover.

Since the long-driving, powerful ball yields less easily to the light blow, this property permits it to be dead on the green, a fact which conduces to accuracy in the approach shot and in putting. For the average player, the difference in distance to be gained between the hard and the soft wound ball is negligible. In fact, the light hitter will gain more distance from the softer ball. The game is won, after all, by the ordinary golfer not on excessive lengths of drive so much as on accuracy in approaching and putting. We can, however, gain longer flight by the choice of balls a little softer wound.

How long should a golf-ball last? Most of them last until they are lost. Since the rubber thread is an exactly made rubber composition and is protected from the action of the air by means of the cover, there is no reason why the internal part of the golf-ball should not last for many years. The cover is durable and reasonably permanent; the paint is inclined to dry and on old balls to check when struck with a club. It is probable, therefore, that the present construction of golf-balls is such that they all should last as long or longer than any player is able to use them.

Another important use of rubber in sport is in the tennis-ball. A British army officer is popularly credited with the invention of the game of lawn-tennis. His original idea was a game to be played on a court shaped like an hour-glass, sixty feet in length and thirty feet in width at the base-line. Tennis is essentially a modern game; its genealogy is rather obscure. The first record of any such game in Europe occurred sometime in the middle ages, when a crude form of it was a popular sport of the European nobles. The French game was played with a cork ball which was struck by the hand and driven over a bank of earth serving the purpose of our modern net. It flourished in England for a number of years; and was introduced into America probably about 1874, when rackets rather awkward in shape were used and the balls were made of uncovered rubber, similar to the toy balls of children. The balls were later covered with flannel and then with felt.

The tennis-balls now universally used are made of rubber of a resilient composition. This composition is made into the form of a sheet upon a sheeting calender. It is then cut in sections, like an orange peel after quartering. Carefully cutting the edges at an angle or skiving them, girls cement them, and press them together. The ball is then placed in a hollow steel shell or mold. Before this, however, a little water or other blowing material is put inside. The ball is then placed in a curing-press and heated with steam. The steam causes the water or ammonia to blow and force the rubber against the walls of the mold. During vulcanization, therefore, the pressure developed by the steam is sufficient to keep this rubber against the inside surface of the mold. After vulcanization, the ball is removed from the mold and gaged for size. A hollow needle is stuck through it at a little point where a self-healing bit of rubber exists on the inside of the ball; through this hole the ball is blown up to the proper pressure, about ten pounds to the square inch. The ball is then slightly roughened on the surface and covered with cement, and a layer of flannel is carefully applied. It is then ready for packing.

There are several other methods of manufacture in detail, each of which aims at the end of exactness in shape, weight, size, and durability.

The size and the weight of these balls have not been varied since the beginning; the laws on both sides of the ocean prescribe them to measure two and one half inches in diameter and to weigh two ounces. Great care has to be taken that the rubber part of the ball be not porous; although under the best of conditions nitrogen and oxygen diffuse through rubber, and the ball gradually loses its life. It is a remarkable fact, however, that of all the gases that might have been chosen, the constituents of air are those which diffuse through rubber the least readily. If carbon dioxide had been used, for instance, the life of the tennis-ball would be much shorter than it is at present.

There is a prescribed standard of resilience. If balls are dropped from a height of ten feet, they must rebound not less than five nor more than six feet. The game is a fast enough one as it is, without making the snappiness of the ball too great.

So one could go on with various other sports. The hand-ball of the gymnasium is a beautifully constructed spherical ball of strong, lively rubber. There are also the squash-balls. Polo employs a rubber ball and hockey a rubber puck. In foot-ball there is the rubber bladder inside the leather case; the players are protected by rubber nose-pieces and ear-guards. The basket-ball is a sphere of carefully softened and shaped leather, inside of which is a rubber bladder blown up to tension. Even in billiards the cushions upon which the player depends for the return at his chosen angles are a most carefully worked out rubber composition of high resiliency and of great permanence. Here is no particular question of durability, for the action of billiards is not one of an abrasive or wearing character, but there is a question of permanency and resiliency. The moment the billiard cushion becomes even slightly dead, the skilled player can determine the fact, and the accuracy of the game is reduced.

In the realm of sport the use of rubber products is essential to most games. They surely would be dead and lifeless without it.

CHAPTER XIII

POWER AND LIGHT

One simple little thing, small in size, easy to make, used in thousands of forms, brings into the home, tamed, a mighty force. By it power to move mountains is controlled, the dark places are made light; by it the waters of Niagara disrupt the rocks and deliver them as aluminum pots and pans into the kitchen; by it coal is made to drive the trains rushing through the smokeless tunnels and the trolleys over city streets; by it the invisible force of electricity lights homes and streets. It is insulated copper wire.

Our school children scuffle along on the carpet in the winter and surprise their mothers with a spark on the back of the neck. They play with frictional electricity, known in the year 941 B. C., when the Greek philosopher Thales, on rubbing the natural fossilized resin known as amber, found that it took on the property of attracting light bodies, such as straw and feathers. From the name of the tears of Heliades, called "electron," came in later years our name "electricity."

The kind of electrical discharge, however, which made necessary some type of insulation is the electrical current that "flows," as we say colloquially, along metallic conductors or wires. This type of current was discovered in 1780 by the Italian anatomist Galvani. He and Volta discovered how electrical currents may be generated and the fact that they flow from place to place through wires.

When the induction-coil was invented, by which magnetic forces could be generated through the medium of coils of wire, it became necessary to provide some means of insulation; that is, of separation of wires, so that the different strands would not come in contact with each other and thus cause the current to flow by the most direct path rather than through the entire length of wire. When the brilliant British scientist, Michael Faraday, in 1831 discovered that a current of electricity could be induced in a coil of wire either by moving the wire away from a magnet or toward it, or by moving the magnet toward the wire or away from it, there began the development of that marvelous machine upon which our greatest electrical developments rest, the dynamo, and its brother, the motor.

The first dynamo, made in 1832, was constructed of a length of insulated wire wound upon two bobbins with soft cores. Step by step, these machines have grown and changed, until from them have come our high tensions and vast transmission systems. The fact that a dynamo could be reversed and run as a motor was known probably as early as 1838, but the value of this reversibility does not seem to have been realized until 1873.

Now alternating currents generating at high pressure from 2000 volts up to 11,000 volts are produced at almost any power station. In the United States currents have been conveyed to places one hundred or more miles from the station, at pressures as high as 120,000 volts. Usually, however, the generation is at lower voltages; for purposes of transmission they are changed to high voltages by step-up transformers and then stepped down in step-down transformers for use at or near the point of reception.

Insulation is, therefore, a basic necessity in electrical work. The heat generated in dynamos and motors is too great and the space available too small to permit of rubber insulation. In the generator revolved by the water or the steam turbine, rubber is not used for wire insulation. The high-tension wires that stretch cross-country like great spider-webs are bare. But as soon as wires come close together in cables to lead electricity into your house, rubber insulation becomes at once a necessity. Rubber is high in insulating value. It is strong, durable, and flexible.

In the manufacture of insulated wire, there is a certain procedure characteristic of this particular use of rubber. A trip through a wire factory would lead us to observe a number of cleverly worked-out processes. A mass of copper is "drawn," as they say, or forced in molten condition through a small hole or die to form the wire. It is passed in continuous lengths through a furnace, where molten tin is laid on in a thin layer for the purpose of protecting the copper from the deteriorating action of the sulphur in the rubber, for copper combines directly with sulphur to form a black sulphide. After the wire has passed through the bath of tin, it is coiled rapidly upon spools by an automatic process, in lengths usually from one thousand to five thousand feet.

Let us go with these spools of copper wire into a room where they are placed upon racks, ready to be covered with rubber insulation. For this purpose a tubing-machine is used. Unwinding from the spools rapidly, the copper wire passes through an apparatus known as the insulating head of the tubing-machine. The wire is drawn through two holes in either end of the head, each a shade larger than the wire itself. By the pressure developed by a slowly turning screw within the cylinder of the tubing-machine, the rubber composition, softened by warming on a mill, is forced around the wire. Thus, as the wire is drawn through, rubber is forced around it, the exact amount of rubber being controlled by the size of the die from which it issues. This insulating head makes it possible completely to surround the wire with unvulcanized rubber composition. From this die, the wire is carried on to a machine which covers it with talc, that in the unvulcanized or sticky form the wires may not stick together. Then carefully wrapped upon a large drum, it is ready for the next operation, vulcanization. This big drum with several miles of wire upon it is rolled into the vulcanizer, a horizontal steel shell. The door closed and the steam turned on, the heat is created to vulcanize the rubber. This is the simplest process for one ply of wire surrounded by one layer of rubber.

But there are many other grades and types of insulated wire for special purposes. When several wires are to be insulated from each other and all of them insulated from something else, it becomes necessary to use other methods in addition to this simple one. Several of these wires may be coated separately with

Courtesy of The B. F. Goodrich Co.

VULCANIZING HOT WATER BOTTLES

rubber and then, to prevent them from spreading apart, they all may pass through a braiding-machine that wraps around them interlaced cotton threads. The electric light cables, for instance, which may have in them one ply or two plies of wire, are not only insulated with rubber, but the rubber itself is protected by a layer of braided thread. That, in turn is protected on the outside by a layer of water-proofing material. When two plies of wire are together, as in what we call the duplex cable, the construction requires a layer of rubber, then a layer of braided thread around each wire, then a layer of rubber and a layer of braided thread around the two together; in this fashion there may be built up many wires, each with its rubber insulation, with its strength-giving thread, and with its protection on the outside.

Cable containing a considerable number of wires and all of them inclosed in a sheath of lead is made for underground work. The application of this sheath of lead is an interesting process, which is, as a rule, applied before vulcanization. In a manner somewhat similar to the application of rubber insulation, the insulated and braided wire is carried into a lead press, where molten lead under high pressure and very rapidly applied is forced as easily as though it were cheese upon the rubber-covered wire, which is pulled through a die, leaving a quickly cooled layer of lead on the surface. This serves as a water-proofing and protecting coat, and is commonly applied to underground light cables and to telephone wires to be stretched over the city streets.

One of the most important uses to which rubber insulated wire is put is for railway signaling purposes. The handling of electrical signals upon railroads is so vital and so exacting that it is necessary to make certain that the wire used is in all respects uniform and perfect. From this has come the development of exact specifications for the insulated wire, drawn up by the Railway Signal Association in coöperation with rubber men. Where speed and number of trains are sufficient, the automatic block signaling systems are fundamental in all railway operations. Out of the 99,360 miles of block signals installed in the United States up to 1919, 36,600 of them were automatic. To maintain the automatic system of block signals, the track is divided into blocks varying in length from a few hundred feet to several miles, the distance depending on the speed of trains and the physical conditions. The trains operate these block signals by means of an electric current flowing through insulated wires strung along the right of way, the return circuit running back through the rails. The various signal circuits are opened or closed by contacts so arranged in combination with signal wire as to apply electrical energy to the signal system when conditions are safe for train movement. The signal arm is counterweighted, so that whenever the signal circuits are deënergized it is thrown to the horizontal or "stop" position. It will only assume the vertical or "proceed" position when the track is clear, a condition which means that the track circuits are unoccupied and all the electrical relay contacts are closed in the block over which the signal governs the train movements.

If anything should happen to the electrical circuits, all signals would automatically assume the stop position until the signaling system itself could be put in order. All switches on the main tracks or sidings in use in this automatic territory are provided with circuit controllers. Such details have been carefully worked out. If the side-tracks have upon them a car or an engine so close to the end of the side-track as to foul a main track movement, there will be an electrical reaction that will operate the semaphore stop. The insulated wire controlling this mechanism in all sorts of weather is vital to the safe operation of the trains; this constitutes one of those great and important uses to which rubber insulation is put.

From the best of data, the first block signal system in this country was put into operation by Ashbel Welch of the United New Jersey Railroad and Canal Companies in 1863. This was considerably later than the introduction in England, which was as early as 1842. "The Scientific American" states that the automatic block signal was invented in 1871 by Thomas J. Hall.

To show the degree of care which surrounds the manufacture of this kind of insulated wire, one may note a few of the items from the specifications developed by the Railway Signal Association and upon the basis of which the manufacturers of wire are obliged to work. They vary as to quality of the copper wire, but insist that it be uniform in size and composition. The rubber insulation must be made of a composition in which are used only the best of rubber and those ingredients which conduce to uniformity of strength and aging properties. The braiding is carefully regulated; and, subsequent to manufacture, a series of tests is performed upon the wire to make sure that each coil of it has the proper strength, both as to wire and rubber, and proper electrical conductivity. The wire is examined to see that the right amount of tin has been applied, that the braiding and the waterproofing have been properly done, that the rubber insulation is of the right tensile strength, and that various other properties adapting it to the purpose for which it is intended are present. The insulation is then thoroughly tested for electrical properties, to make sure that there are no leaks, pin-holes, or other defects. Thus every possible effort that intelligence can bring to bear is put on this insulation material to make it approach perfection.

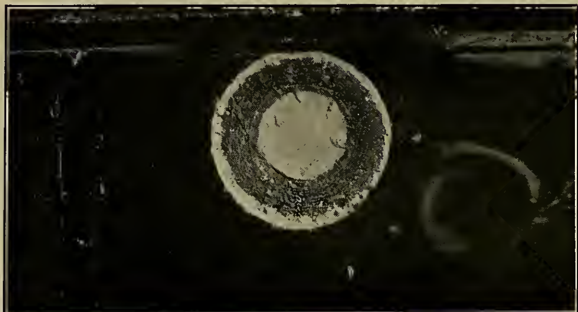
The wires that bring the current into your house are rubber-insulated in the same careful way, subject, however, to a slightly different code of regulations than have been mentioned for the railroad signal wire. In this case, it is the insurance companies that protect you; for the main risk that is run by electrical wires coming into the house is that of short circuits which might produce sufficient sparking to set fire to woodwork. There have been many cases known in which mice and rats have gnawed through the insulation of copper wire, causing the bare wire to come in contact with wood. Most modern houses have the wires carried through iron pipes known as conduits; and the code of regulations permits also the use of porcelain insulators to keep the wires a certain distance apart. Thus danger from lightning, from sparks jumping

Photo by "International Newsreel"

THE FINISHED BALL IN THE MOLD

Photo by "International Newsreel"

CORE SHELLS BEFORE COVERING



Courtesy of The B. F. Goodrich Co.

A GOLF BALL CUT IN TWO TO SHOW ITS PARTS

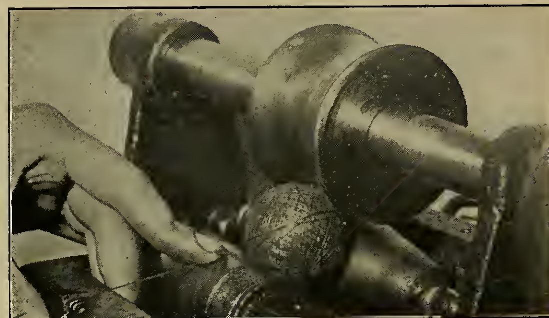


Photo by "International Newsreel"

WINDING RUBBER THREAD TO MAKE UP THE CORE

from one wire to another and igniting the woodwork, and from short circuits is avoided.

When building a house, it is wise for a householder to look personally into this important part of the construction. Electricity is a servant when controlled. Be careless with it, and it may be master. Not much damage is done to appearance if some of the hidden brickwork or masonry does not strictly conform to specifications; but it may save considerable expense if the electric wiring be properly installed under the most careful supervision and in accordance with the most rigid regulations that municipalities can adopt. Workmen may err; look over your own electrical installation, and make sure that no insulated copper wire is in contact with woodwork. See that porcelain insulators of sufficient length are used; then you will be taking the most vital precaution possible in the building of your house—that of preventing any accidental baring of copper wire, with its subsequent short circuit and probable fire.

Copper wire brings the electricity into the house; rubber is the protection used, and the best protection; for its flexibility, high insulating properties, uniformity, and long life serve to make it the ideal one for this purpose. It does, however, gradually harden with age. For the user to examine carefully the electrical wires that connect lamps to sockets and, in particular, to examine the wires that connect the vacuum-cleaners and other devices that are moved around the house, is a wise precaution. For as the wire wrinkles and bends, in the course of time the rubber may break and thereby expose the wire, the exposure leading to short circuits. One should replace these wires often enough to make certain that the insulation is always in the best of condition.

The early dynamos produced current at low voltages of 110 to 200 volts. As the transmission lines were extended, the central station in a small city lost a great deal of power, both from heating of the conductors on account of resistance and from leakages. In the development of this important engineering science, as the years have rolled on, the voltage or tension at which electricity is transmitted has become greater and greater, until to-day central power stations, such as those at Niagara Falls, customarily send out over the wires electric current at many thousand volts, and several wires, as a rule, are strung over the same electric pole system. Because it is inadvisable to shut down all wires while the workman may repair one of them, proper protection is vital to his safety. The electrician high up on a power-line pole surrounded by death-dealing, high-tension wires is in no ideal situation. He must be protected against the power of the live wire while he repairs the dead one. So he throws over adjacent wires a rubber blanket on each side of him; and he works in security. These blankets are made of a highly uniform rubber composition; they have high dielectric strength. Each one is carefully tested for its resistance to puncture with a high-tension current; that is, two terminals from the secondary coil of a high-voltage transformer are placed on each side of the blanket and the voltage is raised until the spark jumps through. Thus the voltage is measured at which a spark will penetrate the rubber blanket. The blanket must resist the penetration of a spark at high voltages.

We see the man who changes the carbons in the arc-lights on our city streets, as well as the repairman of high tension lines, wearing rubber gloves. It is necessary for him to be able to handle the wires with impunity; certainly he could not do good work if it were necessary to incase his hands in porcelain gloves. Here Charles Goodyear comes to the front again; he made the first vulcanized rubber gloves to protect electrical linemen. Being flexible, rubber is generally used throughout the electrical industry, where we find linemen and others wearing heavy gloves made of a pure, uniform rubber composition that is nearly perfect as an insulator. The lighter weight gloves are usually tested to resist puncturing or against excessive conductivity of current up to four thousand volts; those used in high-tension circuits are thicker and are tested to withstand ten thousand volts. They give excellent service until wear and repeated creasing across the palms cause cracks to develop; then they are either repaired or new ones are purchased.

Care must be taken in testing linemen's gloves, or in repairing them, for they must above all things be non-conductors of electricity. Each glove at the factory is tested for breakdown or dielectric strength. For this purpose, a glove is placed in a copper case open at the top and with an opening at one side through which the thumb projects. The glove is then nearly filled with water and immersed in an iron bucket filled with water. Inside the glove and outside of it, there are placed electrodes connected with high-tension current. This current is increased up to the point where the glove fails.

Heavy rubber gloves are all made on fundamentally the same principle; that is, a form of tin or steel is made the shape of the hand. Workmen, usually women, build sheet rubber upon it around the fingers and the hand. The glove is finally placed in a mold, pressed, and vulcanized.

I have spoken of wire and the transmission and use of power. Manifold are the uses of electricity, and with them rubber insulation. The ignition system of automobiles, the hot days cooled by the swiftly rotating fan, the electrical adding-machine in factory, office, and store, vacuum-cleaners, the breakfast toaster, form a host of conveniences. We feel civilized by means of electrical power. Without it how bare would our lives become! And without rubber, we should lose the use of most electrical appliances.

CHAPTER XIV

COMMUNICATION

The rubber hydrocarbon is a versatile substance. Combining with small quantities of sulphur, it yields soft, vulcanized rubber. It keeps its secret, however; for apparently no chemical compound, as the chemist technically terms it, is formed with any of these small amounts. In any event, the chemist admits his ignorance as to just what soft rubber is. When thirty-two parts of sulphur, though, are mixed with one hundred parts of rubber and vulcanized over a long period of time,—six to twelve hours,—there seems to be formed a combination with fixed properties, which chemists believe to be a definite chemical compound, expressed by the formula $C_{10}H_{16}S_2$. The compound is hard rubber or ebonite.

The inventor or discoverer of hard rubber was Nelson Goodyear, a younger brother of Charles Goodyear; and the first hard rubber patent was that granted to him on May 6, 1851. He had assisted his brother in experimenting with rubber; but he had, to this time, made no important contribution of his own. Because the need for some such substance had attracted him, he set out to get it. He mixed "one pound of caoutchouc, half a pound of sulphur, and half a pound of magnesia or lime or carbonate of magnesia or lime or sulphate of magnesia and lime." For vulcanization he specified three to six hours or longer and a temperature of 260 degrees or 275 degrees Fahrenheit. His specifications claim the combining of India rubber with sulphur, either with or without shellac, for making a hard and inflexible substance, hitherto unknown.

Thus Nelson Goodyear was to the hard rubber industry what his brother Charles was to the soft. On March 22, 1852, he granted a license to Conrad Poppenhusen for the use of his patent in making imitation of whalebone; and in July of that year he died. His estate was managed by a third brother, Henry B. Goodyear. In 1858 the patent was regranted and was issued in two parts; various suits were sustained in favor of the Goodyear patent.

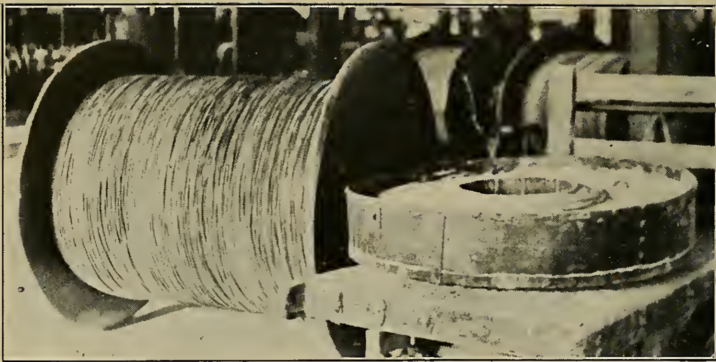
At first hard rubber was considered a substitute for ivory. In the early history of the business, too, the demand for hard rubber to incase the magnet of the ordinary relay and for other uses in connection with the telegraph field gave it a great impetus. Then it was stimulated by the telephone, the druggist sundry lines, and buttons. In 1851 the India Rubber Comb Co. of New York was organized for its manufacture, with a factory at Williamsburg, Long Island, and later a factory in Hamburg, Germany.

Hard rubber and soft rubber have ever worked together. Probably no better illustration of this cöoperation can be given than in the case of the telephone. It was in 1875 that Alexander Graham Bell in a Boston attic made the first telephone, a crude box-like affair, about as much like the desk telephone of to-day as the stage-coach is like the aëroplane. A great many years elapsed before his invention came into general use. Now in the city of New York alone there are more than one million telephones in operation.

In a recent report of the American Telephone & Telegraph Co. the statement is made that during the last ten years the investment in plant and equipment has increased from $672,500,000 to $1,569,000,000. During the last twenty years, while the population of this country has increased only 45 per cent., the number of telephones has increased about 900 per cent. In 1921 there were more than 13,380,000 stations in this telephone system, constituting approximately two thirds of all the telephones in the world. Two and a half million telephones serve the farms in this country. At the end of 1921 there was a total of 27,819,821 miles of Bell-owned aërial and underground wire, an increase of something more than two million miles over 1920. We are now able to telephone across the continent.

It was on June 2, 1875, when Dr. Bell was studying transmitter rings on the telegraph instrument in the room of Thomas A. Watson, that the idea occurred to him that if the vibration could be heard over an electric wire so could the voice. He developed the idea. Great strides upon the original invention of Dr. Bell, but with many additions, have been made. The part that rubber plays is generally that of an insulator, a protecting cloak that keeps the feeble current within bounds and prevents it from going astray from the metallic path laid out for it.

The story of the efficiency of rubber begins the moment you use the telephone. The instrument on the desk has much metal in its construction, through holes in which the wires run, but from contact with which they are insulated by hard rubber bushings. The instant the receiver is removed from the hook on the instrument, an electrical contact is made. The current, always ready in hard rubber storage batteries like the horses in the fire-station, flashes over the wires to a light at the switch-board in the exchange, thus signaling to the girl operator that you would have speech with her. The American switch-board operators made a remarkable record during the war in France. They are the best trained in the world, and the most courteous. The operator grasps the metal plug, incased in its hard rubber and connected with its cotton (not rubber) insulated wire, and pushes it into a hole lined with metal in the bank of the switch-board and in contact with the flexible metal parts of the jack. The light goes out, but the electrical connection is made and you tell her your desires. These jacks to which the individual lines are connected are set in hard rubber, ten jacks to a bank. The parts of the jack are insulated by thin hard rubber sheets, about ten to a jack. Each of the thirteen million stations appears on a switch-board several times. Literally millions of little, important, hard rubber parts assist the accuracy of telephone conversation. Hard rubber is a firm, strong material, superior in insulating properties, which with ease and accuracy can be sawed, drilled, or machined. The transmitter of the telephone on the desk and the parts of the receiver are hard rubber because of these very properties of strength and insulation. Some new substances have



Courtesy of The Rome Wire Co.

READY FOR THE VULCANIZER

Courtesy of The Rome Wire Co.

COVERING WIRE WITH RUBBER INSULATION

Courtesy of The Rome Wire Co.

BRAIDING WIRE WITH COTTON THREAD

now entered this field; it will be interesting to see which lives.

The wires on the telephone and the intricately arranged forests of them on the switch-board are not insulated by rubber, or are the large lead-covered cables stretched from pole to pole or underground in tile conduits, but by cotton thread impregnated with wax. But from pole to house in the open, and from lightning-arrester inside the house to the bell box, rubber-covered wire seems necessary to withstand the action of light and weather. In short, where resistance to the elements or where the demands of insulation are high, rubber is the one most trustworthy material.

In no place has the rubber-insulated wire seemed to demonstrate its value more than during the war, where the part played by the telegraph and telephone was remarkable,—more so than most people realize,—for the telephone connections that were strung over the western front by the mile were the means of communication between outposts and headquarters. In the World War messages over insulated wires, instantly delivered, took the place of the man on horseback or the runner on foot. There were men on motorcycles and there were runners on foot, to be sure; but the great majority of signals and communications were over modern telephone systems.

Crowell and Wilson state that the outpost wire insured secret communications at the front; it was a twist of two wires, each single wire being made up of seven fine wires, four of bronze and three of hard carbon steel. Stranded together, these were coated first with rubber, then with cotton yarn, and finally paraffined. The wire was produced in six colors—red, yellow, green, brown, black, and gray—for easy identification in the field, each branch of the service employing its own color.

The wastage of outpost wire was enormous. In an advancing movement, it was folly to stop to pick up the wire. Miles of it had to be left in the field to be salvaged later. The proposition of producing 68,000 miles of outpost wire every month almost staggered the wire manufacturers of the country. Since there were not enough braiding machines to complete such an order, new ones had to be built before necessary production could be attained.

Although rubber thus plays a vital part in electrical systems, there is one most important use in communication wherein it has failed to serve as well as its cousin, gutta-percha. Gutta-percha is necessary in 532 privately owned submarine cable lines and in 2628 government-owned lines, with a length of 56,000 miles. Nearly 50 per cent. of these are owned or controlled by British interests, a fact which may largely explain the great size of British foreign trade; for there is hardly a port in the world that a British ship enters wherein it cannot find a British cable office. Communication across the sea as well as transportation upon it has been an enterprise in which the United Kingdom has ever kept ahead of its rivals.

Atlantic cables carry four times the traffic they carried in 1913; Pacific cables carry nine times the traffic. While the armament conferees were assembled in Washington in the autumn of 1921, we all recall how important the little island of Yap became in the eyes of America and Japan. Merely a volcanic spot on the surface of a great ocean, yet it was a landing point for a trans-pacific submarine cable, a point of intercommunication of vital interest to the great nations.

The wire man calls two or more wires bound together a cable. He has electric light, power, telegraph, and telephone cables. When they are to be laid under water they become submarine cables, even though they never see the ocean. Gutta-percha is the insulating material for one class of them—those that connect the continents. These are long, and because gutta-percha needs no vulcanization it may be applied to such extreme lengths without the necessity of vulcanizing several sections and splicing them together. Another reason for its use is its purity, no compounding ingredients are needed to improve the strength. It shows in the cable the low specific electrostatic capacity of pure gum, a property of major importance in long cables, in which this low value permits speed of transmission of messages.

On the other hand, a large number of cables are laid in rivers and harbors and between the islands of the sea. Where distances are short rubber insulation is used to better advantage than gutta-percha. It is a more reliable insulating material where a comparatively high dielectric strength is necessary and because of its better resistance to rough handling and to changes of temperature. Gutta-percha softens when hot and hardens when cold even to a greater degree than raw rubber, and it oxidizes readily when exposed to the air. Down at the bottom of the Atlantic and the Pacific oceans the temperature changes but little, so there gutta-percha is in its element. But the cable around the Philippine Islands and that from Seattle to Alaska are rubber-insulated. The one in the Red Sea and the Suez Canal was laid originally with gutta-percha insulation; but on account of the very high temperature of the water in shallow parts, it had to be replaced by a new one in which rubber insulation was used. Gutta-percha became disfigured and soft—a condition causing irregularity in signals.

The laying of the first Atlantic cable is one of those classics of enterprise in the face of obstacles. Every school-boy has been taught how in 1856 the Atlantic Telegraph Co. was formed with the object of establishing telegraphic communication between Ireland and Newfoundland. The first Atlantic cable was estimated at 2500 nautical miles in length; and after the struggles with which we are all familiar, the principle of cable communication came to be a proved success, although the first cable failed after a few months. The name of Cyrus W. Field is one to conjure with, for it was due to his persistence that a successful Atlantic cable was finally laid. In those early days a fierce battle was waged between the advocates of gutta-percha for insulation of submarine cables and those of India rubber. Some experts believed gutta-percha to be worthless and India rubber the only proper material. The test of time, however, proved India rubber to be too perishable a commodity for this purpose; in fact, it has been only within recent years that a degree of control of the aging properties of vulcanized rubber has been successfully un-

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AN ARMY FIELD SWITCHBOARD

Courtesy of Western Electric Co.

A MODERN TELEPHONE SWITCHBOARD

dertaken. Possibly in the future vulcanized rubber may be used for any purpose with assurance of permanency.

Yet a new brand of communication has come among us. The use of the radio telephone in connection with aëroplanes, the development of direction finders, making it possible for ships at sea to ascertain in a fog their exact direction with reference to lighthouses, the use of the internal aërial in homes, and the perfection of receiving sets, making it possible for one in his home to listen to broadcasted concerts, lectures, and reports, form one of the remarkable electrical developments of this age. Its end is not yet. So great has been radio development that confusion in the air has made probable a limitation by legislation of the number of sending stations. Since continuous waves of different frequencies, that is, at different lengths, may be sent, a classification of possibilities has been made, with the result that very soon the sending stations will probably each have its own definite wave-length or frequency. Thus a remarkable means of communication will rapidly be systematized in a way to avoid interference.

Since these waves travel through the ether at the speed of light, 186,000 miles a second, one can sit in his house, tune his receiver to receive the voice of a speaker in a large auditorium, and actually hear the words more quickly than those in the rear of the audience. Sound-waves travel at the rate of 1090 feet a second. A person a thousand miles away will receive the voice in one one-hundred-and-eighty-sixth of the time the sound will require to reach a man a thousand feet away from the speaker. A voice has been heard across the ocean; signals have been heard at the antipodes.

The part played by rubber in radio development is marked, for today the aërial may be made of a single strand of insulated copper wire instead of one made of a bare wire. The insulated wire throughout the circuits in a house, the hard rubber storage-battery cells, the hard rubber used in condensers, in panels of receiving sets, in the dials, and in other places, are all notable developments which assist in making the radio possible.

One of the numerous uses to which hard rubber is applied, and one of the greatest of them in the present day, is the hard rubber cell for storage batteries. This prince of our rubber realm serves in many capacities. When the electrical starting and lighting systems were developed for automobiles, they called for the use of a storage battery; this has led to a high development of the hard rubber cell for this purpose. Storage batteries to supply current at even voltage without noise form part of the telephone system and of radio installation. In the earlier days, glass was used. But glass is too friable a substance for an automobile running over a rough road, and too difficult to make precise enough in shape to economize space. Therefore, the hard rubber battery cell has come to be generally used. Its value lies in its strength and lightness. Some day if you will examine your storage-battery, which unfortunately most of us fail to do often enough, you will find it to be, in many cases, a wooden box containing three and sometimes four narrow cells or boxes of hard rubber. Each of these has a hard rubber cover or top that fits tightly into the cell, resting upon a little shoulder molded into the rubber. The manufacturer of the cell then usually fills this space with a soft plastic composition to prevent the splashing over of the cell liquid.

Whether the battery cell be of the size used in the automobile,—about a foot high, with a wall probably an eighth of an inch thick,—or whether it be a huge one made for the storage-batteries of the submarine,—frequently five feet high and over two feet square,—the principle of manufacture is essentially the same. First there is made a lead and tin alloy, which is cast in a mold to the exact size desired for the inside of a battery jar. When this comes from the mold, it is called a mandrel or form. It is made four to six inches longer than the jar, in order to give a sufficient manufacturing leeway.

After the compound is mixed, it is calendered to the proper thickness, and sheets of the rubber composition are cut so that the length of the sheet constitutes the distance around the jar and the width constitutes its height. In the manufacture of a battery cell, therefore, the workman first places in the end of the mandrel, in the spaces provided for them, triangular-shaped pieces of unvulcanized hard rubber to form the lugs or supports for the grids or metal parts inside the cell. These are often known as "bridges." In order to have a permanent support for the lead members, it is necessary that the lugs be vulcanized to the jar. When these are put into spaces provided by the mandrel, the workman covers them with a layer of hard rubber composition that is of the exact length and width of the bottom of the jar. This is usually somewhat thicker than the side wall material, because of the necessity of having the bottom well supported. Around this mandrel, then, is wrapped the layer of composition, and it is carefully overlapped and rolled together so that no leaks can occur at the seam. It is then turned over the bottom part, and the corners are all carefully rolled down to avoid "leakers."

In many of the hard rubber cells, in order to give them a high polish, a sheet of tin is wrapped around the outside of the cell after the layer of rubber has been applied. In some instances, the sheet of tin is rolled upon the side-wall composition before its application. Recent methods require no tin; for, after all, the user of the hard rubber cell never sees the cell itself, and the expense of polishing it is an unwarranted one. After the hard rubber battery cell is thus completely formed in its unvulcanized condition, it is stacked upon the shelf of a small truck, which is pushed, when loaded, into the shell of a horizontal vulcanizer. With the vulcanizer door closed, steam is turned in, and the cells are vulcanized. In the old days it required eight to ten hours to vulcanize even these thin layers of hard rubber; in modern days compositions have been developed which permit of vulcanization in as short a time as three hours.

The making of the covers for the hard rubber battery jars is a simple process. Pieces of rubber of the right thickness and width are placed in one side of a steel mold. The other side is then adjusted so that when, under hydraulic pressure, the two sides are brought together, the rubber, being soft, flows and fills all of the cavities in the mold. Then it is heated to the proper temperature and for the necessary time to vulcanize it into the required form. When removed from the mold, after inspection and trimming of the slight excess that has flowed from the mold into what is termed the rind cavity, the cover is ready for shipment.

Rubber manufacturers make only these parts of the battery. The battery manufacturers assemble the rubber parts, together with the electrolyte, the lead plates, the grids, and the paste. In other words, the rubber man makes the rubber parts; and the battery man assembles them into the battery. When the battery is assembled, the terminals that pass through the holes in the cover must be surrounded with hard rubber so closely that the liquid cannot splash out. For this purpose, as well as for a stopper between the terminals through which electrolyte can be added or removed, hard rubber is used.

Although several different substances have been developed to take the place of hard rubber for battery cell work, thus far none of them has superseded it, largely on account of the superior strength and lightness of the hard rubber mixture. The Germans during the war were obliged to use other substances, particularly for their submarines, but without complete success. These large submarine battery jars are made up in essentially the same way as the little ones;

that is, calendered sheet rubber is built up about a large form or mandrel until there results an unvulcanized jar.

There are manifold other uses, of course, to which hard rubber is put: electrical switch-boards, fountain-pens, combs,—indeed, thousands of articles. Truly, in the field of communication, rubber as insulation for wire and hard rubber for telephone uses work in perfect unison.

Business methods of to-day, though, demand more than the telephone and the telegraph. Conversations are confirmed by mail; orders are written down; contracts are prepared and signed; records of transactions and agreements must be permanent. Memory is too frail a thing upon which to erect the structure of business intercourse. Therefore, in the office the stenographer is queen, where the business man is king. In the realm of commerce, during the reign of rubber, no more important servant exists than the typewriter.

The first typewriter of which we have record was patented in England in 1714. In 1829 an American, W. A. Burt, patented what he called a "typographer"; and about 1833 another kind was produced in France. Again in 1844 and 1846 typewriting machines were developed in England. From then on to 1850 there were a number of English modifications. A. E. Beach in 1847 constructed a fairly successful instrument, which utilized the principle finally worked out in the modern machine, that of a basket of levers arranged in a circle, delivering their impressions to a common center. He never perfected the machine, however. The names of Sholes, Soule, and Glidden, of Milwaukee, are really connected with the modern typewriters, for upon their ideas, developed from 1868 and 1873, the Remington typewriter was constructed. In this instrument the short arms of levers were connected by wire rods with levers proceeding from the keyboard. The paper to be written upon was passed around a rubber cylinder, the lower side of which received the impact of the type face while an ink ribbon intervened between the type and the paper. This is the principle underlying all machines as they are to-day.

Nearly seventeen hundred patents have been granted on many hundred machines, each employing the rubber cylinder or typewriter platen. This rubber shell or platen is to the typewriter what the pneumatic tire is to the automobile. It receives the blow of steel, softens the shock to just the right degree, and yet is hard and uniform enough to permit a true impression.

Typewriter platens are made of a peculiar sort of rubber composition, capable of vulcanizing neither into hard rubber nor soft rubber, but into an intermediate grade. The rubber compound can contain only substances capable of the finest state of subdivision; no particles of grit must show through the surface to blur a letter. The platens are vulcanized to a tested hardness. If they are too soft, the impression of the letters upon the paper will be blurred; and if too hard, the paper is liable to be cut or the type injured. Through compounding and vulcanizing, the maker must obtain an exact degree of hardness.

Would it not be comfortable if in our communications we could compose our thoughts and exercise our fingers to make no errors in writing? We do make them, though, and we need to erase them. Every typist has erasers. In every office desk we find them. All school children use them. An indispensable little article is a rubber eraser; indeed, rubber received its name from its ability to rub lead-pencil marks from paper, the people of England calling it "Indian rubber." Erasing is the first successful commercial use of rubber on record.

The eraser, as we now call it, is a very different substance from the "rubber" of 1770. In it we do not use crude rubber only. We have improved it, and cheapened it. In this instance cheapening went hand in hand with improvement, for you would not be at all satisfied with a piece of crude rubber for erasing lead-pencil marks. It erases, yes, but not so completely as necessary; for the rubber itself, being too soft and strong, does not wear out upon the paper. In the practice of the years, the making of rubber erasers has come to be essentially the art of incorporating with rubber those substances that cause the mixture after vulcanization to wear out most rapidly. That is done for a purpose. As the little particles of the eraser wear away upon the paper, they pick up the lead-pencil marks, sticking to them so that they are removed. That the eraser may grip the paper tightly enough, and not slide over it, the proper quantity of pumice-stone is used in the mixture. This tears away the paper, roughening it and easily removing the pencil marks. More pumice-stone of a coarser grade is used in ink-erasers. In this case we not only remove marks but, in erasing the ink, wear away some of the paper itself.

The eraser wears out because we mix with rubber what is known as a rubber substitute. Men seem to love to find substitutes. The rubber substitute, or "factice," has come into the industry for many particular uses. When certain oils, such as rape-seed oil or corn oil, are boiled with sulphur, they turn dark, the sulphur combining chemically with the oil and thickening, after which the mass is poured into trays to cool and congeal. The resulting substance is a soft, resilient solid which may be ground into fine particles. The oil may be "vulcanized" by sulphur-chloride, which combines directly with it at ordinary temperature. When this mixture is cooled, a light-colored, resilient substance remains, which we call "white substitute." Incorporated with crude rubber and vulcanized, factice seems to have the property of breaking up the cohesion of rubber, forming the most valuable substance in making an eraser erase both itself and marks on paper.

In your desk on which you write your communications lies the rubber band. Its convenience is appreciated not only by the small boy for his sling-shot, but by the business man for snapping around packages. Rubber bands are made from pure rubber compositions with as little admixture of any substance as possible; for the one value gained from them is their ability to stretch as far as possible and then snap back and hold articles together.

For check indorsements and the like, many men sign their names with a rubber stamp. Millions of checks pass through banks and clearing-houses with one or more rubber-stamp impressions on them. It is easy to make any desired lettering or wording for a rubber stamp very quickly. Rubber stamp-making is a little industry by itself in every city in this country. The operators who make the stamps prepare molds by the use of what they call a matrix compound—a quick-setting mixture of mineral powders, into which, while soft, the impression of the steel type is forced. An unvulcanized rubber compound of the size and thickness desired is then laid in sheet form upon this matrix when it is set and dry. Pressed in a steam or electrically heated mold, the rubber is forced into the lettering in the matrix and vulcanized. After vulcanizing, the set of rubber type is removed, and the stamp is trimmed and mounted upon a sponge rubber backing on a wooden block with a handle.

Rubber stamps are numerous; in fact, they are as indispensable to the business activities of the world as the telephone, for they are tremendous time savers. Small as the stamps are, it has been estimated that the rubber-stamp manufacturers of the United States employ fifteen million dollars in capital to produce an annual output evaluated at about five million dollars.

Though strikingly different in physical properties, each of these two forms of rubber, hard and soft, plays its joint part in extending the range of speech, in bringing ideas near at hand, and, like the brothers who invented them, in quietly laboring in the interests of mankind.

CHAPTER XV

FIGHTING FIRE

"Venite, pueri, eamus ad ignem!"

The boys of ancient Rome stood around on street corners, waiting for something to happen, just as our small boys do now. At the clang of a fire-bell, if it was used in those days, the boys probably rushed off with a "Come on, boys; let's go to the fire." The fires of Rome were not easy to put out. While the flames curled out of the windows, the small boys might have seen men stretching hose made of the intestines of oxen. For a fire-engine, a few men sat heavily on a skin filled with water, and so forced a tiny stream upon a second-story blaze. So says the architect Apollodorus who wrote in the time of the Emperor Trajan, about 100 A. D. These means accomplished little, but they expressed an attempt to control fire.

The Romans probably fought fires with other crude engines that delivered meager streams of water through some kind of pipes, but history is somewhat obscure. Pliny the Younger speaks of the *sipho* as a fire-engine of some sort, but no hose was known. The ancients, even two hundred years before the Christian era, recognized the need and made crude engines to throw water.

The earliest record of flexible hose is in the writings of Herodotus, who says that the Persian Cambyses, who invaded Egypt about twenty-four-hundred years ago, was obliged to camp in the desert, a twelve days' journey from the river Corys. In order to keep his followers supplied with water, the monarch made pipes of the skins of beasts and through three different lines brought water to the camps.

Concerning early use of hose with fire-fighting apparatus, Professor Beckmann, writing in 1801, says, "This invention belongs to two Dutchmen, both named John van der Heide, who were inspectors of the apparatus for extinguishing fires at Amsterdam. The first public experiments were made in the year 1672, and were attended with so much success that at a fire in the next year the old engines were used for the last, and the engines with movable hose for the first time. In the year 1677, the inventors obtained an exclusive privilege to construct engines according to their principle for twenty-five years."

Great savings were made by using the new apparatus to extinguish fires. The hose was constructed of leather, thick enough to withstand the force of the water. The leather hose was screwed upon the engine, the end of which widened into a kind of bag supported near the reservoir, and kept open by means of a frame; laborers poured water into the bag from buckets. The Van der Heides, however, for this purpose employed a pump, which they called a "snake pump." How it was constructed has not been recorded; it was probably a cylinder with a lever. Every leather pipe employed for conducting water was called a "water-snake." The water-snake was not made like the hose of the fire-engine, of leather, but of sail-cloth. It is said, however, that for this purpose the sail-cloth required a peculiar preparation, which consisted in making it water-proof by applying a certain kind of cement. The hose through which the water was conveyed had to be stiffened by metal rings also; otherwise the external air on the first stroke of the pump compressed the hose so that it could admit no water. Seamless hose was made of hemp in the year 1720, in Leipsic, and in 1801 at Bethnal Green, near London.

Apparently the first record that we have of rubber hose, as a definite competitor of these improved leather pipes was that of a hose invented by Thomas Hancock and manufactured by Charles Mackintosh & Co., of Manchester. Experiments were carried out on board a floating fire-engine belonging to the London Assurance Corporation in September, 1827. A length of leather hose and one of rubber were attached to the engine, each of them furnished with a tightly-closed plug. After the engine had been worked for a short time, the leather hose burst in the solid part of the leather. The India rubber hose remained firm and uninjured; and the engine itself became disabled by the breaking of one of its cranks without producing any effect upon the elastic material. Hancock's hose was made with an inner coat of unvulcanized rubber; other layers were applied to the principal folds of the canvas.

It was about this time, 1829, that the first steam fire-engines were built in London; but they were not used for a number of years because of the prejudice against them. The London fire-department reported that they required too much water; that the water might be injudiciously applied; and that they were too heavy for rapid traveling. This prejudice seemed to last until about 1852.

Rubber hose was a tremendous improvement. It was necessary to make leather hose from the best part of the hide. The hose was usually in forty foot lengths, and a great deal of the work was required to keep it lubricated with tallow and wax, so that it might remain pliable. Since rats and mice thrived on the leather, it was frequently soaked with infusions of bitter apple. Even though canvas hose had the advantage of lightness and strength, the wet cotton had a tendency to decay; it would not stand rough usage, either. After the days of vulcanizing, at least in England, highly satisfactory fire-hose was made by the North British Rubber Co., for the use of steam fire-engines, which was strong and well-built, and which satisfactorily stood tests at the Crystal Palace in 1863.

The invention of the hose-coupling, a most important part of fire-hose, came from the Van der Heides of Holland, who have already been mentioned. They attached brass screws to the ends of their fifty-foot lengths of delivery hose, so that any number could be quickly connected together as occasion might require.

In America, the year 1785 saw the organization of the first fire company; and but a few years later, in Brooklyn, the first fire engine was ordered from Jacob Roome of New York, who had just begun the manufacture of engines in America, all the earlier ones having been imported from England. Great and striking is the difference between the modern high-speed, efficient motor-engines and this most primitive water keg. It was a wooden box holding 180 gallons of water, which was poured into it from buckets filled at wells and cisterns, there being no provision at that time for procuring water by suction. Three feet high, a condensing-case arose from the middle of the box; and the arms were placed lengthwise of the engine. With the handles four men could work the pumps at each end. From a gooseneck beginning at the top of the condensing case ran a six-foot pipe with a three-quarter-inch opening at the nozzle. Through this pipe, canted toward the fire, a stream could be thrown sixty feet. This crude thing was christened "Washington No. 1."

From then on, the development of fire-fighting apparatus became more and more active. The organization of fire-departments proceeded as rapidly as men's minds could accustom themselves to the need for them and to the invention of the improvements necessary for the efficient combat of fire. In these old volunteer days, which have lived down even to the present, the entertainment of "visiting firemen" played a social part in the life of America, as well, probably, as a highly influential political one.

There have been large fires. The great London fire of 1666, fanned by a raging east wind, destroyed a city; for the only means of fighting fire in those days were buckets, large syringes, and crude engines. The great New York fire of December, 1835, shows fire-fighting methods in striking contrast with the modern ones. Then the water was so intensely cold that it rendered efficient working of engines impossible, and the fire held the mastery; the efforts of firemen were powerless, because water almost instantly froze in the engines. Even the hose lines froze.

High-pressure water, with delivery so rapid and supply so unlimited that it has no opportunity to freeze in the winter, and electric fire-alarm signals to notify instantly the permanent fire station of the discovery of the first small fire, mark the changes between the life of former years and that of to-day. Our buildings are more nearly fire-proof, but enough of them can burn to call for speed in reporting and answering the fire call.

The employment of flexible hose, strong enough to bear a high working pressure of water, has in no small degree increased the facilities with which fires can be fought. In particular, one must not fail to mention those admirable agencies, such as the Underwriters' Laboratories in Chicago and the Associated Factory Mutual Laboratories in Boston, that, in order to give the highest degree of uniformity to hose purchased from any one of a number of manufacturers, have developed specifications up to which much fire-hose must measure. Such great cities as New York, Chicago, and Boston have made careful study of it in coöperation with rubber manufactures, with the result that fire-fighting rubber hose has reached a high state of development.

Up to 1859 in this country, fire-hose, either rubber or leather, was imported from England; but in that year Henry S. Herkener began the manufacture of flat, seamless woven hose on a few looms. He used linen

Courtesy of The B. F. Goodrich Co.

WEAVING THE COTTON JACKET OF FIRE HOSE

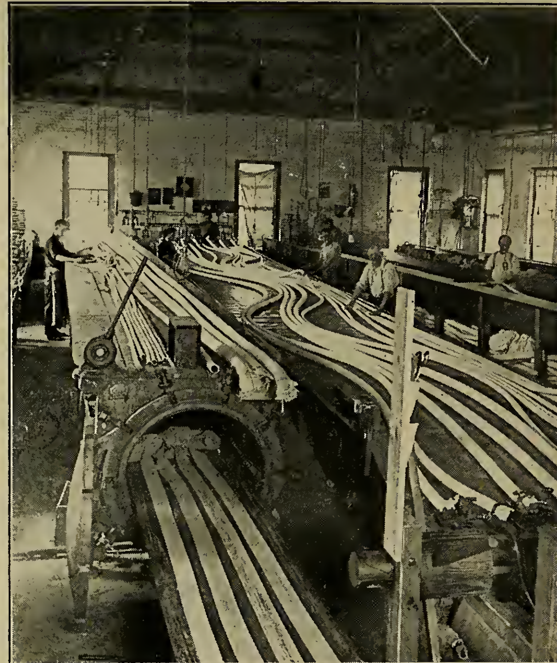


Photo by Underwood & Underwood

VULCANIZING COTTON RUBBER-LINED FIRE HOSE

yarns instead of hemp. John Clark of Malden, Massachusetts, had a factory for this purpose; and the New England Linen Hose Co. was also in the field. A similar hose woven by the Fitchburg Duck Co., some assert, was the first. This hose soon became popular for mill and factory purposes, and, to some extent, for fire-engines in the larger cities.

About this time James Boyd's Sons of Boston manufactured at Lowell a heavy, selvage-edge duck hose, coating it on the inside with rubber and riveting it lengthwise in the lap as they had in the case of their leather hose. This rubber coating was put on by the Boston Belting Co. Although it was a bulky, clumsy article in four-ply rubber construction, it was much used; since the heavy working pressure of the steamers soon made short work of the now antiquated leather hose.

Cotton flat-woven hose, rubber-coated inside and then turned inside out, was next manufactured. This, however, was a failure. By many experiments and much study, men attempted to find a means of lining this hose woven in a seamless form. Pouring rubber cement into the hose and drawing a metal cone back and forth through its length was one idea. Vulcanization, however, was not sufficiently well understood, and the fiber was injured. Various other schemes were invented in those days, particularly in the weaving of circular, seamless fabric.

In 1872 James E. Gillespie invented a circular loom for weaving a multiple tubular fabric. He, together with Robert Cowen, a young machinist, worked out the fundamental ideas; but the multiple-cotton, circularly woven hose was finally abandoned, and the single-jacket or straight-weave was manufactured in its stead. The need for fire-hose and the development of it led to the organization of many companies, among them the Boston Woven Hose & Rubber Co., which was built around the ideas of Gillespie and Cowen. J. B. Forsyth of the Boston Belting Co. finally patented a process by which the cotton, rubber-lined fire-hose was made possible.

Cornelius Callahan was another pioneer. He made a machine for weaving cotton in tubular form about two inches in diameter, and conceived the idea that it might be used for fire-hose, although his original thought was of weaving woolen goods in tubular form. This hose was lined by the Boston Belting Co. He then made a fire-hose that was strong enough to stand the water-pressure. Callahan continued to experiment; in 1876 he made a double-jacket hose which did not burst until subjected to a test at a pressure of 1180 pounds.

Like that of most developments, the history of hose-making is one of constant change, but the problem now seems to be settled. Rubber-lined fire-hose in reality consists of two parts, a cotton jacket and a rubber lining, the strength of the hose and its flexibility being supplied by the jacket. This jacket is circularly woven, a process that means it is built upon a loom by which a number of cotton threads are unwound from spools and are woven into the hose parallel to its length. This constitutes what is known as the warp and serves the purpose of keeping the strength-giving part of the hose in position; for the filling is, in point of fact, a heavy, strong cotton thread that is spirally and closely wound in one continuous length from end to end. The loom is so made that the warp or lengthwise-threads are woven in and out among the spirals of filling. Thus, there is built a seamless, heavy, strong cotton tube with no rubber in it.

The rubber lining is made of a high-grade rubber composition—in fact, the highest grade that the rubber manufacturer is capable of producing for this purpose. A great deal of experimentation has been done in the development of the composition. Because it is too soft, pure rubber cannot be used. The compound used must be stiff; it must be strong in tensile strength, indicating the highest quality; and it must resist aging to the maximum degree, for hose stands in locations convenient for use, not best for storage. It must also have those properties that permit it to adhere to the cotton. Since fire-hose must be in perfect condition when the call comes, every part of it must be designed, constructed, and finished accordingly.

In order to put the tube, or "lining," as it is called, into the circularly-woven jacket, the whole tube is sheeted on a sheeting calender to proper thickness and width to make up the inside circumference of a hose two and one half inches in diameter—the standard size. In the factory a fifty-foot length of this lining is wrapped upon a mandrel or folded over by a skilled workman upon a table, so as to make a tube out of it, the edges being overlapped and the inside being dusted with talc to prevent its sticking to itself. This tube is then carefully laid upon a long truck or metal tray, which is pushed into a steam heater, where partial vulcanization occurs. The purpose of this operation is to add that degree of strength and stiffness to the lining which will permit it to be handled in the subsequent operations without distortion or breaks. After this is accomplished, it is taken back to a table. Upon the tube is then applied a layer of rubber known as the backing—a soft, flexible composition used for the purpose of assisting in the adhesion between the lining and the cotton jacket. Thus, in this incomplete form, the hose consists of a partly vulcanized tube or lining with an unvulcanized soft backing cemented to it.

This rubber tube must now be drawn into the jacket—a trick done by a clever device something similar to that by which our mothers force a darning egg into a stocking, except that in this case the egg is followed by the tube. Each end of the tube is then carefully fastened to steam-tight pipes, and free steam is brought in, which at the pressure used expands the lining against the jacket. The heat softens the backing and causes it to flow into intimate contact with the cotton threads of the jacket. During the period of time, therefore, while steam is blown through the tube, the rubber vulcanizes. The result is a vulcanized rubber lining in close adhesion to the jacket. Ready for inspection and the application of the couplings at each end, the hose is completed.

Out of the many articles made in the rubber industry, there are few subjected to such careful supervision, testing, and accuracy of workmanship as fire-fighting hose. Each length is submitted to a hydrostatic test. During this test, it must not leak, nor must the threads break; it must not contract in length or diameter; it must not rise from the level of the test table. Circular-woven hose has a tendency under pressure to untwist, with all kinds of peculiar movements. The manufacturer is required so to make it that these movements will be reduced to a minimum. Imagine the consternation, if not fatality, to the firemen if, when water pressure of 125 pounds came hurling through a hose, the nozzle in his hand should untwist and the hose writhe. He would be thrown off his feet, possibly off a building. Consequently, fire-hose must be as permanent and free from movement as it is humanly possible with the best of machinery to make it.

Fire-hose, too, must be as light as is consistent with strength. A fifty-foot length of single-jacket fire-hose weighs about forty pounds; and the double-jacket hose, such as is used with the high pressure of some cities, weighs about seventy pounds. Even this is no small weight for firemen to drag over the ground and up ladders.

To make sure that each part of the hose is properly built, test samples are submitted to hydraulic pressure until they burst; the bursting pressure, which must exceed on single-jacket hose five hundred pounds to the square inch and on double-jacket hose six hundred pounds to the square inch, is measured. Since the average water-pressure of most fire-departments does not exceed 125 pounds to the square inch,—some cities run it as high as 160 and 200 pounds, but this is relatively rare,—the test gives a generous leeway in strength. Furthermore, in the system of testing, the fire-departments nowadays usually follow up the hose purchase for the purpose of determining the life of the rubber composition. In addition to tests taken at the time and place of manufacture, for strength and other physical properties of the rubber composition used in the lining, tests are made a month later, again three months later, and a year later. Usual experience shows that if the hose stands up to the specifications until the end of the year, with the normal deterioration known to be natural to rubber, it will last throughout the life required in the fire-department.

Fire-hose is occasionally made, but very rarely nowadays, in what is known as "rubber hose." This type consists of a rubber tube, upon which is rolled, on a mandrel, square-woven heavy duck that has been covered with a layer of rubber in a friction and coating calender. The number of plies or layers required for a particular purpose is built up; on the outside is rolled, while the tube is still on the mandrel, a cover of rubber. This is then usually wrapped with cotton cloth and the mandrel placed in an open steam vulcanizer, where it is heated to vulcanize the rubber, the operation giving strength to the tube and the cover and adhesion by means of rubber between the plies of canvas. This rubber-covered hose is rarely used however, because it is too heavy.

Fire-hose has become a basic necessity. Damage to property caused by the bursting of hose at fires has been great in the past; delay from the same reason in applying water to the fire has been costly, too. This bursting, however, is to-day either wholly prevented or at least can be prevented by careful coöperation between manufacturer and fire-department in the selection of the highest type of hose and by the careful storage of the hose between fires.

Since cotton is affected by moisture, decaying the threads and thus weakening the hose, firemen should always be careful to see that the hose is dry before replacing it on the trucks ready for the next fire. No questionable or bruised piece of hose should be used; for the breaking of one strand at one point is, in reality, the breaking of the entire concentric thread, which, as we have shown, is wound in one length from end to end. And, too, rubber is perishable and must be stored away from the light and in as cool a place as possible. Even under the best of storage conditions, it gradually deteriorates and loses its strength. When old and brittle, it develops cracks that produce slow leaks in the hose. Deteriorated rubber is, however, less dangerous than torn cotton in causing breaking.

I wonder what will be the future of fire prevention; since the losses in this country alone are startling. Fire-proof buildings, adequate alarm systems, hose, and chemical or water fire extinguishers, undoubtedly are means that will assist in fire prevention. And fire prevention is certainly a field in which the utmost coöperation on the part of every one can yield remarkable rewards in the form of money saving.

Fire losses in the United States in 1920 amounted to $330,853,925. In New York City alone there were 14,628 fires and losses of $18,806,908. Something more than hose is needed to check this appalling destruction.

Care in building; care in the use of electricity, gas, and matches; hose at hand in every home to catch the incipient fire—all these will help.

We have equipment for efficiently fighting fire; we have over six million feet of fire-hose ready for instant use; but we need care to avoid the fire.

Courtesy of Minneapolis Journal

THE USE OF RUBBER HOSE AT A FIRE

CHAPTER XVI

IN THE SERVICE OF HEALTH

We may succeed in "outwitting our nerves," but it is rare to find one able to keep his appendix in order. He who has joined the fraternity of the appendixless individuals remembers well the details: the wonder what it was all about, the feeling that he must have eaten something that did not agree with him, finally the examination by the grave physician and the smiling surgeon. A perfectly simple thing to the doctor, it is a journey into an unknown land for the patient.

Once the diagnosis was made and an operation for appendicitis was certain, you may remember the rubber-shod orderlies who kept you in a horizontal position on the stretcher, while they gently and noiselessly carried you down and into the waiting ambulance. Perhaps you were so afraid the offending member would cut up that you thought little of the part rubber was playing in your affairs at the time. The tires on the ambulance freed you from jar,—in dangerously acute cases an item of no small moment, for should that obstreperous appendix have been broken by a sudden shock, you would have been in for, perhaps, disastrous consequences.

Your reception at the hospital was into an atmosphere of quiet and seriousness. The noise-absorbing floors of rubber tiling, the rubber shoes on the nurses and the internes, even the rubber-tired carriage from the ambulance to your room, were planned in advance to keep you free from the irritation of noise and from jar or shock. These floor coverings—extensively used rubber products found not only in hospitals but in many other buildings where quiet and comfort underfoot are essential—are, generally speaking, classed by the rubber man into two groups; the one which he calls "tiling" and the other which he calls "matting." The tiling is a heavy, rather thick block of material made in different colors and in a variety of sizes and shapes. The one most generally used is known as the interlocking tiling, which in 1896 was first made by the New York Belting & Packing Co. Composed of small blocks, the projecting ends of one piece dovetail or interlock into corresponding cavities in the other. The composition generally used is one containing but little rubber and a good deal of mineral matter. In the old days, this was done not alone because rubber was expensive, but in order to give stiffness and to permit purity of color. The more mineral matter used, the purer the color. Even though rubber is today one of the cheapest ingredients, tiling is still made with little rubber and much mineral matter. Yet color and firmness are so vital that rubber tiling has become one of the more expensive rubber articles.

The other type of floor covering is matting. Frequently it is used for stair treads, because it may be removed for cleaning. Sometimes it comes corrugated or in the form seen in Pullman cars, in little blocks of different colors that have been put together on a strip of heavy fabric. Matting is rubbery and thin; and it is made, in the case of corrugated matting, in long sheets to be rolled and cut up to the size and shape desired. The thicker pieces or mats at one's door-step are heavier, with cut-outs or spaces. Vulcanized in molds, the cavities of which are of the thickness of the material desired, the mats are designed by a workman with a die that cuts out the spaces of the pattern. There are many different kinds of mats and matting; in the hospital, however, the floor covering that we call tiling is the one most generally used.

But let us come back to one's self as a patient, and consider many of the things that make the hospital what it is to-day. In case of an emergency operation, the surgeon would probably order the removal of everything you had in you. If so, he would call upon the stomach-pump to take out that last dinner you had eaten, in which case a rubber tube, with a bulb rubber pump at the end, would be slipped down your throat. To drain the intestines, he would probably give you an enema, using a rubber fountain syringe with its rubber tubing and hard rubber tip.

In every detail of the preparation for your operation, you could scarcely get along without rubber. Again you would be laid carefully upon a rubber-wheeled stretcher, and this time be pushed along into the room adjacent to the operating-room, where the kind-hearted anesthetist would see that you were quietly put into the deep sleep afforded by ether. Then, happily you cannot see the things the surgeons use; but under other circumstances, you might appreciate the role that rubber products play during the operation itself.

The practice of modern surgery constitutes one of the greatest advances for the well-being of humanity. There is a tremendous difference between the old methods and the new. Surgery has been performed for hundreds of years, war, if nothing else, necessitating it. Amputations were necessary. In the days of Hippocrates and of the Arabian physicians, there was little done in the way of cutting for fear of hemorrhage. Affected parts usually become gangrenous and were removed only when they virtually fell off. One marvels at the fortitude both of surgeon and patient during the middle ages, when, to prevent hemorrhage in amputations, the cautery was used. Imagine the contrast with the methods of the present operating-rooms. In those days, with no anesthetic, the poor patient lay in the operating-room, such as it was, awake to all that happened. Cauteries were heated in the fire in another room. Yet, however careful the surgeons were to hide the apparatus, one can imagine the pain and the shock of such operations.

Ashhurst in an address entitled "The Patience of Surgery" makes the remark that "Esmarch (1873) introduced his rubber tube and inaugurated an era of absolutely bloodless surgery." While we must not give rubber the full credit for changes in operative surgery, yet it came to be one of those important tools which contributed to the technique of the surgeon.

No one who has been brought up in the school of antiseptic or aseptic surgery can have any idea of the horrors that were perpetrated in the name of surgery by our ancestors. The lack of anesthesia in those days perhaps was an advantage rather than otherwise, as it limited the scope of operations. During operations, patients had to be forcefully restrained. The wards were hotbeds of surgical fever and other manifestations of unsanitary methods leading to an appalling post-operative death-rate. Alleviation of pain came with the discovery of anesthetics (1842-46), involving the names of four investigators—Long of Georgia, Morton of Hartford, Wells of Hartford, and Jackson of Boston, who began to use ether and nitrous oxide. Finally, chloroform was used in 1847 by Simpson in England.

Despite the fact that bacteria were discovered by the Dutch optician Leeuwenhoek of Delft in 1683, and studied further by many men, including Schoenlein in 1839, Holmes in 1843, Cohn in 1850, and Pasteur in 1858, it remained for the great Lister to apply the knowledge to operative surgery.

Micro-organisms of various kinds, both pathogenic and non-pathogenic, are minute vegetable cells that cause us much trouble. Early in the hospital experience of Lister in England he had been deeply impressed with the high mortality from septicemia, erysipelas, tetanus, and hospital gangrene. The fatal cases were numerous. Those were the days of "laudable pus"; yet when his attention was drawn to the work of Pasteur, he set out to prevent the development of micro-organisms in wounds. At that time gangrene was so common that without pus and suppuration surgical operation was considered inefficient. Where he perceived that sterilization would avail nothing, he turned to chemical antiseptics; and, by a lucky chance he hit upon carbolic acid. He employed it with success; and, although subject to a great deal of criticism, he developed his idea and labored continually to improve his dressings.

From this idea modern antiseptic surgery has grown. The day of the bare-handed surgeon began to disappear. To-day when the time comes for an operation, the surgeon and his assistants put on duck trousers and thin, short-sleeved shirts of white muslin. They sterilize hands and forearms; they envelop themselves in gowns that have sleeves long enough to cover forearms and wrists; they wear sterile caps; and many operators even wear respirators over nose and mouth to avoid the possibility of saliva or mucus being projected into the wound.

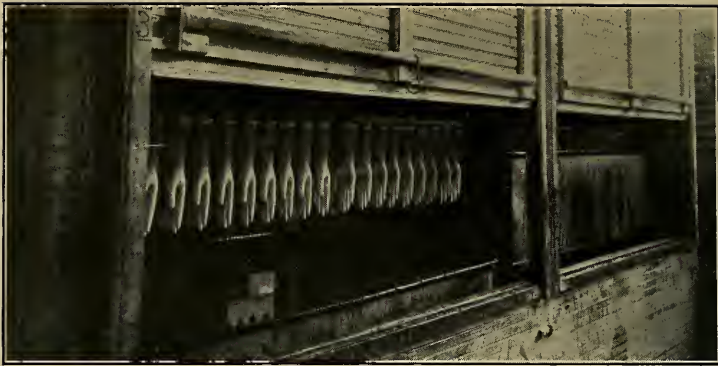
While Lister believed that the chief danger from micro-organisms came from the air, it is now known that the real risk is from actual contact of hands, instruments, dressings, or foreign bodies. Therefore all of the things used are sterilized. Most surgeons, however, are so much impressed with the impossibility of sterilizing bare hands that they wear gloves in operations. More than sixty years ago at King's College, Sir Thomas Watson in a lecture suggested that obstetricians wear gloves. Some surgeons had used cotton and others silk gloves, but cotton and silk are not impervious to micro-organisms. Because rubber is impervious, to-day we find the operative surgeon using thin, seamless rubber gloves.

After gloves are sterilized by boiling, they are dried and kept in a sterile towel until ready for use. Every precaution is taken by the surgeon when putting on the glove that nothing comes in contact with it. It is placed upon his hand just before the operation is to begin. Even during the operation, should the glove come in contact with any infected object, a clean glove is substituted. These rubber gloves, to be sure, some what impair the sense of touch; but the surgeon has become so used to them that, except in rare conditions where the danger of contamination is remote, gloves are used. One great surgeon states, "I always wear gloves"; but that it is absolutely necessary to wear gloves in all cases has not been proved. The rubber glove serves to protect the surgeon as well as the patient from infection, both during examinations and operations.

Dr. William S. Halsted of New York, who when a professor of surgery in Johns Hopkins University, Baltimore, made many important advances in surgical practice, was the first to use rubber gloves. He says that he was led to do so in 1889 by reason of his experiments on the disinfection of the hands and the skin. Since it was virtually impossible to sterilize them, he adopted the use of rubber gloves, a practice that has continued from that day to this.

Because these gloves constitute one of the fundamentals upon which modern antiseptic hospital practice depends, it is interesting to consider how they are made. All of them used for this purpose are constructed by what is known as the "dipping process." Surgeon's gloves, toy balloons, and nursing nipples constitute virtually the entire output of dipped-goods factories. In the manufacture of dipped goods, only the cleanest, finest grades of rubber (smoked sheets, pale crepe, or up-river fine pará) can be used. Before it is started through any process, the manufacturer takes excessive care to see that this rubber is free from dirt, chips, or any foreign material; for these little particles of foreign matter would cause holes, and a hole in a surgeon's glove makes it useless and brings danger both to the surgeon and the patient. Therefore it is customary to wash this rubber with great care and to dry it by the methods which maintain the maximum of its natural toughness and resiliency. The rubber is masticated for a long enough time, in a mixing-mill that is comfortably warm, but not hot. Modern chemistry has shown that masticated rubber or rubber softened by mechanical action readily forms a thin cement when mixed with a solvent. In making surgeon's gloves, in order to limit the number of dippings required for a given finished thickness, it is advisable to have a well-softened rubber.

In the case of toy balloons some coloring material is used, red, blue, yellow; but in the case of surgeons' gloves no color of any kind is utilized. For a solvent, a pure grade of gasolene is employed, but one that does not volatilize too rapidly. It must be pure and free from waxes and high boiling ingredients, for these would be left in the rubber after evaporation. In the best factories, the rubber, after weighing, is cut into pieces of convenient size and placed in a fairly large-sized, revolving, drum-like apparatus known as a cement mixer. This is tightly sealed to avoid loss of solvent. As the gasolene swells it, paddles inside pull



THE DIPPING MACHINE OPENED TO SHOW ONE RACK OF GLOVES READY TO BE DIPPED AND ANOTHER RACK ABOUT HALFWAY SUBMERGED IN RUBBER SOLUTION

THE ENCLOSED DIPPING MACHINE WHICH KEEPS THE CEMENT AND THE GLOVES FREE FROM DUST

Photos by courtesy of The Faultless Rubber Company

IN THE FINISHING DEPARTMENT, TO SHOW OPERATORS ROLLING AND BINDING GLOVES and tear the rubber, which, gradually becoming weaker, forms a sticky mass of cement.

In a tall tank the cement stands about twenty-four hours, until any impurities have settled. The solution in the upper half is drawn off and strained through a fine-mesh brass wire screen. Then the cement is carried on to a tank called the "dipping tank," in connection with which is used a machine known as a "dipping machine." Dipping machines are simply a series of frames arranged over the tanks in such a way that one frame can be dropped slowly down into the cement, allowed to remain a proper time, and removed. They carry upon racks, porcelain forms that look like human hands. A series of different sizes are made, numbered usually from six to ten, with half-size intervals; although seven, seven and a half, and eight are those most generally used. In operating the dipping machines, which may be either intermittent or continuous, the forms are placed with the fingers down upon racks on the machines. The forms are slowly forced into the cement, where they are allowed to rest a moment, and then are removed. With the layer of cement upon them, the forms are allowed to stand in the air of a room to dry. At the end of about two and a half hours, they are dipped again. Thus a thin layer of rubber is deposited uniformly upon the form. The operation is repeated from six to ten times, until the proper thickness, by this repeated dipping and evaporation, is built up.

Because the tacky, sticky, half-dried, unvulcanized gloves are easily contaminated by dust, insects, or particles from walls or ceiling, the dipping room must be clean. A well-planned system of ventilation carries out the solvent vapors and replaces them with fresh air, without, however, the introduction of foreign material. The gloves must be perfectly dry before they can be passed on to the vulcanizing stage of the process. Such conditions as humidity and temperature in the room are controlled by automatic devices in the best factories. Suitable thinness or proper thickness of cement is another important matter cared for by watchfulness on the part of workmen.

The final drying, which follows the last dipping, eliminates all solvent. Depending upon the weather, the drying time usually varies from eight to twenty-four hours. When conditioned air is used, it is regulated to a schedule. Because dipped goods, like all other rubber products, are made in definite weights, careful standardization is attained in the dipping room by test-weighing materials stripped from forms as the dipping nears completion. After the dipping and the drying of the gloves in a finishing room, such refinements as beaded edges are applied, either by hand or machinery.

Vulcanization is accomplished by one of two methods. Surgeons' gloves are usually vulcanized by exposure, in a special room arranged for that purpose, to the vapor of sulphur chloride at a temperature of about 180° Fahrenheit during a period of one hour. This is a practical application of the cold cure or Parkes process. During vulcanization it is in foggy weather very difficult to keep moisture away. Every care is taken to do so, for sulphur chloride is rapidly decomposed by moisture, with a separation of sulphur and the forming of hydrochloric acid. However, some forms of dipped articles are vulcanized in a bath consisting of a solution of sulphur chloride either in benzol, carbon bisulphide, or carbon tetrachloride. This is a weak solution of about 2 to 4 per cent., in which the article to be vulcanized is dipped and allowed to remain for a time varying from fifteen to sixty seconds, depending upon the thickness of the rubber.

After they have been vulcanized the gloves are taken to a stripping and inspecting room, where they are removed from the forms, dusted with soapstone, tested to be sure that they are free from imperfections, and packed for shipment.

Surgeons' gloves are the finest article of the kind made. By this dipping process they come to the hospital seamless, with wrists usually reinforced by rubber tape or cord. Since the vulcanization was performed by sulphur chloride, they are entirely free from any hard substances inside the rubber. This not only serves to limit the danger from puncture, but naturally renders true the sense of touch. They are smooth, although some have been made with a finely pebbled surface. For special purposes, many of them are made with long sleeves.

During the course of an operation there are a number of other rubber articles that play important parts. Although I have concentrated upon gloves, there are solutions of specially prepared sterile rubber which may be applied over the cutaneous surface and thus prevent the spread of infection. The commonly used protectives developed by Lister included not only silk protectives, paraffin paper, and so on, but rubber membranes and gutta-percha tissue.

It is a long way from the modern, beautifully kept hospital to the surgery practiced during the World War, with the sudden changes from place to place because of troop movement and the exigencies of battle. It is also a long distance in the practice of surgery from the methods used in the World War to those used in the Civil War in this country or in the European wars during the middle of the last century. Ashhurst, writing about the great French surgeon Nélaton (1807-73), remarks upon his wonderful discoveries. He had the characteristics that have endeared modern surgeons to thousands of patients; for he stood at the turning of the ways between the brutality, necessary possibly, of the older method and the gentleness and refinements of the new. Ashhurst says: "He wished surgery to be gentle, and he was happy to think that the patients who forget in after life the pangs surgery had made them endure, retained an affectionate memory of the surgeon." He invented, for instance, the soft rubber catheter now in universal use. It was during his time that Chassaignac introduced the rubber drainage tube (1859). The old war methods were crude; if they were brutal, it was because the facilities that have marked the more gentle modern surgery were lacking.

As a good illustration of the difference between the early wars and the present ones, it is of interest to know about the illustrious Garibaldi, who was wounded in August, 1862. The best Italian surgeons "explored the wound." Exploration of a wound meant a painful probing process. They failed to find the ball, and this great general lay for two months in an uncertain condition. Finally it was only by the use of Nélaton's porcelain-tipped sound that the ball was located, where he had predicted. Imagine the change from those old methods to the ones in the modern wars, by which the location of any foreign matter—pieces of shell or shrapnel—is immediately discovered with the X-ray apparatus. Frightful as the World War was, it would have been infinitely more so without these many refinements; and the X-ray, while definitely a discovery in pure physics, is assisted in no small way by rubber insulated wire.

The use of rubber tubing to convey antiseptic solutions had its most marked advance during the World War. Many is the soldier who owes his life and health to the Carrel apparatus for administering Dakin's solution. The perfection of the Carrel-Dakin technique was the most marked advance in the treatment of infected wounds since the discovery of antiseptic surgery. The experience gained during the last fifty years from civil, military, and industrial surgery had contributed very little toward the combating of wound infection. Because of the character of the wound and the nature of the infection, the extent of damage in the great war was far more deep-seated than in previous wars. So the problem which confronted Carrel and Dakin was the same as that which confronted Lister. They worked out a method of bathing the infected wounds with a constantly flowing solution. To accomplish the greatest facility in bathing wounds of different types, it was natural for them to turn, as men have for years, to rubber and to rubber tubing as the most flexible tool. Without rubber, imagine the difficulty of twisting glass to shapes necessary for the treatment of all kinds of wounds.

It would be impossible here to catalogue the manifold uses and services to mankind achieved by rubber in army medical work. It plays its part in a general movement emanating from the minds of men in the field of surgical and hospital practice to make the patients' lot endurable.

To return to our appendicitis operation, let us imagine the patient in the quiet of a clean, white room, beginning to recuperate. We have spoken of the rubber drainage tubes, but we find also the hot-water bottle, the ice-bag, the sheeting on the bed, the elastic bandages, the movements of chairs and beds rendered noiseless by rubber tips, all tending to make him more comfortable.

Since in the advance of medical practice, as in all other paths of life, the use of new tools to gain the end of comfort and health is probably one of the most important services to be rendered, let us keep our eyes open to the results of the present and search on for new attainments. In the words of Ashhurst: "To know the wisdom and the accomplishments of the past, and from them to gain a clearer vision of the needs and the possibilities of the future; to record and to study the experiences of the present, and compare them with the learning of others; to recognize the shortcomings and the disadvantages of current methods and theories, and to search for better; to let neither feeble health nor prosperity, neither the indolence of youth nor the procrastination of advancing years deviate them from the path of learning and of progress; to prove all things and hold fast to that which is good: This is the patience of the saints. This is the patience of surgery."

May rubber ever play a strong, vital part in the service of health!

CHAPTER XVII

BELTING, PACKING, AND HOSE

Belting, packing, and hose are the rubber triumvirate in mines, mills, and railroads. Machinery must be driven from prime movers, boilers must be steam-tight, railroads must run in safety.

For the transmission of power, the rubber belt came into use in relatively recent years. Probably the first time was in 1844, when two Englishmen, Alsap and Forster, patented improvements in elastic fabric as driving bands for machinery. Again, in 1858, an Englishman named Parmalee worked out the principle of stitching together two or more layers of woolen material which had been previously spread or coated on both sides with India rubber or gutta-percha. A basic patent, this was for many years known as Parmalee belting.

Modern factories contain forests of belting. Where the operations of the machines are variable with respect to load, the electric motor connected directly to machines has not displaced belting.

In the woods of Maine or in the far Northwest, the planers and the great saws of the lumber mills slash their way through wet timber, impelled by power transmitted through rubber belting. Here, with variable loads and wet lumber, conditions are not at all favorable; and rubber-covered belting alone seems to stand the irregular service. Of all the types of materials used for the transmission of power between moving parts, rubber belting is capable of widest application under conditions ranging from the frigidity of winter's cold to the boiling of summer's heat.

Belting is a combination of rubber and strong, tough cotton fabric. The cotton fabric is the backbone of the belt. The rubber compositions, the sinew and the muscle, hold the layers of cotton together and cover them to give friction-grip upon the pulleys and to protect them from wear and weather.

In the design of belting the number of layers or plies of duck and the width and length necessary to transmit the amount of power required with a minimum of loss and a maximum of life must be determined. With these data, one who understands belting can design it for any purpose, in a way that will give the longest possible life and the most uniform service. Herein lies one of the evident advantages of the cotton-rubber belt—flexibility of design. Given the most difficult installations, a rubber belt can be made to fit them.

The most important, probably, of the belting compositions is the layer of rubber between the plies of cotton duck. We shall not stop to consider how any of the compositions is mixed; nor is it necessary to mention the constituents. Belt duck usually comes from the cotton mill forty inches to fifty inches wide, depending upon the design and the purpose for which it is intended. It is wound in long rolls upward of 150 yards in length and weighing about three hundred pounds.

The rubber composition for the belting is softened on a warming-up mill. If it were fed to the friction calender when cold, it would be too hard to flow, even at the ordinary summer temperatures; therefore beside the big calender are mills very similar to the mixing mills in the mill-room. Upon these an operator places pieces of the mixture. The rolls squeeze and work them until they are soft. Pieces are then cut off and placed between the two upper rolls of the calender, which move at a slow, steady speed. This causes the rubber to be sheeted and passed around in direct contact with the middle roll. The space between the middle and the bottom rolls is kept at just that amount of separation which will permit the thick cotton fabric to pass between without crushing. On the way through, the rubber compound is forced against it and into the interstices between the threads. It is wound upon a drum on the opposite side.

Since the middle roll of the calender is moving at a faster speed than the fabric, it gives the fabric a wiping action in passing. Because of this the calender is known as a "friction calender"; and the operation of applying rubber to cotton duck is called "frictioning." Thus, the first process in preparing belting is to friction the fabric with the proper rubber composition.

Rubber is applied in this way to each side of the long roll of duck; then an additional coat of rubber is laid on. Rolled up again for ease of carrying, with a layer of cloth between the plies to prevent sticking, the rubberized fabric is transported to the belt department. In the belt department the operators measure off the required length and width; and by a systematic method of procedure they lap one layer upon another until the requisite thickness is built up. Each ply from top to bottom is balanced with respect to width and relation to each other ply, so that the belt in bending around the pulley will work as a unit.

The belt is then taken to long vulcanizing presses heated by steam. Here rolls of uncured belting are supported at one end of a long hydraulic press. Several strips of narrow belting together are drawn through the press upon the surface of the lower plate or platen. Through hydraulic pressure this lower platen is raised, so that the belting is gently squeezed between these two steam-heated, polished, hollow steel platens. To prevent squeezing it too heavily, guides or metal strips of proper thickness are laid upon each side of the belt. After a period of time which varies according to the thickness and size of the belt, the rubber is vulcanized. Then the hydraulic pressure is relieved, the press plates are separated, and another length of belting is pulled through. Thus, section by section, the roll of belting is vulcanized and wound up.

Vulcanization, however, has accomplished the primary purpose of creating a degree of resistance to separation of the plies of cotton cloth, that in action prevents pulling apart. Obviously this is the one important function that rubber performs, and herein its peculiar character is again remarkably well demonstrated. There is no other material which applied in any way gives to such layers of cotton the two properties necessary for service. These two properties are adhesion and flexibility.

One cannot be greatly dissatisfied with rubber when he hears of the case in one of the lumber mills in the State of Washington, where a fifty-six-inch-wide, eight-ply transmission belt ran from October, 1905, until April, 1917, or nearly twelve years, although its top cover was torn off by accident and it was twice submerged in water during flood times. During this period it transmitted 26,000,000 horse-power-hours. This is equivalent to an amount of work sufficient to move a mass of one ton 211 times around the earth.

Rubber belting has been manufactured in the United States since 1836, even before vulcanization was discovered. It was later a monopoly under the Goodyear patent, controlled by Henry Edwards of Boston. It became one of the important lines manufactured by all the leading rubber goods producers.

Since every fiber can be governed during the process of manufacture, rubber belting is uniform in make-up. The duck is tested ply by ply and foot by foot. When the belt is finished, its "friction" can be governed and tested. Where a belt is required actually to run in water, as is the case in mines and concentrating-mills, the rubber belt has merited its extended use. Like tires, footwear, and other goods, the modern rubber belt is the result of remarkable evolution in manufacturing. The early belts had the inherent faults of a product of an undeveloped industry; but after years of experimentation and study, the virtually perfect belt of to-day was found; and it has become a valued article wherever power transmission is needed.

One important phase in the application of the rubber belt is the fastening of the ends. Proper fastening permits the maximum amount of power to be transmitted. It means a steadier drive and freedom from jerks, flapping, vibration, and side-sway; for the belt it means less wear and longer life.

There are various types of lacings to hold the ends together. Endless belts are built for special purposes; but they are often made in the field by cutting back the several plies and lap-splicing them, using rubber cement and either vulcanizing on the spot or drying under pressure.

Underneath the Pullman car, pelted by cinders and sand, in winter's cold and summer's heat, runs a belt that affects us when we travel. It is the axle-lighting belt, connecting a pulley on the axle of the truck with a pulley on the dynamo that generates current for the lights in the cars. It runs continuously day and night, in all kinds of weather. The service is most severe; yet test records show that many of these belts have run more than forty thousand car-miles, and some more than one hundred thousand car-miles.

Belting for power transmission is the little fellow but the eldest of the family. The younger brothers are larger of stature. They are the burden bearers, for upon their backs are conveyed materials of all kinds. In the mines and smelters in any of the great mining centers of Montana, Utah, Colorado, Arizona, or anywhere in the world, slow-moving, heavy conveyor belts transmit ore from crusher to concentrator over relatively long distances.

Thomas Robins was the pioneer of conveyor belts. He made a suggestion that apparently revolutionized the conveyor-belt design. Believing that a rubber cover would outlast many times its own thickness of cotton fabric, he conceived the idea of a belt with a thick layer of rubber on one side. After making numerous compounds and testing them with a heavy stream of ore, he found one that would stand abrasive wear for the longest time. From then on, he developed the idea of idler pulleys and the trough-shaped belt, so that, in point of fact, the ore was continuously in motion, carried in a moving trough. This idea was the best fundamental conception of a conveyor belt. After a good deal of difficulty, he succeeded in interesting people in the conveying of iron ore and also of anthracite coal.

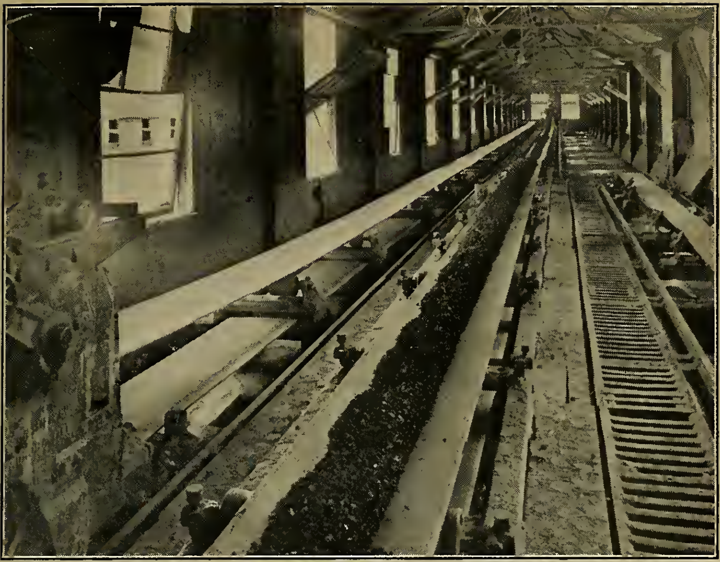
Conveyor belts are made on essentially the same principles as transmission belts. Heavy cotton canvas, frictioned and coated with rubber, is built up in several plies, so as to be flexible and contain the rubber best able to resist wear. But the rubber is thicker in the center and the fabric thicker at the edges. Thus, the most rubber is concentrated where it will resist wear; and the most fabric is placed at the edges, where it will carry the strain of power. The belts are easily moved; they may be given concave or flat surfaces, as the conditions demand; they are light in weight as compared with metal buckets; they show a minimum of wear from friction on the rollers, as compared with buckets traveling in chutes: all these properties have made extensive installations of conveyor belts a necessary part of many mining operations. The design of these belts for special purposes is a matter of engineering construction and is different with nearly each installation, for various kinds of ore, for particular speed, for the weight and the type of material. The duck must be strong and flexible, and the rubber adhesion must be maximum during the life of the belt. The rubber cover must resist heat, for many materials are hot; it must resist abrasion, for the ore particles are sharp-edged.

In the mines of the copper companies in Salt Lake City, there are installations of belts three hundred and more feet long, a yard wide, which have delivered more than seven million tons of ore. In conveying sugar in California from evaporator to warehouse, belts fourteen hundred feet long and thirty-six inches wide have operated continuously over nine-year-periods and delivered during that time eight billion pounds of sugar. To charge gas retorts, belts carry coal from bin to charging machinery over distances as long as thirteen hundred feet. Some belts weigh more than fourteen thousand pounds. The presses in which these giant workers are vulcanized have, in recent years, grown to thirty feet long and eight feet wide.

It was difficult even a few years ago to convince the mining engineers that so soft and resilient a material as rubber could withstand the abrasive action of stone. Such a supposition seemed unreasonable, but the test of the actual use of rubber in comparison with metal, leather, and other materials has demonstrated that under this cutting and abrasive action it outwears by several times any other substance. The rubber-surface conveyor belt has come to be the most efficient means of handling sharp-edged material. It carries crushed stone, assists in unloading hot coke from coke-ovens and in delivery to the cars, is used in loading steamers with coal or stone, and handles ores of many different kinds.

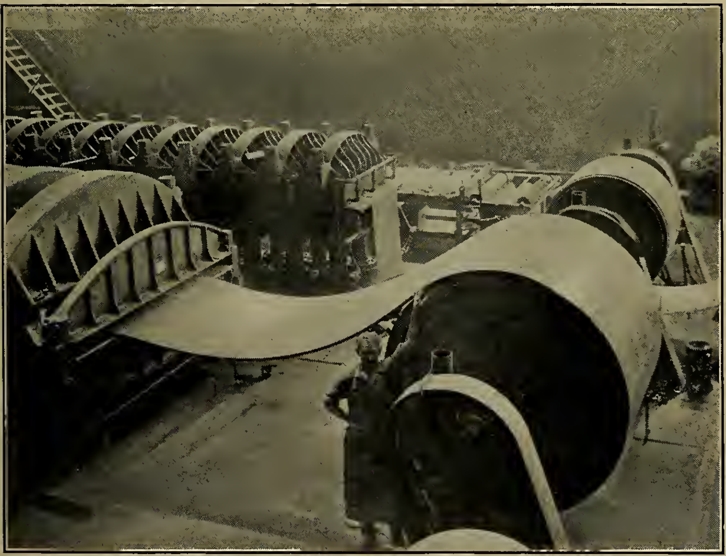
The service is rough and varied. Thomas Robins writes in "The India Rubber World" the story of a belt salesman who offered his product to a quarry superintendent with a guaranty that it would outwear any other belt in the market. The superintendent took the young man over to the plant where the big crusher was at work turning out the two thousand long tons an hour. Watching the empty belt, they stood at the base of the huge machine. Suddenly the first loaded car from the quarry dumped its thirty tons of rock with a crash and a roar into the hopper that fed the big crusher. The shock and thunder so frightened the salesman that he ran away. After he had been stopped, his first question to the superintendent was, "Where was the accident?" He received the reply, "That is an accident which happens one thousand times in every twenty-four hours at this plant, and it means that this belt which carries away the product of the crusher has a practically continuous load of two thousand long tons per hour, a large part of it in pieces which you could n't lift."

Metal would wear out and be gone before rubber would show serious evidences of wear under these conditions. As a consequence, for purposes of carrying trap-rock and limestone in stone-crushing plants, charcoal and ashes in sugar refineries or in concentrating plants and mines, earth and stone in large excavations, blocks and logs of wood in pulp-mills, clay in brick-yards, coal in breakers in connection with large power plants and culm piles, tobacco in process of manufac-



Courtesy of The B. F. Goodrich Co.

A CONVEYOR BELT IN ACTION



Courtesy of The B. F. Goodrich Co.

VULCANIZING A CONVEYOR BELT

ture, customers' packages in large retail stores, grain in elevators, mixed goods in coffee-mills, phosphate ore in the southern mines, chemical fertilizers in plants all over the country, the cotton-rubber conveyor belt is essential. For these uses and many others, it has come into being and serves with a relatively low cost of installation and a cost of maintenance that is unbelievably smaller than that of any other type of conveyors. Furthermore, it is quiet; and because it is uniform in action, it is less wearing upon the motive-power. More than twenty-two million dollars' worth of belting was sold in this country in 1919.

Little out-of-the-way things, unheralded and unsung, often serve large purposes. The youth who stopped the leak in the dike was made famous—a rare accident. The inventor of the steam engine, be he Hero or Watt, found great difficulty, though, in sealing the parts of it from leakage. In fact, in Watt's patent of 1769 he states: "Lastly, instead of using water to render the piston or other parts of the engine air or steam-tight, I employ oils, wax, resinous bodies, fat of animals, quicksilver and other metals in their fluid state." Such packing between the cylinder and the cylinder-head could not last long. Because boilers, pipes, and engines need a little thing,—packing,—but a stable one, rubber sheeting came to be used. Even to lubricate and prevent steam leakage around the piston-rods where they issue from the cylinder, stuffing boxes in which packing is used are required. An early engineering writer says, "The great desideratum in a piston is that it shall admit of no leakage and have as little friction as is consistent with this independensable quality." Watt, the father of the steam engine, tried to arrive at these results by the use of a metallic packing, but with so little satisfaction that he gave it up. A number of metal packings patented in England before the middle of this century were displaced largely by vegetable and animal substances, specifically hemp and leather. Engineering works of that period show accounts of pistons packed with unspun hemp or long rope prepared for the purpose, kept supplied with tallow by means of a funnel on the top of the cylinder lid.

The employment of cotton and fiber packing is of comparatively recent date. Having engaged, however, the ingenuity of some of the best inventors in rubber, and possessing a fundamentally sound merit, the use of rubber for this purpose has been steady and rapid in its increase. The demand for packing has broadened until that for piston rods is only one of the many kinds produced. Most manufacturers make rubber-sheet packing, in the form of cloth insertion and plain packing. The advantage in the use of rubber wherever steam, air, or water joints are to be made is that no other substance which has so much elasticity stands so high a degree of heat. No satisfactory substitute can be found where the iron surfaces of the joints are rough or uneven. Rubber packing made with cloth insertion is in wide use for steam joints, and the steady increase in the yearly production is an evidence of its value.

With the advent of superheated steam, there came a demand for packing of special composition that would render steam-tight the joints of pipe-lines where high-temperature and high-pressure steam is used. Although rubber alone cannot serve here when the steam temperature rises as high as 500 degrees, a combination of rubber and asbestos fibers gradually has taken the place of all other sheet packings for use under these conditions. Cotton, hemp, and flax do not possess great resisting qualities. Asbestos alone has not the cohesion necessary, but a combination of rubber of proper composition and asbestos as "superheat packing" serves well. This type of packing is, in reality, a combination of hard rubber and asbestos—the asbestos to give strength and the rubber to give tightness. Wherever steam is generated, rubber packing is found. Gaskets prevent leakage of air and steam. Water pump valves go up and down millions of times—some more than thirty millions before they die and pass out.

Hose is the third of our trio. It is a family name with many members: fire-hose, water hose, air-drill hose, gasolene hose, radiator hose for automobiles, suction hose for fire-engines and for drawing water from excavations, garden-hose, sand-blast hose, hose for chemical fire-extinguishers. Of all sizes, these hose vary from an inch long to five hundred feet. One of this large family keeps trains running. Like the axle-lighting belt, he lives in a poor place under the end of a railroad-car. He is married to one on the next car to him, although an iron coupling is required to keep the twain together. They are out in the weather in a swirl of cinders or snow, bending and creaking when the car swerves around sharp curves. Serve they must at any time, at all times, for through them passes the compressed air by which the brakes are operated. We call them the air-brake hose. Although only twenty-two inches long and one and three-eighths inches in diameter, they are essential to the successful operation of railroad-trains.

George Westinghouse probably made himself more famous by his creation of the automatic air-brake, patented in 1872, than by any other one of his many inventions. The original non-automatic or straight air-brake was based upon a very simple steam-actuated air-pump on the side of the locomotive. Through the reservoir a pipe-line was carried the length of the train; and even in those days, the connection between the coaches was by means of the hose and couplings. This apparatus was inoperative in emergencies. Westinghouse developed the automatic principle in such a way that each vehicle carried its own source of power; and by an ingenious valve connection he caused the application of the brake whenever there was a reduction of air-pressure in the train pipe-line. This has gone through numerous improvements and changes since the early one; yet the rubber parts to seal properly the air in the valve, and the air-brake hose, still constitute essentials in this important factor of railroad transportation. The quality of the hose has been developed by coöperative action on the part of rubber manufacturers and the Master Car Builders' Association, so that bursting hose is nowadays something almost never heard of.

Several others of the hose family live in the dirt under the car; they seem to like it. Safety in railroad transportation depends heavily upon rubber. An air-signal hose connects the coaches of a passenger-train, and steam-heating hose carries exhaust steam from the locomotive to radiators.

In every passenger coach there are six pieces of hose, two of air-brake, two of air-signal, and two of steam-heating hose. On the 2,500,000 freight-cars, 60,000 passenger coaches, and 10,000 Pullman cars, it is probable that the air-brake hose equipment in the United States includes a matter of 5,000,000 lengths. Each of these is replaced about every six months or year, because they cannot live long in an atmosphere of water, snow, cinders, and dirt. About 10,000,000 pieces of air-brake hose are necessary every year. End to end, these would stretch over 3500 miles—enough to reach across the continent.

Air-brake hose is of uniform size, measuring one and three-eighths inches in diameter and each piece being twenty-two inches long. It is made of an inner tube, several plies of strong, rubberized fabric, and an outer rubber cover, all vulcanized together. After this process, it is tested to make sure that each piece will withstand the suddenly changing air-pressure of about 125 pounds to the square inch, the bending as the trucks go around curves, and the deteriorating action of the elements.

A sum of $26,998,000 was expended for rubber hose of all kinds in 1919.

Were rubber to disappear, the price of copper, cement and coal would go up; for in mines delay and added expenses would result. The rubber conveyor belts, the hose to carry air to the drills that punch holes in rock preparatory to blasting, the elevator belts that carry buckets loaded with acid slimes; these and other rubber articles lead a rough life in the mines and smelters. Dragged over rock, submerged in water, confined in an atmosphere of fumes, exposed to heat and cold, none but the most rugged material can stand the abuse; yet rubber lives and works cheaply.

In every industry rubber works in diverse ways and under varying conditions to serve mankind. The paper of which this book is made was, when pulp, held in place by rubber deckle straps. It was pressed into sheets by rubber-covered couch rolls.

But in the oil industry rubber is given its severest test. Oil attacks rubber; it is the chief enemy. Therefore the chemist has been obliged to mix with rubber other substances and in this union to change its nature.

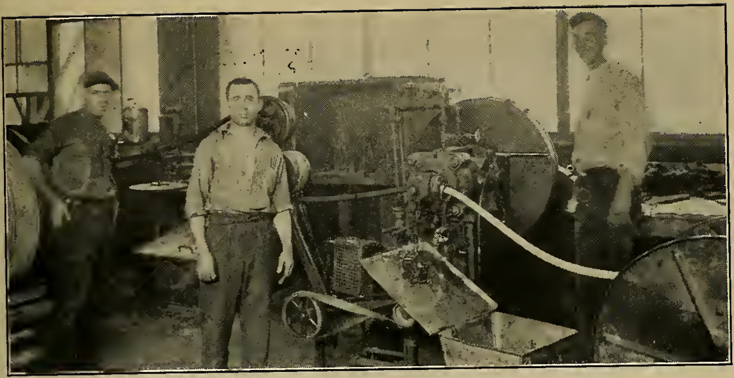
From California to Oklahoma, from Ohio and Kentucky to Pennsylvania, oil is pumped out of the ground, delivered into tanks, passed through great pipe-lines, and put on board ship for transport to other countries. The big oil companies have tried all kinds of belts for driving wells at high speed for twenty-four hours a day, both by rotary chisels and percussion. By the percussion method a 625-pound bit is lifted and dropped into the hole; in the boring method a one-hundred-pound bit with a serrated tip is revolved at the bottom of an eight-inch or ten-inch iron pipe. In both these methods rubber belting is preferred, because it is tough, flexible, cohesive, and has greater strength than belting made from any other substance. It is water-proof, and it is more oil-proof than other materials, although to make rubber oil-resisting is one of the most difficult problems faced by the rubber chemist. Submitting to heavy, uneven shocks, rubber belting has a durability that often extends as long as five or six years, despite the oil and sand that come in contact with it and the rough and careless usage to which it is subjected.

In conveying oil, special grades of oil hose are used; and since these are dragged around a great deal, they are frequently protected by metal armor consisting of wire wrapped spirally about the length of hose. Some of them carry water, some convey air; but all of them come more or less in contact with oil. For conducting oil from tanks to barrels, the hose ordinarily has four or five plies of frictioned duck, lined with an oil-resisting rubber compound, and a closely-set, spiral, flat wire extending through the core, not only to protect the compound from possible corrosion but also to prevent the hose from kinking or collapsing by reason of the vacuum so often employed. To draw oil from storage tanks of steamships or tank-cars, a suction and discharge hose of exceptional strength is employed. It must withstand the utmost extremes in weather, the harshest handling, and continual contact with rapidly moving oil.

Rubber in the oil-field probably gets its severest test in the pumps and the pump packings, which are of various sizes, kinds, and shapes. The foregoing enumeration of rubber needs in oil-fields does not take into account the many other articles that are quite indispensable to handling oil from the time when the heavy black fluid is drawn from the depths of the earth to the time when, in the form of gasolene and lubricating oil, it is delivered to consumers—the tires on the trucks, the boots and the shoes, the gloves and the hats, the rain-coats used in sunshine as well as in rain. Slopping about in sand and water, splashed with oil, rubber truly has a hard life in the oil-fields.

Of the four billion gallons of gasolene used by motor-cars each year, all of it flows through rubber hose from the filling station to the tank in the car. This is a specially made length of hose, the composition of which resists gasolene to the maximum. Here, if the manufacturer had not been alert, the gasolene would swell the rubber and disintegrate it; small pieces of rubber would pass into the tank of the motor-car, eventually to clog the needle-valves of the carburetor. By joint action between such institutions as the Underwriters' Laboratories in Chicago and the Rubber Association, special constructions of hose have been developed by which the amount of action of gasolene upon the rubber has been reduced to a minimum. This gasolene hose is usually made with a cotton duck lining and a helical flat wire to further safeguard the rubber. Outside of this comes rubber, then four plies of cotton fabric, and finally a spirally wound layer of wire, usually covered by rubber. Here again one finds flexibility, strength, and resistance to corrosion.

For those who go down to the sea in ships, be it in man-of-war, submarine, or passenger transport, rubber articles do many things. The first and the last work in which Charles Goodyear was concerned had to do with life-preservers. Even now, though, rubber in connection with life-preserves is not used to the ex-

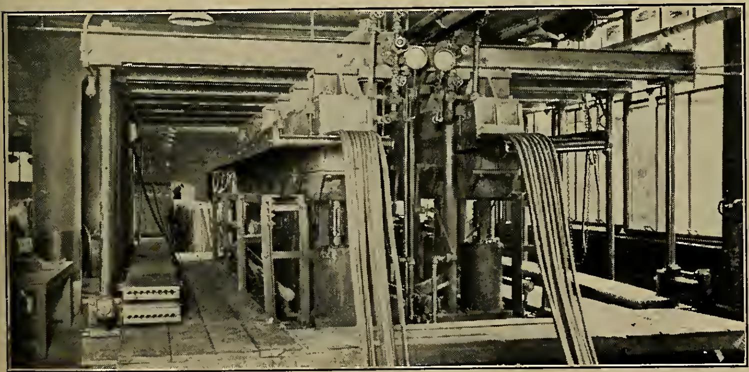


Courtesy of The B. F. Goodrich Co.

APPLYING RUBBER INSULATION UPON THE BRAIDED JACKET OF GARDEN HOSE

Courtesy of The B. F. Goodrich Co.

THE BRAIDING MACHINES MAKING GARDEN HOSE



Courtesy of The B. F. Goodrich Co.

VULCANIZING GARDEN HOSE

tent of cork and cotton. It does not age well enough, and air-bladders puncture. Life-preserving rubber suits would be more largely used were they not perishable. When the day comes in which all rubber articles are as permanent in the air and sunlight as wood and steel, then the marked superiority of the life-preserver made of rubber and fabric will be recognized; and ship-owners will use such articles rather than the somewhat more permanent but less adaptable cork belt. To provide greater safety in time of need to the passengers, is a field in which shipping concerns should interest themselves.

The diver depends for his life upon suits of rubberized fabric, with heavy rubber gloves, with a metal headpiece made water-tight by means of rubber gaskets, and, most important, with the hose that go down from the pumps, to transmit fresh air and to remove exhausted air.

An ocean-going vessel is much like a small city; every phase of human life and every convenience is found there. Consequently, if we were to enumerate the part which rubber plays in ocean or lake transportation, it would be necessary to catalogue the ways in which rubber is used in the home, in the office, and in the mill and the factory, with, however, the additional requirement that on board ship, in the course of storms, it is necessary to tighten all openings to keep the water out.

The numerous articles used in the mines, in factories, on railroads, and on board ship constitute, broadly speaking, what the rubber manufacturer terms "mechanical rubber goods." Rubber products are grouped under the names of clothing, footwear, pneumatic tires, druggists' sundries, and mechanical rubber goods. Mechanical rubber goods include a vast number of products, large and small, the mere enumeration of which would fill volumes; for there are probably upwards of 20,000 to 40,000 different articles in various sizes, shapes, and colors, and for myriads of uses.

CHAPTER XVIII

RUBBER IN THE HOME

A comparison between the American bath-room and the English one, reveals some interesting differences. In England one may not find a rubber hot-water bottle hanging behind the door, but he is likely to find a stone or metal one under the wash-basin. Of late years, the English bath-room has achieved a rubber sponge, sometimes a solid rubber shaving-dish, and a rubber bath-plug to keep the water from running out of the bath-tub. In American homes, however, rubber has worked its way into a large variety of convenient uses. The hot-water bottle is one of the basic necessities. Then there are fountain syringes, rubber bath-mats, rubber soap-dishes, rubber aprons, rubber sponges, women's bathing caps, the tooth-brush with its hard rubber to keep the bristles from coming out, hand brushes, nail brushes, shower attachments, and, in the spring when colds are prevalent, the rubber bulb and tube connected to the nasal spray outfit. We surely depend upon rubber in the American bath-room and medicine-cabinet.

The American loves his bath-room, whether it has tub or shower. But he does not want the water to run all the time. It leaks too much from bib and faucet as it is. By a soft rubber disk pressing against metal when the wheel is turned, the water is shut off. If our plumbers would use high-grade rubber mixtures for these disks, there would be less trouble in the household; too many of them contain no rubber at all, being merely paper, which soaks up water and wears out rapidly.

I am afraid this chapter will read too much like an advertising man's copy, with rubber, rubber everywhere. But we do live in the reign of a rubber democracy in which there are many members. Not the least of them is the gentle lord of the bath—the rubber sponge. Purity and cleanliness characterize this intimate individual. Usually, it is formed of a large proportion of rubber, with considerable oil to make it soft and flexible. With this is mixed sulphur in the finest form. To attain such fineness the sulphur is made by chemical precipitation with the vulcanizing ingredient, antimony sulphide, a mild accelerator. Incorporated with these is some substance like ammonium carbonate, which, upon heating, produces a gas. This rubber mixture is not mixed in the usual way, but so as to be soft and uniform. Unless plasticity is attained, the rubber will not "blow," as we say. After pieces of the mixture are put inside hollow iron molds, heat is applied only at the temperature at which gas is given off from ammonium carbonate. The soft plastic mixture, by reason of the gas, rises like bread, blowing up into bubbles with little membranes of rubber between them. Finally, as the process goes on, the entire cavity of the mold is filled with the porous mass. The heat is then increased up to the vulcanizing temperature, and kept there until the rubber is completely vulcanized. After cooling the mold is opened, and the sponge, in somewhat rough form, is removed. By a simple device the outside skin is cut off, and the sponge as we buy it in the drug store is ready.

But the flowers, garden, and lawn need their shower-baths as much as do we, to keep their vitality during the summer's heat. Rubber garden-hose is their true friend. Out on the golf course night after night a little twinkling light may be seen, flitting from green to green. The spooks might be playing golf, but it is not they, nor is a duffer player practicing putts. Most of us putt in the dark on Saturday afternoons. No, in this case the greens man waters his greens by night with length after length of rubber garden-hose to convey the water needed for the growth of the delicate bent and fescue grasses. Players are exacting; each square inch of green must needs be covered evenly with fine blades of special grass. We cannot drag iron pipe over greens to tear and roughen them. Thus, rubber garden-hose serves the golfer as well as the gardener. Probably two thousand miles of garden-hose are made in the United States every month.

Garden-hose is constructed of several essential parts: an inner tube heavy enough and uniform enough to retain water and not to deteriorate on standing; a cotton fabric or cord body of several plies, between each pair of which is a rubber layer to stick the cotton together; finally, an outside rubber cover, thick enough to withstand tearing as the hose is pulled over the lawn and the sidewalks. It is probably the one article that is handled by the user with the least consideration. Who of us picks it up carefully and carries it out to the front lawn? We grab one end and drag it. We kink it in several places; we haul it over the sidewalk; we jerk it and pull it if the coupling happens to catch. We give it every possible abuse. It is out in the weather constantly; and when the cover or tube is punctured, the fabric decays in contact with water.

The rubber mixtures for tube, insulation, or cover—and they do not differ greatly in composition—are taken after mixing into the hose manufacturing department. Here the first operation is to form the tube of the hose by squeezing the compound through the die of a tubing machine, as previously described. Before the rubber is fed into the tubing-machine, an operator softens the compound, or, as he calls it, the "stock." He then cuts it into strips and passes it to another man, who operates the machine. The second operator feeds this warm, soft stock into the cylinder at the feed end, another man watching the issuance of the long, hollow tube and seeing that it is carefully wound up upon a large reel or drum. The composition must be stiff enough not to collapse; and to prevent its sticking together in any place, a little soapstone is fed into it through a special attachment in the die. Meanwhile, a slight air pressure is maintained inside this tube to keep it in shape. When about five hundred feet of it are wound upon the reel, it is rolled to the braiding-machine. After the tube is rounded out by just enough air-pressure to give it shape, it is automatically fed to the center of the braiding-machine. This is a noisy instrument, like all cotton machinery. Little spools containing cotton cord are forced by the mechanism in and out and around each other in such a way that, as the rubber tube passes up through the machine, it is surrounded by interbraided cotton cords spirally and continuously woven.

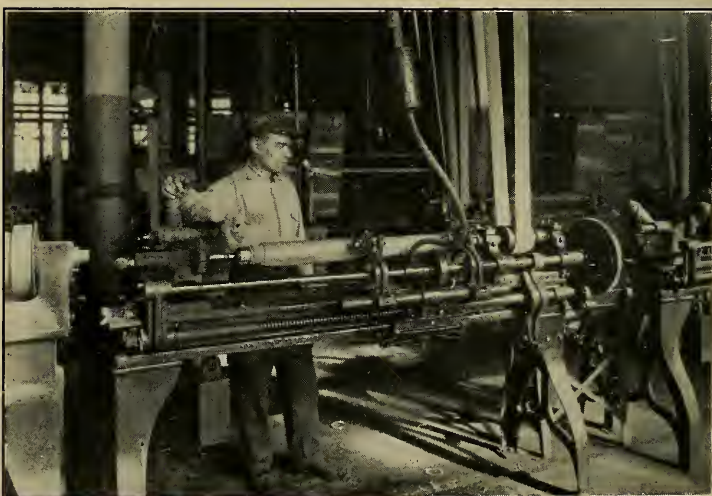
Some garden-hose is made on the plan of the cotton, rubber-lined fire-hose, but in the type we are describing one ply or layer of cotton cord is not sufficient to give strength and durability; therefore, when this reel of unvulcanized hose is covered with its layer of cord, it is taken back to the tubing-machine again. But how shall a partly made hose be covered with rubber? We certainly cannot pass the hose through the cylinder of the machine and through a die, for that would simply grind it up, cotton and all. Here a leaf is taken out of the book of the insulated wire manufacturers. Upon this particular tubing-machine is an insulating head; that is, a piece of metal with holes properly arranged in it is so placed on the head of the tubing-machine that the entire hose may pass through a cavity running at right angles to the direction of the flow of the rubber. As the hose passes through this cavity, the tubing-machine forces soft, unvulcanized rubber around it. By an ingenious device the die of this insulating head permits only a certain thickness of rubber in the form of a continuous tube to be laid on the surface of the cotton. Thus, our rubber hose now issues from this operation with a thin layer of rubber on top of the cotton layer. After the reel is filled again with five hundred feet or more of insulated hose, it is taken back to the braiding-machine. Once more the little spools run around each other, and a second ply or layer of cotton cord is wound upon the partly manufactured hose.

Still the hose is not complete; for certain uses, three or even four plies of cord are necessary. We shall assume, however, that three plies are required. The hose, after the application of its second layer of cord, goes back to the insulating head of the tubing-machine, through which it again passes and adds another layer of rubber. Then back it goes to the braiding-machine, where the third layer of interlocked, woven cotton cord is applied. So far as strength is concerned, we should need to add no more rubber to this hose, with its tube, its three plies of cotton, and its two layers of rubber between them. But we know that it will be dragged about on the ground and in the water; we know also that water causes deterioration of cotton, for wet cotton mildews and decays rapidly. Therefore a protecting layer of rubber must be applied outside this last layer of cotton. Back again goes the almost completed hose to the tubing-machine, where it passes through the insulating head and die. In this case, however, there is applied a somewhat thicker layer of rubber of a different mixture, a tougher one, designed to resist the wear and tear on the ground.

These operations have produced five hundred feet of garden-hose, blown up with a few pounds of air-pressure to keep it fully rounded. Wound up on a reel, the layers separated by paper or varnished cloth, the hose, on a factory type of small wheel truck, is pushed into another room. Here several of these reels are gathered together at one end of a long vulcanizing press, for the hose is to be vulcanized at the rate of about twenty feet at a time. To accomplish this, two heavy steel plates have been made, each of them

Courtesy of The Boston Woven Hose and Rubber Company

FORCING THE JAR RING COMPOUND THROUGH A TUBING MACHINE



Courtesy of The Boston Woven Hose and Rubber Company

CUTTING JAR RINGS FROM THE VULCANIZED TUBE grooved full length. When these two plates are brought together, there is a circular opening through their length of the exact diameter desired as the outside diameter of the hose. One of these plates is bolted to the top of the press, and the other is bolted to the movable part. Each plate contains six to ten of these semicircular grooves. The operator draws into the grooves a length of hose from different reels sufficient to fill them from end to end. Then the lower half is pushed up by hydraulic pressure against the upper half, thereby confining the hose in the tubular openings formed by bringing together the two sets of grooves. The hose is in contact with the hot plates or molds long enough to vulcanize the composition. The plates are then separated, and the hose is pulled through to bring another length in contact with the mold. Again the molds are closed and heated. Thus, twenty feet or more at a time, the hose is vulcanized from end to end. When it is inspected and the rough ends cut off, finally it is rolled upon a wooden packing reel, ready for shipment. There are other methods of making garden-hose, but this is probably the simplest of them all.

There are many different kinds of hose, not the least important of which is that for conducting solutions of chemicals used in spraying orchards. Fruit would be poor indeed were insects not killed by chemicals applied by orchard sprayers, with their rubber hose connections of special sizes, lengths, and types. The little bucket-spray pumps with four- or five-foot lengths of three-eighths-inch spray hose, the large horse-drawn, and the gasolene-power types, all have hose connecting them and permitting the operator to move about and thoroughly spray his orchard. Sprayers of the power type usually develop pressure from 250 to 300 pounds to the square inch. The fabric construction of the spray hose must be made to withstand these pressures. Furthermore, since spraying liquids are composed of different chemicals, the lining of this spray hose must be made of most carefully constructed rubber mixture. The problem is not wholly one of pure rubber; it is a question of mixing with pure rubber those ingredients which give toughness and strength to the composition, and an ability to withstand the action of the chemicals. This condition is somewhat difficult to attain in rubber, particularly when emulsion sprays containing oil are used. Rubber absorbs oils with great rapidity; it swells, softens, weakens, and deteriorates under their action. Therefore, he who sprays his orchards would be wise if, after each operation, he were to pass through the hose a sufficient quantity of water to wash out the chemicals and thus minimize the action of them in the deterioration of the rubber.

Another of the necessary uses of rubber in modern days is in the home canning of fruits and vegetables. We think of the process as new, but in 1795 a method was invented by a Frenchman, Appert, for preserving foods in hermetically sealed receptacles. He was awarded a prize of sixteen thousand francs by the French Government. His process consisted in placing the articles to be preserved in cork receptacles and subjecting them to the heat of boiling water for various lengths of time, depending upon the nature of the foods. Although Appert's process was kept secret for some time, it gradually leaked out; in 1815 it was brought from England to America. In 1819 an Englishman named Daggett had a canning factory in New York City for packing lobsters, salmon, and oysters; and in 1825 fruits and vegetables were canned. At this time only glass jars were used; but the cost and frequent breakage led to the use of tins, the first patents for which were secured in England in 1823 and in America in 1825. Because sterilization by boiling in water was found to be insufficient for many products, salt was added to the water to raise the boiling-point. In 1874 a Baltimore man invented a closed retort for cooking with superheated steam. From this came our modern steam-pressure devices, which produce various temperatures above 212° Fahrenheit.

The canning industry has become extensive. The figures amaze one. The National Canners' Association reports that in 1919 there were packed in the United States more than 1,385,000,000 cans of vegetables, more than 634,000,000 cans of fruits, and more than 716,000,000 cans of fish and oysters. These make a total of more than 2,736,000,000 cans "put up" in one year. And the home is not heard from in these records.

Without entering into the principles of hot canning, we should note one fact as fundamental; the cans must so be sealed as to prevent any ingress of air. Among the many substances used for this purpose, the chief of them is rubber; even the tin can usually has a little rubber seal between the sides and the base. Because it is odorless and tasteless, because it is resistant to the action of fruit acids, because bacteria cannot grow in it, rubber has become one of the most necessary links in this chain of important operations, the end of which is the preservation of food in palatable, healthful, usable condition. Before canning, all the fruits and vegetables are picked over in the factory, just as our cooks do in the kitchen. Girls with carefully sterilized and manicured hands sit before a long table upon which slowly moves a sanitary rubber conveyor belt, usually white in color, which carries the fruit to be sorted.

In the home, large quantities of fruit and vegetables are preserved each year in glass jars. This process is more economical than the use of tin, because the jars can be used repeatedly. The glass top, however, must be air-tight; and for this purpose, ever since home canning began, the rubber ring, known generally as the "jar ring," has been used. The jar ring is busily engaged in filling its mission in the twenty-four million homes in our country during the canning season. One rubber company alone informs me that it makes every hour during the winter enough rubber jar rings of one brand alone to make a pile, one on another, as high as the Woolworth Building; and their production for a year of this particular brand would, if linked in the form of a chain, go around the world three times.

In the process of making jar rings the first essential is the choice of a rubber composition. This composition must have certain properties: it may contain no substances that can be absorbed into the acid liquids and give either taste, odor, or poison to the preserves. After it is mixed in the usual way this rubber compound is manufactured by a very simple process. It is taken from the central mixing-room to the jar ring factory, where it is warmed on a warming-mill and forced through a large die in the head of a tubing-machine, much in the same fashion as garden-hose. Garden-hose tubes are small, but the tube from which the jar ring is cut is large in size and thick in wall. The thickness of the wall is that of the width of the thin section of the ring as the consumer obtains it.

As the tube comes from the machine, it is cut into short pieces, usually about three feet long. An operator places the tube upon a mandrel or iron pipe. Then a large number of these mandrels are put into a vulcanizer containing water; and the vulcanizing is done by heating this water to the proper temperature and maintaining in the water, usually, a slow but regular circulation. When this heavy tube is vulcanized, it is removed to a jar ring cutting machine. Here the workman has but to remove the tube from the mandrel and place it upon a cutting mandrel, and the machine does the rest; that is to say, a sharp knife runs in and out, cutting the rings automatically at the rate of fifty thousand an hour. After they are cut, they are carefully inspected by expert girls, counted, and packed in the boxes in which they are sold.

As I write, the canning season in my home has just begun. Strawberries are coming in from the garden; soon it will be currants, raspberries, and later, peaches. For several weeks the kitchen will be redolent of sweet smells, but mere man must stay out of the bustle and boiling. Whether hot pack or cold is being used, as a rubber man, I look after the jar ring purchases, to see that they are of proper quality. I demand good quality; the rings must be strong enough to stretch around the top of a Mason jar and not so soft that they will squeeze out and leave places for air and fungi to creep in and spoil the fruit, if I am to purchase them.

All rubber men like fruit in the winter, I imagine. Perhaps for this reason, as well as from a sense of responsibility for the needs of the householder, they got together some years ago and, with the coöperation of the Bureau of Standards, developed for the Department of Agriculture, that loyal agent of the housewife, a specification according to which jar rings should be made. Responsible manufacturers take pains to see that these specifications are carried out. It is simple for you to test jar rings in accordance with the Farmers' Bulletin No. 1211 of the United States Department of Agriculture, "The Home Canning of Fruits and Vegetables." The tests, if followed, will show you whether the jar ring will sustain a load of seventeen pounds before breaking, and whether it is flexible enough to stretch from four inches up to ten inches without breaking. These two tests of strength and stretch are the fundamental ones indicating a good rubber composition. For use in the hot pack method it is advisable to test the ring in boiling water. In position on a jar and placed in boiling water for four hours, it should not, after cooling, be swollen or show signs of cracks or cuts resulting from pressure.

If your home happens to be on the farm, you probably sell milk. The old-fashioned method of milking by hand is gradually giving way in the larger dairies to newer methods of milking by machinery. Conservative as we may be, and desirous of holding to the old and not taking on the new, yet demands for sterile, clean milk have grown to be so heavy that every possible method to prevent contamination by dirt or bacteria must be adopted. Therefore the milking-machine is coming more and more into use.

There are many different types of milking-machines. The experimental work leading to their development began probably as far back as 1819, but modern development began about 1878. There have been three different principles. The milk-tube idea, providing for an opening into the milk cistern and allowing the milk to flow from the udder, is dangerous and is not used. The second method adopted the pressure principle. The third method, which has come into extensive use, places the teat into cups from which the air is exhausted, the exhaustion producing a vacuum in the manner produced by a calf when suckling. There have been different patents, but the fundamental principle consists of a vacuum pump or "pulsator." To this pulsator are attached two lengths of rubber hose and a specially designed connection for teat cups and teat-cup mouthpieces. Thus a pulsating vacuum is applied to the teat, bringing its flow of milk into the vacuum milk-pail.

The particular rubber parts which make this milking-machine possible are the teat cups, the rubber tubes that convey the milk into the pails, and the rubber hose that permits a vacuum to be applied to the milk-collecting pails. These cups are made of purest rubber, soft, flexible, and permanent.

All things that come in contact with milk must be kept clean. To enjoy good milk, one must keep the rubber parts just as clean and sterile as the pails and cans. Those who use milking-machinery should be careful to see that the directions of the milking-machine companies are carried out. The rubber parts should be washed and carefully sterilized; and between the times that the machine is used, they should be kept immersed in plain boiled water. The rubber tubing and cups should never be allowed to become dry. To sterilize them, the College of Agriculture at Cornell University recommends a solution of water containing salt and chloride of lime. It is well to remember that the fats of milk are readily absorbed by rubber; if, therefore, the rubber parts are not washed after each milking and kept in sterilized water, more and more butter fat will be absorbed into the rubber, with consequent deterioration. The secret of keeping the rubberware sweet is always to store it wet with clean water and never to let it come in contact with oils or fats, for they swell and weaken rubber.

Within the limits of our space, all the articles of rubber found in the home could scarcely be described. They are too numerous, although different enough to warrant separate treatment. For comfort on cold nights millions of hot-water bottles are in use. They are made from sheeted rubber, colored, adorned with configurations on the surface, to be agreeable in appearance. Girls build them into shape, or men mold them in steel molds under pressure. Only the cleanest rubber and the most dirt-free processes are employed, for the bottle must not leak.

Even straw and felt hats, awaiting the call to adorn the head, have been helped by rubber forms upon which they were pressed in the making, and in so intimate an article as the garter and the "braces" of the Englishman we depend upon rubber thread, while rubber has come to replace leather in the belts preferred by American men.

But it is in relief from the burdens of housework that rubber serves as a real aid to the housewife, in city or country. Sweeping and dusting are made easier by rubber-wired and rubber-tired vacuum and carpet sweepers. To the sewing-machine electricity is conducted by rubber-covered wire. But best of all is the routing of blue Monday wash-day. The laundry in recent years has changed from a back-breaking place, dreaded each week, to a light, happy room. Equipped with motor-driven washing-machine and rubber wringer rolls, with soft, warm rubber mats and with electrically heated mangle, this part of the home has become a scene of happiness.

Rubber in the home is a dependable commodity. It is gentle, noiseless,—a good servant.

CHAPTER XIX

GAS-MASKS

One fine afternoon in May, 1917, a telegram came to my office from Washington, which stated that Professor Gibbs of the Bureau of Mines would come to see me on an important matter connected with the war. The following morning he arrived and showed me a gas-mask of the box-respirator type that had been made by the English. He asked if it could be duplicated easily. There was very little gas-mask information in the United States at that time. The first mask brought to this country from the front was of German make. This type seemed to fit the needs of the Navy Department, and a small order had been placed with the rubber companies. After the usual difficulties incident to a new article, we had duplicated the German construction as closely as possible. Little was known over here at that time of the type of chemicals used for gases; else I am sure a considerably different type of rubber material would have been employed in making these first gas masks.

On Wednesday of that week, Bradley Dewey came into my office, after having been heralded in advance by a telegram from Washington. His first remarks were, as always, straight to the point. "We want you," he said, "to make the rubber parts for 25,000 gas masks by ten days from to-day." He was nothing if not direct. We told him that he might as well ask us to move the building in which we were sitting to Brooklyn in ten days. Such a retort made no impression; he went right on: "I am not yet commissioned; I have no formal order to give you. You will have to run your chances of getting your money back; but we want the masks, and we are going to have them." He gave no reasons for his statements; but we sensed one and thought at once, as it subsequently developed, that probably a force of American soldiers was to go overseas immediately and needed full equipment. It was of no special credit to the B. F. Goodrich Co., that we accepted the call. All American business men did the same in those days.

Because of the method of design, it would have been impossible to create an exact duplicate of the English mask in so short a time. Short cuts, modifications to permit speed of production, were necessary. The technical staff, officials, and Bradley Dewey sat down together and worked out the program. By Saturday there were thirteen machine-shops making the metal forms and molds. They jumped in to help, as did thousands of little shops in this country, whose names are unknown but which were keystones in the arches of the war machine. By Monday the regular peacetime occupations of two departments of the factory had been abandoned, and in place of them various gas-mask parts were in process of manufacture. By Wednesday we were making more than three thousand masks a day; and at the end of the ten days we had nearly completed the order. These were not good masks; but they did have a definite value in offering some protection against gas.

More than all else, however, this initial attempt taught us many things regarding the size and details of the gas defense problem. As Crowell and Wilson say in their "Armies of Industry": "To produce 25,000 gas-masks in three weeks meant to compress England's two years of experience into twenty-one days. The military authorities at that time could plead entire ignorance of the qualifications of an efficient gas-mask. The prevailing idea seemed to be that you could go out into the market and buy them by the hundreds of thousands as you could buy Hallowe'en masks."

More information filtering through to us from abroad during June, we came to realize—manufacturers, and War Department—that this was no ordiary war and that protection against the highly complex and constantly changed poisonous gases was a matter that would require research work of the first magnitude and coöperation of the highest degree. For this purpose the Gas Defense Division of the War Service Committee of the Rubber Association was organized to coördinate with the War Department. To their lasting credit, be it said that always the army officers were pleasant, courteous, progressive, and fair. The committee and the officers together wrote specifications according to which the manufacturers produced the masks. They made them severe in order to insure to the soldier a resistant, durable protection.

To comprehend gas-masks, one should understand a little of gas warfare. Gas is the most treacherous of all the weapons of offense, for it may be something like the ancient Greek, Pelopidas, who, so Plutarch states, on hearing the remark of a soldier, "We are fallen among enemies," replied, "How are we fallen among them more than they among us?" In its use, the wind may change and blow the gas back to the place whence it was sent. Poison gases were first used in warfare between 431 and 404 B. C., when the Athenians and Spartans, in the southern part of Greece, besieged certain cities. In doing this, they tried to overcome their opponents by the use of burning sulphur, which produced fumes irritating to the eyes and throat. While we may look back to ancient Greece with awe and admiration for wonders of art and literature, we must give them the discredit of having instigated the use of chemicals in the attempt to outdo their enemies.

Despite international prohibitions, Germany had planned the use of noxious chemicals before the war broke out. Ludendorff states in his "War Memories" that the Germans used gas shells against the Russians on January 31, 1915. Gourko, the Russian, writes that at about the end of December, 1914, the Germans introduced shells charged with asphyxiating gases.

Regardless of these early preparations of the Germans, the English and French were taken completely by surprise in April, 1915. Because something had to be done and quickly, Lord Kitchener appealed to the women of England, by whom the first mask was made, which was not a mask at all. It was merely a series of cheese-cloth pads soaked in chemicals.

The French studied protective devices. The first

French masks were also pads impregnated with chemicals. The chemicals were repeatedly changed, and glasses for the protection of the eyes were introduced. By the end of October of that year the French had developed an apparatus called the M-2 mask, which consisted of a series of fairly loosely fitting gas pads, with permanent eye-pieces of cellophane. In this, as in the earlier ones, air was breathed in and out through impregnated cloth.

The English had been at work in the same general way; and during the same year they had developed what was known as the PH helmet, a heavy cloth hood containing eye-pieces. The hood went over the head, the air coming through the cloth impregnated with chemicals to absorb the gases, and the exhalation passing out through a special rubber valve known as a flutter-valve. The difficulty of breathing through these contrivances was serious. Nor was protection complete. It became necessary rapidly to develop apparatus that a soldier could wear with a reasonable degree of comfort and by means of which he could live in an atmosphere of high gas concentration. The French organized commissions for chemical investigation in 1915. The English, under the leadership of the late Lieutenant-Colonel E. F. Harrison, C. M. G., were organized likewise; as a result of this organization the English box respirator was developed. Colonel Harrison prepared the manufacture of the respirator on a large scale; and it is a great testimonial to his foresight and energy that despite all the difficulties of production, the supplies promised to France never failed.

The gas-mask is not wholly a matter of rubber. It comprises four parts: first, the rubber face-piece, including eye-piece, inhalation tube, and rubber exhalation valve; second, the flexible rubber hose; third, the canister containing chemicals; fourth, the canvas knapsack or carrying-case. The purpose of a gas-mask is to protect the eyes from the irritating effects of gases and to filter them from the air through a series of layers of absorbing chemicals in a canister. The exhaled air is forced out through a separate valve, to prevent it from vitiating the chemicals.

Making such an apparatus was a complicated problem, involving a knowledge of the intricacies of chemistry, physiology, rubber, and, not the least, the temperament of the soldier. The canisters were required to exclude smoke, suffocating gases, tear-gases, sneeze gases, nauseating gases, and the more virulently toxic gases. As a chain is no stronger than its weakest link, the canister for filtering the chemicals from the air would be of little consequence if contaminated air leaked in around the edge of the mask because of faulty design or through an easily penetrable material. All sorts of substances for face-piece construction were tried; yet only vulcanized rubber seemed to combine strength, durability, and a reasonable degree of impenetrability.

The flexible rubber hose was a problem of its own. A rubber composition free from porosity was mixed. Covered with a flexible cloth known as stockinette, the rubber was molded to be light, strong, and flexible. The exhalation valve or flutter-valve, through which the expired air passed, consisted essentially of two flat pieces of rubber vulcanized together on the edges. When air was breathed out of it, it opened easily; but it shut itself tight at each inhalation.

The face-piece of the English box respirator was made of a thin cotton fabric dyed olive drab, upon which was applied a smooth layer of rubber vulcanized in hot air. It was secured upon the head by means of tape and elastic bands. In order that there might be no breathing through the nose, a nose-clip with rubber ends was used, the force of wire springs keeping the nose shut. The breathing, therefore, was done through the mouth, into which fitted a special mouthpiece of rubber upon which the teeth could close. A rubber flange that lay between the teeth and the lips prevented the soldier from breathing any bad air that might be inside the face-piece, when he opened his lips under severe exertion. This arrangement gave to the mask what was called the double line of protection.

There were serious objections to the mask. Perspiration from the face rapidly condensed upon the eye-pieces, so that vision was seriously interfered with. The nose-clip, the mouthpiece, and the lack of ventilation within the face-piece chamber produced extreme discomfort.

To overcome these difficulties, particularly that of the fogging of the eye-piece, Dr. Tissot, a Frenchman, in 1916 invented a mask that consisted of a metal box carried on the back, containing the absorbent materials, through the lower part of which the air came in, and out of the upper part of which the flexible tube passed over the shoulder to the mask inlet. The face-

THE ENGLISH PH HELMET

THE AKRON-TISSOT GAS MASK. THE 1917 MODEL

urtesy of Chemical Warfare Service, U. S. Army

THE 1919 MODEL GAS MASK

MEN IN FULL MASK AND PROTECTIVE CLOTHING

piece was made of almost pure gum rubber. To avoid the dimming of the eye-pieces, little tubes were run up to them from the inlet, so that all the air breathed in was swept over the inside of the eye-pieces, and prevented moisture from condensing upon them. This Tissot mask was used for artillerymen, observers, and sappers. When it first came to America, the idea stimulated development for the infantry. Because the face-piece was tight and comfortable, because the eye-pieces did not become dimmed, because there was nothing in the soldier's mouth to prevent his talking and to compel salivation, this mask was more comfortable than any previously developed apparatus. The rubber was thin and of great flexibility, but lacked durability.

To perfect such a comfortable mask required constant tests and studies. It had to fit the face perfectly, leakage around the edges having been observed in testing-chambers built for that purpose by the Chemical Warfare Service. By going into these chambers in the presence of different gases and under different concentrations men tested leakage. The "poison squads" were always at work. The physiologists and the psychologists studied the best shape of masks. It was necessary for them to fit into the hollows of the temples and give the jaws free space in which to work, yet not press back against the Adam's apple. The early masks were a joy to the fat man, but a terror to one with a cavernous face. With the pressure of the mask on the forehead carefully determined, the line of pull of the attaching bands was regulated so that pressure upon the supra-orbital nerves, just above the eyebrows, became so small that the discomfort from it was reduced to a minimum.

To fit all sizes of faces and heads was a problem. Equipped with regular as well as experimental masks, men of the Field Testing Section of the Gas Defense Division were constantly in and out of gas. They played base-ball in masks, dug trenches, laid out wire, cut wire, and fought sham battles at night, both with and without actual gas. Without ill effects, men worked, played, and slept in the masks for a week at a time, only taking them off for thirty minutes to eat, and each day entering high concentrations of deadly gases.

The dream of the gas-mask designer was to create one that could be worn constantly, and to this end the greatest efforts of rubber men and army officers were devoted. The first step toward this ideal was a modification of the French Tissot, which came to be known as the AT or Akron-Tissot mask. The face-piece was made of the cloth known as stockinette, under which was a layer of rubber, the whole being vulcanized on a form the size and shape of the face. An attempt to build a mask to fit a face, just as a rubber shoe is built to fit a foot, was made by coöperation between the Chemical Warfare Service and the Rubber Association. In order to keep the eye-pieces free from moisture, a specially formed rubber tube was made to fit upon a peculiar, snout-shaped, metal nose-piece. This rubber tube was of a Y-shape, laid inside the mask, in distinction from the French Tissot. Therefore, the incoming air went through these tubes and swept over the eye-pieces. Cotton webbing containing rubber thread was attached at the proper places to hold the face-piece in contact with the head. Although still not quite thick enough to withstand gases for the maximum time, these masks gave an excellent account of themselves. Another type was known as the KT mask.

I have made little mention of the other rubber parts of the mask. The face-piece, the flutter-valve, the head-bands, and the flexible hose all are made of rubber to a greater or less degree. There is also a necessary little rubber valve, about which no one has said much, on the inlet side of the canister. This valve has the duty of closing on exhalation and opening on inhalation, so that it acts exactly in the reverse way from the flutter-valve. If it ever fails to act, some of the air passes back through the canister and decreases the absorbing power of the chemicals.

At Long Island City was built a large gas-mask factory with technical laboratories where ideas were worked out in a spirit of coöperation and earnestness to produce the best possible gas defense equipment for the American soldier. The speed with which the organization was brought together and harmonized and production accomplished will ever stand as a monument to the Chemical Warfare Service. It brought together and combined the ideas of those who had been overseas and those connected with rubber, with the result of field tests. Coöperation was the watchword, a real part of which was with the liaison officers from England and France. Those who came to know Major

Dudley appreciated the spirit of the English. His keen knowledge, his quiet yet forceful manner, stimulated us to greater efforts.

Just at the close of the war, before all gas-mask work was transferred to the Edgewood Arsenal and these wonderful laboratories and factories closed, the latest type of mask, known as the 1919 Model, was designed and put into production. It has been described admirably in some detail in Fries and West's recent work "Chemical Warfare." It was capable of high-speed production; the face-piece was made of heavier rubber, so that the resistance to penetration of gases was much greater; the attachments and the head-bands were scientifically worked out to give the minimum tightness upon the head, with a maximum freedom from leaks at the temples; the eye-pieces contained triplex glass, so that danger from breakage injury was reduced to a minimum. The incoming air was thrown upward and over the eye-pieces, keeping them clear no matter how much the exertion or what the temperature, except in rare cases when the thermometer was below zero. The fitting of the mask in its knapsack was made more convenient than in any other type, with the result that the soldier could get the mask on his face more rapidly. The canister was literally a work of art as well as a science, for it filtered smoke and absorbed gas. All this progress led, therefore, to the shipment toward the end of the war, with troops who were going across, of the best and most protective mask that the world had seen.

Starting a mask production effort in May, 1917, Americans turned out, up to June 1, 1918, 1,719,424 respirators. Up to December 31, 1918, the total production had amounted to 5,692,499 respirators, of which there had been shipped overseas, up to the signing of the armistice, 3,938,808 completed masks. As to the quality of them, it is only necessary to say that they gave twenty times the protection afforded by the best German gas-mask. We protected our soldiers against the German poisons effectively, and Crowell and Wilson write: "No American soldier was ever gassed because of the failure of an American gas mask, and such casualties as did occur were due to the fact that the masks were not quickly enough utilized when gas was thrown over, or because the soldiers were unaware of the presence of gas. With such protection, there was no longer reason to fear that the frightfulness of chemical warfare would reduce Americans' morale."

In France, from February 1, 1916, to November 11, 1918, about thirty million M-2 masks were made; and the ARS, which is somewhat of the German type and which was manufactured in France beginning February, 1917, was made to the extent of about five million. In England, out of fifty million masks produced, nineteen million were box respirators. In the manufacture of Tissot masks there were 100,000 large models from the year 1916 to July, 1918, and 600,000 small models from April 1, 1917 to January, 1919. France supplied other powers with 3,240,000 units of protective equipment.

The World War became toward its close literally a chemical one. In July, 1918, the German Divisional Ammunition Dump contained 50 per cent. of gas shells; and in May, during the German preparation for attack on the Aisne, the artillery programs contained as much as 80 per cent. of gas shells for certain objectives. Chemical warfare really includes incendiaries, smokes, and gases. The aëroplane and the dirigible on both sides used incendiary bombs, as well as gas shells. Which is worse, to be suffocated by the smoke of burning buildings, or put out of action by phosgene or chloracetophenone? All war is painful and dangerous. We naturally think in terms of personal experience.

When chemistry becomes better understood, we shall be free from the idea of the mystery of it; and the pain and suffering from these numerous types of gas will be found, in point of fact, to be less than that from shrapnel and projectiles. The horrors of gas have been preached from press and pulpits. Yet facts do count; and when the Surgeon-General tells us that the man who was injured by gas alone on the field of battle has twelve times as many chances for recovery as the man wounded with bullets and high explosives, we must be impressed. Likewise, bullets, high explosives, and other methods of warfare than gas, were responsible for twenty-five times as many blinded men; and, in addition, the explosives caused losses of legs and arms to an extent that gas could not and did not do. Even tuberculosis was really less frequent among those gassed than among those who enlisted and were not gassed. It would seem apparent that the evidence is rather in favor of the humanity of gas warfare. This attitude is not the thoughtless one of propagandists; but it is really the cold, definite conclusion of technical men who have nothing to gain by making such statements other than the satisfaction of speaking truth to those who would read it.

General Fries well states: "As between the mask and poisonous gases, we have the old struggle of the battleship armor against the armor-piercing projectile. While the armor-piercing projectile has always had a little the better of the game, it is just the reverse with gases." Nevertheless, protection in the form of further development is a vital national need. New chemicals will continue to be made; it is easy to manufacture them secretly, test them, and get ready for any war which might come. Those of us who are in chemical industry are inclined to believe that all the treaties that may be signed will not eliminate danger from the gas attack. As long as the possibility of war continues, we shall have a problem of defense which should be met by research work on all defensive appliances. If gas-masks can be made having perfect resistance in the face-piece, a high degree of gas absorption in the canister, availability through ease of manufacture, comfort in inhalation and exhalation, and a glove-like, easy fit upon the head, that nation which can produce such protective appliances will at least, be in the strongest defensive position.

Research of this character is of vital importance to this country, and coöperation to that end should be sought; for the world's history shows that no weapon of offense has ever been discarded.

CHAPTER XX

BALLOONS

The captive balloon has been called the eye of the artillery. With this balloon five thousand feet in the air, swaying at the end of a long steel cable, the observer sat in his basket. He was truly, in the World War, the chief means by which fire from the camouflaged batteries came to be accurately placed. The World War was one based on mathematical science, for the barrage and the exact placement of shells were factors which, in no small degree, were responsible for the holding of the lines on the Western Front. No concealment was possible for this observer; he was held aloft by hydrogen retained in a rubberized fabric bag of peculiar design. His telephone wires, insulated by vulcanized rubber, went down through the center of the steel cable. Dependent he was, therefore, in more ways than one upon rubber for the success of his work. It was no easy job. Although he floated over a beautiful country, yet the landscape was not his to view, except in the particular spots where shells struck and burst. Many perils were his; the rapidly moving aëroplanes from the enemy's line were peculiarly enemies, for they were specially commissioned to hunt down captive balloons and set them on fire with incendiary bullets. The balloon was the target both of long-range guns and of aircraft.

It has been stated that the average life of a kite-balloon on an active sector of the Western Front was estimated to be about fifteen days. Some of them lived only a few minutes, and the War Department reports that only one American balloon passed unscathed during the whole period of American activity on a busy sector. It is interesting to the rubber man also to read the reports that show how five or six months of non-war service will deteriorate the balloon fabric; although there are many instances of useful service longer than this. A dangerous business is this ballooning, but a vital one. To the humble observation balloon goes much of the credit for the marvelous accuracy attained by artillery during the war.

Balloons have been known for many years. The Montgolfier brothers, Frenchmen, in November, 1782, made a paper-bag balloon. When filled with hot air, this was large enough and buoyant enough to permit them to send up a sheep, a rooster, and a duck.

I remember well how, as a boy, ballooning attracted me, after a visit of Captain Baldwin to the County Fair in the small town where I was brought up. I suppose most small boys have seen the balloon and the parachute-jump made by these early spectacular performers, who entertained the multitudes by ascending in spherical balloons and jumping from them. Then it was simple for us to study how balloons were made. With light-weight paper, scissors, and paste, it was easy to lay out the parts in the barn and to construct the panels and gores for making balloons larger than could be bought from the fireworks store. We sent them up with hot air generated from a wood fire, with a piece of tile as a chimney and a concentrator; and night after night, during the summer, when the air was clear, these little balloons have floated above the country, dropping parachutes with Japanese lanterns in them, scaring the timid with fear of fire, but stimulating in the soul of American youth that future love of the air which was to develop so rapidly and so successfully during the war. We but repeated in a small way the Montgolfier brothers' exploit.

A little later, after the brothers had performed their feat, two other Frenchmen, De Rozier and De Vilette, ascended to a height of three hundred feet and came down safely. From that day to our Civil War, ballooning remained a spectacle of the circus and a sport for the intrepid. But during the Civil War, balloons were used for observation to a limited extent. Later on, they were anchored by means of cables, for sightseeing purposes; and many is the person who, having gone up a few hundred feet in a spherical balloon swaying and tossing in the wind like a cork on rough water, became seasick and weary as the result of a rather harrowing experience. For observation purposes, this tossing about of the spherical balloon made its use uncertain; it was difficult to obtain exact data, because the observer was frightfully seasick.

What substances to employ to retain hydrogen in a balloon was ever a problem. Special varnishes made of linseed oil were used in the old days of circus balloons. The first "inflammable air" balloon made of silk was launched on the European continent by the Roberts brothers and J. A. C. Charles in the year 1783. G. J. Wright in 1803 suggested, however, strong cambric muslin, rinsed in drying oil or varnished with a solution of resin or gum lac with linseed oil. He found that the compositions for varnishing balloons had been variously modified, but, upon the whole, the most approved appeared to be the bird-lime of Faujas St. Fond. However, he wrote: "As the elastic gum known by the name of Indian rubber has been much extolled as a varnish, the following method of making it, as practiced by Mr. Blanchard, may not prove unacceptable: Dissolve elastic gum in five times its weight of rectified essential oil of turpentine, by keeping them some days together. Then pour one ounce of this solution in eight ounces of drying linseed oil for a few minutes; strain the solution and use it warm." He proposed that the parachute be constructed of varnished cambric muslin.

The first ones to deviate from the old spherical shape to something of the kite idea were the Germans, who made a balloon known as a *Drachen,* sixty-five feet long and twenty-seven feet in diameter. This *Drachen* had an open under-rudder which, filled with air, made the balloon somewhat more steady than without it. A series of tail cups, like little parachutes, served to prevent the balloon from bobbing and swaying too greatly. It was a long cylindrical object, with a series of ropes from a band around its equator carried down and concentrated at a ring. From this ring the cable ran down to the ground. The *Drachen* was, however, unstable in high winds. The likeness of the original

Drachen, with its various modifications, to a German sausage led to the adoption of the name "sausage" in slang expression.

Captain Caquot of the French army met the situation with a kite-balloon that had such superior stability in high winds, that it came rapidly into general use in the armies and navies of all the combatants. This new balloon, which has been known as the Caquot type of kite-balloon, was ninety-three feet long and twenty-eight feet in maximum diameter; as usually constructed, it had a capacity of 37,500 cubic feet of hydrogen.

The Caquot balloon, in principle, consists of an elongated, rubberized fabric envelope, larger at one end than at the other. The rubberized fabric is a layer of rubber between two layers of thin, cotton cloth capable of resisting the outflow of hydrogen. At the lee end, are stabilizers of much lighter rubberized fabric, connected in such a way that the wind blows into these stabilizers, filling them out and causing the balloon to soar up like a kite. Near the top, two of them, something like big wings, have the appearance of elephant-ears; and one acts as a sort of a vertical under-rudder. Even with these stabilizers the balloon would not be steady enough in the wind, if it were not for a rubberized fabric diaphragm which lies inside on the bottom of the balloon and is called a ballonet. The function of this ballonet is to give a space of variable volume, so that when the hydrogen in the balloon contracts because of variation in temperature occasioned by altitude the balloon may be kept taut. This tautness is accomplished by the inflow of air caught by a scoop on the under side of the envelope. The air flows into this ballonet space, raises it, and maintains sufficient pressure in the envelope to preserve its shape. Without the ballonet, the kite-balloon would become a shapeless and unmanageable mass of flapping fabric whenever the gas contracted. When the heat of the sun expands the gas, the hydrogen presses against the balloon, air passes out through the same scoop, and the envelope is kept taut. But if there is more expansion than the ballonet can accommodate, another important device comes into operation. This is the automatic gas-valve located in the top, near the front of the balloon, which operates at a determined pressure to let out hydrogen and thus always to maintain the pressure in the balloon at a constant value. By this combination of devices, there was made an instrument of war observation, permanent and stable in the wind. Its ability to ascend more than five thousand feet gives to the observer a wide range of vision. The basket cables are connected to the balloon by rigging; in the basket, which is made of light but strong wicker, are the observers with their instruments.

When the United States went into the war, our army and navy were virtually without observation balloons. The only company in this country that had systematically studied ballooning was the Goodyear Tire & Rubber Co. of Akron, Ohio. With remarkable foresight, the officials of that institution had for a number of years developed a balloon organization.

In the spring of 1910, with the aëroplane development under way, P. W. Litchfield, vice-president of the Goodyear company, looked into the future and saw great possibilities. He went to Europe in the summer of that year, made arrangements for a supply of the precise cotton fabric required, and in the autumn began the experimental manufacture of free balloons. The first airship attempt was the *Akron,* which was made to fly across the Atlantic, but which met with an untimely explosion in July, 1912.

The company continued to experiment with spherical balloons and had a considerable number of trained men engaged in their manufacture in 1917.

When the emergency came, all joined hands in whole-hearted coöperation: the signal corps of the army, the navy, the United States Rubber Co., the Firestone Tire & Rubber Co., the Connecticut Aircraft Co., the Knabenshue Manufacturing Co., the B. F. Goodrich Co., and the Goodyear Tire and Rubber Company.

Balloon fabric as used in kite-balloons was of three classes. The ballonet cloth weighed two ounces to the square yard; in it two plies were used with the threads parallel, and a thin layer of rubber was properly vulcanized between them. So fine was this cloth that there were 118 threads to the linear inch of warp and filling. The main fabric of the balloon consisted of two plies of fabric weighing two and one half ounces to the square yard, one of them placed upon the other on the bias, with three and one half ounces to the square yard of rubber known as the sandwich layer between them. This two-and-one-half-ounce cloth was so fine that there were 128 threads to the linear inch of width. After it was made up into fabric, a pull of sixty pounds on a one-inch strip was required to break it. It was a delicate, skilled, careful operation to make balloon cloth; only the finest of Sea Island cotton or the Sakellarides Egyptian cotton would answer. There could be no imperfections, for each little knot or each bit of dirt would mean a pinhole through which the hydrogen would leak.

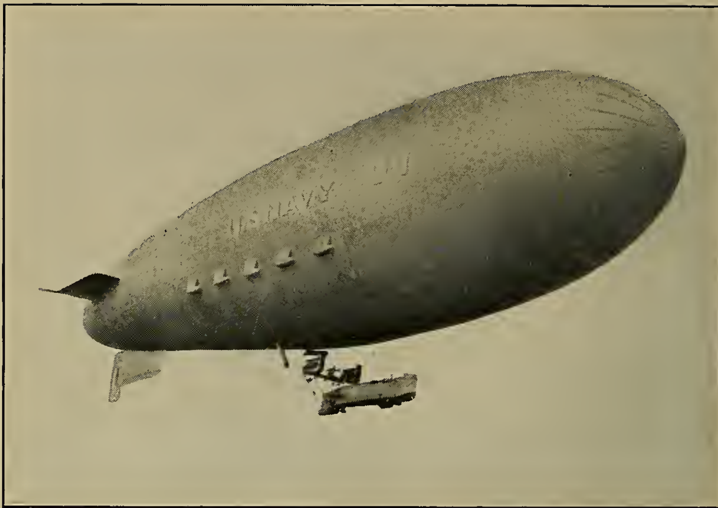
In the manufacture of rubberized balloon fabric, the raw cloth is first placed over a glass table illuminated from below, where it is observed for imperfections. This cloth is then coated with a thin layer of rubber cement. The rubber composition is one chosen after many experiments; each manufacturer has probably a slightly different idea, but all the compositions are subjected to sunlight tests and other rapid determinations of length of life. Only the purest, cleanest rubber of the highest grade is used, and very little of any type of compounding ingredients except those conducive to perfection, to resistance to diffusion, and to resistance to the action of light and heat. It requires as many as thirty-two thin layers of cement to build upon the fabric the thickness of rubber required.

After each layer of fabric has been spread and dried, one of the layers is cut into pieces on the bias and pressed upon the straight sheet with a thicker rubber layer between. Great skill is necessary in order so to lay on the rubber that the diffusion of hydrogen through it is a minimum. This doubled, long roll is then wrapped upon a drum and vulcanized.

The details of the manufacture of the envelope are those of a high degree of creative skill. Strips or gores of fabric run longitudinally, each of these gores being made up of panels in which the warp threads are perpendicular to the length of the gore. Seams between the adjacent panels are made by overlapping the fabric and carefully cementing the edges together. Since dirt is so great an enemy of rubber, in puncturing it, only skilled workmen, usually girls are permitted to work in the balloon-room; and they wear soft-soled slippers. Whenever balloons are handled on the floor of the great assembly-rooms, they are never dragged about on the cement floors, but are moved about on vacuum cleaned carpets of heavy canvas.

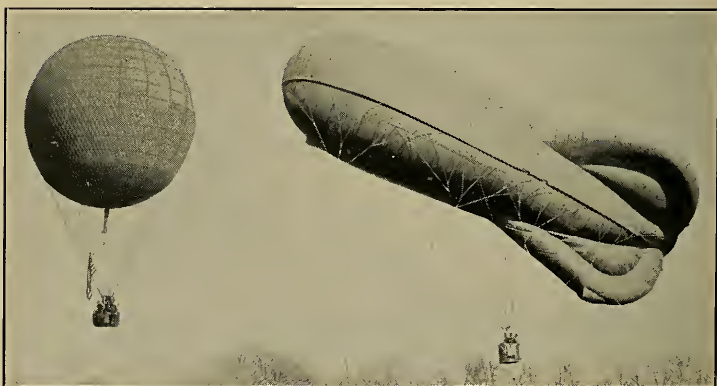
After this long and careful process of manufacture, our balloons during the war gradually were assembled. Special riggers applied the rigging of rope. Certain rubber compositions were used on the outside of the envelope, designed after careful study to protect the sandwich layer of rubber. The purpose of these compositions was to absorb the active or actinic rays of the sun, and also to keep out oxygen from the air. We generally adopted European standards of construction; but we developed our own rubber compounds, times of cure, and methods of manufacture. American fabric burned more slowly than European balloon fabric, and thus when the balloon was struck by hostile bullets it gave the men in the observation-baskets more time to get away in parachutes.

Small Caquot-type kite-balloons were used by the Navy Department for observation purposes on board ships in the spotting of submarines. There were also propaganda balloons. We find that up to the armistice the rubber companies and others in the United States produced 676 observation balloons for the



Courtesy Official Photograph, U. S. Army Air Service

UNITED STATES NAVY TYPE BLIMP DIRIGIBLE



Courtesy Official Photograph, U. S. Army Air Service

SPHERICAL BALLOON CAQUOT KITE BALLOON

army, of which 481 were shipped overseas, and that they made 129 supply balloons and 215 propaganda balloons.

But these kites were not the only aircraft in which rubber was used. For while fewer in number, dirigibles were better known to the public. These were made for the Navy Department. The Bureau of Construction and Repair had been studying dirigible construction; and in February, 1917, the Secretary of the Navy was ordered to proceed with the construction of sixteen such air-ships.

The B-type dirigibles were 160 feet long and of 85,000 cubic feet capacity. Equipped with one one-hundred-horse-power motor, they were capable of making a speed of forty-five miles an hour, with an endurance of about sixteen hours. A larger ship known as the C-type, was 192 feet long, with a gas capacity of 190,000 cubic feet. This air-ship had a possible speed of sixty miles an hour and an endurance of forty-seven hours. It was one of this type that flew in 1919 from Montauk to Newfoundland, with the expectation that it would take part in a transatlantic flight. But unhappily, in a high wind it broke loose from its mooring and was blown out to sea. This accident constitutes one of the many tragedies connected with aircraft.

In making the rubberized fabric for the air-ship of the non-rigid type, the same principles that have already been described in the discussion of kite-balloons were used. The same care in the manufacture of this cloth was maintained. The envelope was stronger because made of two plies of heavier cloth.

Because of the smallness of its size, its comparatively low cost, and the ease with which the envelope can be erected or deflated for shipment, there are great advantages in the non-rigid type of air-ship. Its most serious disadvantage lies in its dependence upon careful control of gas pressure within narrow limits. If the pressure rises too high, the envelope may burst, although ample valves of a proper design limit this risk. It is, however, equally fatal for a loss of pressure to permit the envelope to lose its shape, because nothing is quite so dangerous as a sagging envelope.

All the steering-equipment, rudders, fins, and the car are slung upon the outside of this envelope by wire or manila rope through cemented-on patches. During a wind the stresses in a sagging envelope may therefore be enough to tear this light thin cloth; with tearing of the cloth, comes destruction of the balloon.

Consequently the problems in dirigible construction, and we may say in all types of balloon construction, lie largely in having the strongest and lightest fabric; one of sufficient strength so that when reasonably well designed the application of sudden and irregular loads upon any of the attachments cannot tear the cloth. The fabric must be permanent in the sunlight. Resistance to the diffusion of hydrogen is an important problem in practical operation. While it is always required that this be kept at a minimum, when one considers the losses of hydrogen from the operation of valves in the expansion of the gas on ascending into the sun, it is safe to say that losses by diffusion are minor factors.

The so-called semi-rigid air-ship also has an envelope of rubberized fabric. A girder keel gives it stiffness and renders it less dependent on gas pressure for the maintenance of shape. Here a lower gas pressure and hence a lighter weight of fabric is permissible than in the non-rigid air-ship. The bending forces are so distributed that the keel takes compression while the fabric receives a moderate tension. Therefore, it is possible to give the semi-rigid ship an exceptionally light construction, and so to permit a relatively greater useful load to be carried to a higher altitude than with other types of equal size. With the exception of the keel in the envelope, small, semi-rigid air-ships resemble non-rigids in their general features. They are more costly and less easy to erect.

The most spectacular type used during the war was the rigid air-ship of the Zeppelin type, which employed very little rubber in its construction. Probably it is the largest and most complex of all known types of aircraft—largest in carrying capacity, highest in speed, most intricate in the structure of its duraluminum girders and wire. Triangular-shaped girders make up its backbone. On the outside a ply of cloth is tightly drawn around the girders and coated with aluminum, water-tight "dope." Inside the girders, within the hull structure, are arranged separate gas-bags, usually made of a single ply of light cotton cloth lined with a thin layer of so-called "goldbeater's skin," to give gas tightness. Goldbeater's skin is made from the entrails of cattle; it is a thin membrane almost perfectly gas-tight and very light.

Since air-ships have a promising future, there is a large opportunity for development work in the scientific construction of fabrics to permit very much greater resistance to tearing, with no increase in weight. The rate of deterioration of rubber in the sunlight through oxidation is one of the important problems, but one which, I believe, has been largely solved. Rubber fabric, though, should be applied in greater degree to these aircraft. When the problems of construction, explosion, permanence, and strength of fabric are more nearly solved, the great future of the air-ship will be more completely realized.

The time will surely come when air-ships of enormous size, capable of remaining in the air even if an engine stops, will run between London and New York or across the continent. Then the business man will be able to go from New York to London in forty-eight hours. Since speed in business has come to be so necessary, it seems not unlikely that the demand of the future will require a minimum of time in long-distance transportation; probably this high speed most certainly and safely can be attained through lighter-than-air craft.

CHAPTER XXI

THE FUTURE OF RUBBER

A laudable future for any industry, man, article, or substance can be achieved only because of service rendered to mankind. "For whosoever hath, to him shall be given, and he shall have abundance; but whosoever hath not, from him shall be taken away even that which he hath." This fundamental truth forms a basis for prediction. It is idle for one to dream when dreams but express wishes. It is useless to predict, when predictions formulate only hopes. One can, however, forecast possibilities of growth based upon natural properties of usefulness. "Whosoever hath" means characteristics, physical in the case of rubber, mental and moral in the case of an individual man, a company, a corporation, or an industry. Rubber and rubber companies, we believe, can become greater in a commercial sense only if the qualities of rubber are superior and if they render valuable service to those who would use their products.

Does rubber have properties natural to it which, when expressed in the form of articles made and used, will probably increase the extent of its service? The question is its own answer. There is no substance, and essentially every one known has been tried, to take the place of rubber. Rubber serves, and serves remarkably. If the pages which I have thus far written have accomplished their purpose, they indicate certain fundamental characteristics by which rubber is distinct from any other known material; and they show that rubber has worked itself into life economy by virtue of the fact that it performs definite, valuable functions, not artificially stimulated but naturally possessed and given. Some phases of these characteristics may be reviewed from a different point of view.

Although food, shelter, and clothing are the three necessities for our physical welfare, the relations with our fellow-men give us happiness, and these relations are modified greatly by means of communication and transportation. We have already spoken of the telephone and the telegraph, with their rubber parts, by which wire communication is maintained.

The good fellowship among men is in no small way engendered by freedom of intercourse over wires. There are millions of intelligent human beings on our earth to whom the telephone has not come—a vast field for expansion with boundless possibilities for service. The telephone will span the sea. Distant people will talk to each other. When persons all over the world can understand each other and can freely and rapidly communicate, then, and not till then, will wars cease and peace on earth be a reality.

Communication without wires is a new development which has come along so rapidly in the last few years that it bids fair to extend to almost unlimited possibilities. Since the uses to which radio can be put are diversified, it is certain to bring about changes in life's every-day affairs. It will, through finely developed broadcasting stations, serve to bring in to homes, news, communications, entertainments, and education of wonderful value. For communication from ship to ship or from shore to shore and between aëroplanes in the air, for making ships safe on ocean and lake when in heavy fogs, for out-of-the-way places where wire installation would be expensive and impracticable, wireless constitutes, in addition to the conveying of regular commercial messages, a development of vast importance.

What part will rubber play in wireless communication of the future? It plays a part to-day; for, of all the substances thus far known, rubber is the one which for wires possesses the greatest flexibility and insulating properties, and which in the form of hard rubber has greater dielectric capacity than any other substance, with less dielectric loss. The use of hard rubber and other rubber products in connection with radio has every possibility of increased use.

Regardless, however, of both wire and wireless communications, we still do and doubtless always shall reduce our ideas to writing. The permanent record of business intercourse, the printing of books and newspapers, lie in the field of communication which has been developed to a great degree already, but which has possibilities for further growth. We have spoken already of the typewriter. I wonder whether more parts of it will not ultimately be made of rubber,—a construction reducing the noise to a degree approaching silence? Perhaps some enterprising inventor will study the voice-waves, so that a telephone typewriter will be worked out, permitting the direct transfer of the voice to letters on paper. To wonder whether rubber will play a part in such an enterprise, is, I suppose, to dream.

In the printing of books and newspapers, the last few years have witnessed changes produced by the use of the rubber ink-spreading rolls, which have given marked efficiency and improvement. Despite the fact that oils are used for inking purposes, rubber has been found to resist them relatively well, to withstand in these rolls the change of climate, and to give a marked superiority to the permanence of operation of printing-presses. When, however, in connection with rubber ink-spreading rolls, the water-ink, which is a development of recent growth, comes to be generally used, all phases of the printing industry will economize time and money and gain higher speed. This development of considerable value will have been made possible by rubber and rubber rolls.

Because supplies of wood for wood pulp are rapidly decreasing, materials must be found to serve in the manufacture of paper. We shall be able to grow, without doubt, a sufficient quantity of cellulose; if, though, it fails to have the properties which wood pulp possesses to-day, it may be necessary to follow out the suggestions recently made of using rubber in connection with it. By virtue of its adhesiveness, rubber may give us book and news-print paper of greater value than we now have. Something is certain to be done, for the need is here and will become more and more marked with time.

But it is in the field of transportation that rubber will continue to extend its usefulness. Whatever may be your definition of the word "civilization", one thing is true: the difference between human life as we live it and the lives lived by our forefathers back over the centuries lies in the means that have been used to overcome elemental conditions. Civilization, be it moral or physical, is marked by a development of human facilities. To use and enjoy them, men and goods must be moved from place to place. Thus transportation holds the key to the world's progress; and "the history of the highway by land and sea is the history of civilization and the mark of the progress of man."

We have but to compare travel upon the continent in the days of the old French *diligence* to realize how completely our lives have altered in a short span of years because of improved transportation facilities. In an interesting volume on "Travel in the Last Two Centuries of Three Generations" by S. R. Roget, he describes a trip taken in 1818 in the United States. He says that Dr. P. M. Roget on May 18 of that year left Philadelphia and arrived the same night at Elizabethtown, eighteen miles west of Lancaster, and again on May 29 he passed through Harrisburg to Chambersburg. He remarks that from Harrisburg the roads were very bad. The bridges were constructed of wood, except the piers, which were of stone, and were covered by wooden roofs. "The roads, instead of winding round the mountains, are carried almost straight across them, and appear to have had very little more labor bestowed upon them at any time than that of clearing away the timber which grew upon them." The difficulties of transportation described in the anecdotes of this interesting volume leave no doubt in our minds that our modern life could not be lived without the railroads or without improved highways. Thus, our human progress has been built upon the free movement of goods and of men. Just as England has been made great by the use of the ocean as a highway, so the United States has in the short space of a hundred years been made great by her rail transportation, the most advanced and complete the world has ever seen.

Rubber, just as certainly as steel, has aided the development of the railroads, the signaling system, the ocean ships, and many other fundamental things that have made transportation changes possible. In various ways unsung it plays a great and vital part.

During recent years, however, we have watched the growth of a new form of transportation—that of the trackless car, the motor-car, the truck. Here, in a most spectacular way, the rubber tire and various other rubber parts have come to be vital. In the future, the development of the improved highway, be it the macadamized road or the cement or brick pavement, will surely play an increasingly important part in transportation. The railroads ever will be the main arteries upon which tonnage and speed can be maintained, but the highway more and more will become the feeder. In our cities the trolley-car conveys us from place to place. The motor-bus is the trackless street-car of the future. It is economical, convenient, quiet, and subject to a degree of flexibility not possessed by the electric tram. No dream is necessary to look forward to cities in which motor-buses will be the predominant means of human conveyance. So far as goods are concerned, with the railroad it is necessary to load them at a factory, haul them to a station, unload them in a car, unload them again at a distant terminus, load them into a van, haul them to the consumer, and unload them again. The motor-truck, contrariwise, permits one loading and one unloading, a saving in energy and time.

A vast extension in the use of the motor-car is a logical forecast, and with it an expansion of the rubber industry. In 1896 there were but four gasolene automobiles in the United States; in 1916 there were 3,500,000; and at the beginning of 1922 there were nearly 10,500,000—one car for every ten people. There are about 3,000,000 motor-cars on the farms, that is to say, the farmers own about one third of the motor-cars; while in the cities of 500,000 or over there are only 9 per cent. of this total registration. There are in America 24,351,676 homes. It is hardly possible that in the future there will be one car for every home, but there are more than 6,750,000 farm homes from which motor-cars might serve well to carry food to city centers. Eventually farmers will insist upon further improved highways, and demand the same facilities for communication with their fellows that are afforded to others. So far as the ability of the people of this country to purchase motor-cars is concerned, it is quite probable that a registration of 15,000,000 passenger and commercial cars within the next five or six years will be realized.

These figures refer only to the United States, which has 6 per cent. of the population of the world, 7 per cent. of the land, and 83 per cent. of the motor vehicles. In the great continents of Asia, Africa, and South

America, as well as Europe, the registration of motor-cars has not approximated that in America. Great Britain and Ireland, for instance, afford only an average of one car for every 95 people; while China, on the other hand, has one for every 54,708 persons. The wealth of many countries is sufficient to afford motor-cars to carry food products from farm to consumer. It seems reasonable to suppose that the countries where highway development has proceeded most rapidly will be first to demand and obtain sufficient motor-cars. Thus, the countries of Europe will, in all probability, rapidly acquire them. In the other countries, however, the spread of the motor-car will depend upon highway development. With this development will come exchange of commodities and personal relations that will lead to increase in the national wealth and ability to purchase motor-cars. As a consequence, the need for rubber goods of all descriptions will grow manifold.

Let us see what these possibilities mean to the future production of tires in the United States. The world registration of cars at the beginning of 1922 was 12,528,000, an increase of 1,606,000 over that of the previous year. In the United States the increase will probably not continue at that rate; but, on the other hand, elsewhere a higher rate will no doubt be attained. Assuming the world to add 1,606,000 automobiles and trucks each year for six years, there would be at the beginning of 1928, 22,164,000 cars, a total increase of 75 per cent., a change not only possible but highly probable. At the rate of three tires per car per year, the rubber industry of the world would supply more than 66,000,000 tires to the consumers in that year. They will be cord tires for passenger-cars, with a marked increase in the use of the solid tire on the bus and the truck. Including inner tubes, we assume a weight of fifteen pounds of crude rubber to the tire. For transportation purposes, therefore, we are justified in a prediction of a use for tires alone of 990,000,000 pounds or 440,000 long tons of raw rubber in 1928. The productive capacity for tires in America to-day is probably not far from 44,500,000 yearly, and that of all other countries, 10,500,000, or a total of 55,000,000. The world will need to increase its capacity before 1928 by 11,000,000 tires a year to care for the demand.

In transportation in the sky rubber has played and will continue to play a most vital part. The dirigible has come to stay; the fatal accidents that have startled us during the last few years serve but to indicate how we have attempted to run ahead of demonstrated experience. Rubber in the making of balloons to hold hydrogen or helium has proved itself valuable and will prove itself more so. The business man, with his contract to be signed, will fly from his office to the transatlantic dirigible field, where the great three or four-million-cubic-foot aircraft will be moored. He will ascend in the elevator inside a mooring mast and walk into his cabin as readily as he now does into the state-room of the ocean liner. When all is ready the dirigible will move rapidly and safely, avoiding the storms and the high winds by her ability to rise above them or fly below them. Within the space of a day the business man will find himself landed upon the other side of the water as safely as he now could in five days on board ship.

This change is surely no greater than the change in ocean transportation over the last two decades. With non-combustible helium as the gas, with an oil engine rather than a gasolene one to furnish the motive-power, and with rubber to hold the helium, the fire risk will be brought down to a minimum. The only force to be avoided will be the wind, which for these new dirigibles will be, if anything, of less moment than on board ship; the advantage will lie with the aircraft in its capability of dodging the storm. Certainly there can be no danger from collision, for the radio will serve to locate promptly both direction and distance and the presence of any other aircraft in the same range. Will the supply of helium be found? Yes. For modern chemistry is demonstrating decomposition of the older elements into their simpler ones, and helium is one of the simpler ones.

Other rubber goods will be required. The people beyond the seas will need rubber footwear, as do we. Homes will use increasing quantities of rubber. Mines, mills, and railroads are enlarging everywhere, requiring increased amounts of rubber. Sports, too, are spreading. All the world develops slowly along the same lines. New uses for rubber will arise, not the least of which will be the employment of rubber in building construction. It is no idle prediction which one reads in the reports of the United States Forest Service that the supply of timber in this country is year by year growing smaller. The tremendous waste that has occurred in lumber and the fact that trees take so long to grow, give to the future of building construction a real problem. The time will come when we must grow our own structural materials or dig them out of the ground. Then we shall build our houses of cement or rock or grow them. Perhaps we may construct them of hard rubber. Some day we shall discover how to produce more esthetic colors in rubber compositions; then rubber may replace wood for structural purposes.

About 70 per cent. of the rubber consumed has been in tires. If we consider tires to consume even 80 per cent., the total demand for raw rubber in 1928 will be 550,000 long tons.

Yet a serious question confronts us: can there be produced in the world crude rubber enough to supply this tremendous demand? There were planted in the Far East, at the end of December, 1921, a matter of 3,321,000 acres. This was in British Malaya, the Dutch East Indies, Ceylon, South India, British North Borneo, French Indo-China, Burma, and other countries. Still the area in square miles of the Dutch East Indies is 735,000; of the Federated Malay States, 27,506; of the Island of Ceylon, 25,332. We neglect here, too, any consideration of the enormous areas in South America and Africa that are yet jungle and where rubber-trees may be planted and grown, provided man will be enterprising enough to go into those territories, open them up, and provide means of transportation and labor. The question seems to be one of cultivation of virgin land for raw rubber production.

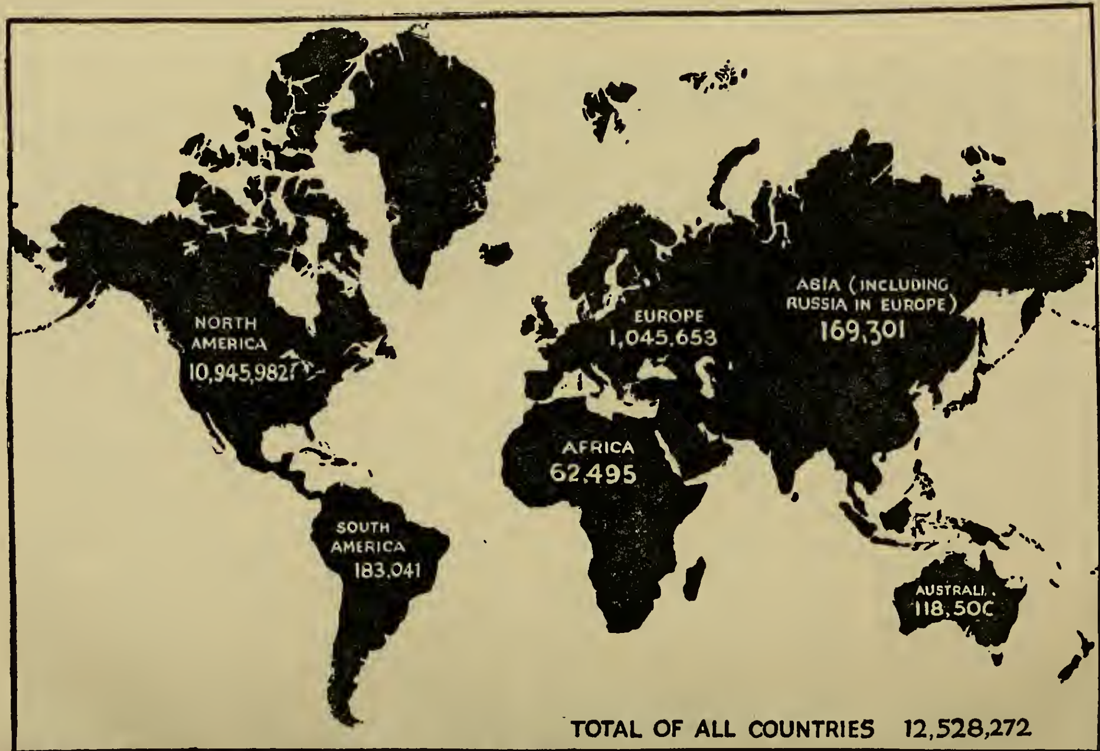
We have, therefore, only scratched the surface of the possibilities of rubber production. Each of these countries, to be sure, contains many areas that are not capable of growing rubber-trees; but I believe it safe to predict that were the world-demand sufficient, there could be a hundred times greater production than even the anticipated figures indicate, and at costs of production sufficient to maintain a relatively low market, with profit to the producer and economy for the consumer.

One of the incidents of the future will be the disappearance of wild rubber. Cultivated rubber has succeeded because of the suitability of soil, the supply of food and labor, and the enterprise of governments and individuals in the development of plantations and transportation. Trees are trained to yield larger returns; coagulation has become a simple process. There is no element of rubber cultivation that cannot be repeated by plantations in any part of the world where rubber trees can grow.

Yet with all this development of the use of rubber and rubber goods, may not the future be limited by a shortage of power? Oil, to be sure, is essential to the operation of a motor-car, coal is needed to run factories, and electricity is required to light them. The geologists tell us that the coal supplies are running out, that the supply of oil is limited. However, there are many unexplored lands where oil may yet be found. So far as a liquid motor fuel is concerned, there can be grown all over the world, wherever crops are possible, plants that yield large quantities of cellulose, from which pure alcohol can be made. Alcohol, by proper adaptation of carburetors, can be made to burn efficiently in a motor-car. Perhaps rubber may yet furnish fuel to motor-cars. It can now, by proper treatment, be converted into combustible oil. As far as coal for heat and power is concerned, so long as the heavens give forth rain, there will be rivers; so long as there are rivers, they will run down mountains, and in so doing give sources of white coal or hydraulic power, which can be changed into electricity and carried over long distances. No; I doubt if there is any possibility of the shortage of power, heat, or light.

But the other raw materials—sulphur, zinc oxide, black, and the other products used in rubber compounds—will they last? Sulphur occurs in so many forms that, so long as the world stands, there will be plenty of it for every purpose desired. Zinc oxide is more of a problem; its present sources are just enough limited to warrant a bit of thought. But yet, in conjunction with lead, it is widely distributed in huge quantities; and chemists can separate the lead, freeing the zinc oxide needed for rubber. Carbon-black, however, made from natural gas, is one of the substances that some time during the future will disappear. Chemists will be ready to replace it with pigments, equally serviceable substances for use in rubber goods. The field from which to draw mineral powders is too vast to cause any concern, were several of the well-known ones to be exhausted.

Cotton constitutes a problem of considerable moment to the rubber industry, because of the operation of the boll-weevil. How rubber men would welcome the elimination of that pest! The boll-weevil is a most active little insect and one whose destruction requires



(Data from National Automobile Chamber of Commerce)

MAP OF THE WORLD TO SHOW REGISTRATION OF MOTOR CARS, IN THE USE OF WHICH 75% OF THE CRUDE RUBBER the coöperation of chemists in finding poisons which, when applied to the ground or other places during his hibernation periods, will kill him. If the boll-weevil is not definitely restricted, then the predictions of the Department of Agriculture may unfortunately be realized, for one of the investigators says: "To-day I predict that unless something be done that will definitely and speedily stop the crime of early planting, the entire cotton growing industry in the United States south of the thirty-second degree of latitude will within the next ten or fifteen years be completely wiped out of existence. And that within the next thirty years the great cotton industry of the United States, formerly considered almost like a monopoly which, from a world production standpoint, has already been reduced by early planting from 67.9 per cent. in 1905 to 56.7 per cent. in 1915, will have to take a back seat to that of British India." Cotton, therefore, is menaced, but can be saved. Perhaps rubber milk sprayed upon the hibernation homes of the weevil might entangle him and hinder his growth.

The research laboratories in the great factories employ chemists, physicists, and engineers whose business it is to create processes and products. New uses for rubber are constantly finding their way into the markets. The dreams of to-day become the realities of to-morrow; possibly, often not in the same form in which they were originally dreamed, but nevertheless the dream made the suggestion. This intense activity will result in articles of increased value and service to the consumer. Rubber is a substance, which, in its ramifications extended by the forces of investigation, will certainly serve humanity in many more forms than it does to-day.

THE END

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