TREES AND TEST TUBES

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TREES AND TEST TUBES

Charles Morrow Wilson

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THE STORY OF RUBBER

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TO

CARL VAN HORN WILSON

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FOREWORD

In all the years before Pearl Harbor there had never been the slightest doubt as to the permanence of our supply of rubber. Only once had we been even remotely conscious of what a scarcity might mean: that was during World War I, when transportation difficulties due to submarine warfare at one time sent the price of crude rubber skyrocketing to $1.25 a pound. Then with the suddenness of a thunderclap, came the news that not only did a serious shortage exist, but the chief source of the world's rubber supply had been indefinitely cut off by Japan's conquest of Malaya and the Dutch East Indies. Though rubber may continue to reach us in minor amounts from Brazil, Central America, and Liberia, and though rubber-bearing shrubs may help us out in certain fields, it is a virtual certainty that no more natural rubber will be available for civilian use for the duration of the war, and probably long after it. For it must be remembered that even when Malaya and the Dutch East Indies are retaken, most of the rubber plantations will have been destroyed. And it takes up to twelve years to bring a rubber tree to maturity. We are even beginning to understand that our domestic rubber problem is only part of a world crisis which promises to have enormous effect on the future peace as well as the immediate war.

The very abruptness of the crisis has opened the eyes of the American people to the importance of this unique substance which they have been abrading away at sixty miles an hour with great unconcern. It has also prompted them to ask a number of pointed questions as to how this dangerous state of affairs came about, and what is going to be done about it. They wish to know why, if Brazil is the home of the best rubber, it was not developed there instead of on the other side of the world; why some other natural substance that is readily available cannot be substituted for it; and—above all—why there has been so much bickering and squabbling about synthetic rubber.

It is no wonder they are confused and worried by the avalanche of conflicting information that has been loosed upon them for many months. One self-constituted authority publicly asserted that ten million tons of scrap rubber were available in this country; subsequently an intensive collection drive brought to light less than half a million tons. Another source announced that over a million tons of synthetics will be made yearly by 1944; a third estimated our 1942 production at less than fifty thousand tons, and predicted hopefully that with good luck there would be enough available by 1945 to permit its limited use in civilian tires. The Baruch Report * is one stride forward in straightening out some of this confusion; but it does not go far enough into the background of the situation to satisfy public curiosity or entirely alleviate its apprehensions.

This book hopes to survey the rubber situation in a realistic, practical way. In the course of that survey it will acquaint the reader with the Amazon jungles and the Far Eastern islands, and with the economic, political, and physical aspects of rubber cultivation; it will describe the work of the pioneers of the modern rubber industry—especially Charles Goodyear, who was so inordinately devoted to rubber that he made himself a suit of clothes out of it. The extent to which our civilization has become dependent on rubber will be discussed, and the outlines of the development of synthetic rubbers will be traced.

One characteristic of rubber distinguishes it from most other substances and makes it an indispensable and unique commodity. Rubber displays an astonishing degree of passive resistance; it is the only natural substance that permits itself to be pushed around, buffeted, mauled, stretched, and pummeled with the utmost indifference. But, though easily imposed upon, it is capable of asserting itself vigorously, as anyone knows who has suddenly let go of a taut elastic band. Rubber's marvelous capacity to "take it" is due to its ability to absorb a blow—and then toss it back vehemently. Therein lies its usefulness to man. Many other substances, such as steel, cotton, and glass, stretch slightly without breaking, if enough force is applied, and can stand a good deal of rough handling before they wear out or disintegrate. Only rubber is able to stretch tremendously

* See appendix at end of volume.

and regain approximately its original form afterward. Because it retracts as well as stretches, it is described by that misunderstood word "elastic."

The importance of this distinctive property of elasticity could be illustrated by any number of examples, but one or two will do. Suppose you are driving happily along at the modern speed of 35 miles an hour. Suddenly that perennially careless "other fellow" darts out of a side road directly in your way. Down go the brakes; the tires screech on the pavement—and behind you in two parallel black lines stretch 300 miles of tire wear. Only rubber could withstand such a frightful scouring and still be of any use in stopping the car. Your rear tires look perfectly normal, but a slow-motion camera would reveal that while the sliding was going on both were badly distorted at the point where they touched the road. A microscope would have shown the tiny fibers of rubber hugging the road, and at the same time clinging together so viciously that only a comparative few were torn away. The instant the strain was released, the tires resumed their usual shape, and the fibers meshed together again.

Much the same thing happens—only more so—when an airplane traveling at a hundred miles an hour touches the ground: the tires are suddenly required to turn at terrific speed on a split second's notice. Grinding, shearing, tearing, and scratching all go on simultaneously. Rubber can absorb this punishment only because it first yields, and then insists on recovering itself. The action of balls, shock absorbers, hose of all kinds, and most of the rubber articles with which we are familiar in daily life is due to this fortunate attribute, known as elasticity, resiliency, or just plain bounce.

But just as cotton gets "tired" of being washed and steel of sustaining tremendous weights and strains, so rubber eventually becomes fatigued and will bounce less and less enthusiastically, until it becomes useless. When a rubber band snaps back, it does not assume *exactly* its original length, but retains a microscopic fraction of its extended length. The longer the stretching and releasing go on, the greater becomes the so-called "permanent set." In other words, the rubber gets tired. This fatigue effect becomes important when an automobile tire is driven underinflated. With every turn of the wheel, the side walls bend outward and retract; if the car is patriotically traveling at 35 miles an hour, this happens at any given point no less than 350 times a minute! This *loss* of resiliency with every deformation—no matter what causes it—is one of the chief reasons why rubber articles wear out; the technical name for it is *hysteresis,* a word derived from the Greek, meaning "to lag behind."

Rubber can also deteriorate without being used at all. The oxygen in the air is one of its most deadly enemies. Molecules of oxygen insinuate themselves between the carbon molecules which form the "backbone" of rubber in such a way as to weaken the bonds that hold the structure together. Just as the chief duty of the oxygen we breathe is to burn our food to produce energy, so this combination of oxygen with rubber is actually a very slow combustion process, which goes on continually until the article turns into a hard, useless mass. Fortunately, ways have been found to reduce the speed at which this oxidation takes place. Small quantities of substances with awe-inspiring names are added to the rubber before it is made into finished products. Without them, no piece of rubber would be much good two or three years after its date of manufacture; but because of their ability to retard the oxidation process, rubber can now be made to give satisfactory service for twenty years or more.

Such are some of the virtues and weaknesses of natural rubber. The virtues are much more important than the defects, and though some of the synthetic rubbers are superior to natural rubber in one respect or another, none of them behaves exactly like it in every way. In spite of all the hullabaloo about the wonders of synthetic rubber, the fact is that if a dependable, permanent supply of natural crude could be assured, our present crisis would be infinitely less acute. Just how improbable such a solution is at the moment can best be realized by going back to the Amazon jungles, where natural rubber as a world commodity began, and recounting the story of what happened there and why it will be a long, long time before Amazonian rubber can come to our rescue.

C. M. W.

New York, 1943.

TREES AND TEST TUBES

RUBBER IS VEGETABLE

I

THE story of rubber began in the jungle wilderness of the Amazon Basin. For the past thirty years, more than 95 per cent of the world's rubber supply has come from a tree known botanically as *Hevea brasiliensis*. As the name indicates, it was originally native to Brazil, and is still especially plentiful in the lower reaches of the Amazon Valley, where it grows wild. About seventy years ago the tree was successfully transplanted into the Far East, where for years it has been cultivated scientifically by the British and Dutch on huge plantations located chiefly in Malaya, Sumatra, and Java. Actually, Hevea can be grown in almost *any* tropical country where rainfall is sufficient. United States Department of Agriculture studies indicate that conditions for its growth are satisfactory not alone in Brazil but throughout the American tropics—that is, from Mexico south to Bolivia. Indeed, seedling experiments have recently been started in the extreme southern part of Florida.

The Hevea tree demands an extremely hot and humid climate. For this reason the Amazon Basin is ideally suited to it. With the possible exception of the polar icecaps, this region is one of the wildest, least frequented, and altogether most disagreeable regions on the face of the earth. The Amazon, the largest river in the world, is from 100 to 150 miles wide at its mouth, depending on whether the season is dry or rainy. For hundreds of miles it flows between almost solid walls of trees, heavy with foliage, and made almost impenetrable by densely matted underbrush through which no man can proceed without slashing his way with a machete. The river and its banks—which are often inundated for miles during the rainy season—are infested with alligators, and the jungle literally swarms with wildlife of all kinds, from stinging insects to boa constrictors. Everywhere is the luxuriant vegetation characteristic of the tropics, with brilliantly colored flowers and mosaics of mosses and ferns. Everywhere, too, is heat—a heavy, humid heat that rises steaming from the forest floor and clamps down sickeningly from above. The daytime temperatures average 90 degrees or over, and nights are seldom cooler than 70 degrees; the relative humidity is always high. The rainfall is about 100 inches a year, compared with an average of about 44 inches for New York City. Most of it comes in the six months' rainy season, when it streams down endlessly as if from millions of open faucets, flooding the low-lying riverbanks and making the jungle reek of moisture.

Hevea is a big tree. Frequently it grows to a height of from 80 to 100 feet with a trunk girth as great as 7 feet. The leaves are trifoliate—three-part, dark green, and lustrous. With good care and suitable location the tree's useful life is fifty years or more. It is propagated from seed, and comes to productive age in from five to twelve years after planting.

The flowers are tiny and pale yellowish green; the fruit is a capsule which contains three smooth brown seeds, splotched with black. These seeds, though comparatively fertile at maturity, quickly lose their vitality and must therefore be stored and transported with extreme care. The kernels are oily; indeed, nearly half their weight is made up of an oil resembling linseed and usable for much the same purposes. (Since the seeds are plentiful, any widespread development of Hevea culture promises a new source of vegetable oil.)

Native stands of Hevea intermittently cover more than a million square miles of Brazil, and follow the Amazon tributaries into the neighboring valley lands of Bolivia, Venezuela, Guiana, and Peru. Though the trees are widely scattered—rarely more than two or three trees to the acre of forest or jungle, and sometimes miles apart—the total stand of wild Hevea in Latin America today is estimated at around 300,000,000 trees. Unfortunately, the total of cultivated Hevea trees now growing in this hemisphere probably does not exceed one-half of one per cent of the native wild growth.

It is a safe guess that tens of millions of the wild-growing Hevea trees of this hemisphere have never been tapped; probably other tens of millions have never been definitely located. Brazilian authorities believe that recovery of latex from wild Hevea trees can be increased immediately to 25,000 long tons per year, and eventually to four or five times that amount. Complete harvest of all forest Hevea in this hemisphere might total 400,000 long tons, or half our probable rubber requirements; but complete harvest, as we shall see, is impossible.

Since it was first introduced into world trade, about 1826, in terms of actual rubber supplies, Hevea has been the single major source of all vegetable rubber. The tree is a satisfactory and productive orchard crop, more easily propagated and harvested than most others. Once it is of "tapping size," the harvest is almost perpetual, since the latex can be drained on an average of every second day, weather allowing, throughout the year. Sometimes trees require a vacation from milk-giving; but except for this, harvest is perennial, slackening only during excessively rainy seasons, when men cannot work in the groves or jungles.

Rubber latex is a milklike fluid containing from 30 to 40 per cent of solids in the form of particles of rubber too small to be seen even in an ultramicroscope; by contrast, cow's milk contains only 12 per cent of solids, mostly fat globules covered with casein. If a small amount of any acid, even vinegar, is added to latex, the globules of rubber unite to form a soft, doughy mass which can be rolled into sheet form. When the "coagulum" dries, it has become an elastic solid—crude rubber. The term "milk" is exceptionally fitting, although latex is of course very different from cow's milk. In fact, drinking latex would almost certainly cause death, as the acid digestive fluids of the stomach would cause it to coagulate into a ball of soft rubber. But, like milk, it is composed of solids suspended in a liquid, and separates, on standing, into an upper layer, which resembles cream, and a lower, more watery layer, analogous to skim milk.

Hevea latex differs markedly from the sap of an ordinary tree. It does not appear to be necessary to, or directly connected with, the tree's nutrition. Its true biological function remains at least partly a mystery. Most latex is secreted from sacs located between the outer bark and the wood, though sometimes it is also secreted from the leaves and roots.

In Hevea and other rubber-bearing trees the latex is best removed by making incisions in the bark, through which it can be drained into convenient receptacles. With exceptionally good growing conditions Hevea may be tapped within five years after seeding. At this age the yields are comparatively small, usually less than two pounds a year per tree; but with skillful harvest and healthy planting stock the yields increase steadily, until when the trees are ten years old, annual yields frequently reach 1,000 or even 1,500 pounds of crude rubber (not latex) per acre of selected planting. With excellent planting stock, skillful budding from high-yielding "mother trees," and efficient harvest routines, these yields can be further increased. In parts of Henry Ford's new Belterra Plantation in Brazil, Hevea trees are already yielding annually over 1,200 pounds of sheet rubber per acre. Goodyear plantings in Sumatra and Firestone plantings in Liberia are said to have reached annual yields of approximately a ton to the acre, which is about five times the average score of a quarter century ago.

Economically, Hevea is in many respects an ideal crop. Unskilled labor only is required to carry the milk to the sheds and perform the very simple operations of its processing. The harvest is nonbreakable and not highly perishable. It is comparatively easy to pack and to ship. If necessary, it can be stored for months pending shipment. When weather conditions or labor troubles interrupt harvesting, latex is merely left in the trees, where it can remain indefinitely.

Correct tapping is not quite such simple, unskilled labor. It requires considerable manual dexterity. Equipped with a specially designed razor-sharp knife and a refuse pan, the tapper makes the rounds of trees, slitting thin spiraled cuts or "wounds" into the bark of each tree or, more commonly, reopening the wound previously cut by slitting off a tissue-thin layer of its edge. This surgery is extremely delicate. If the knife cuts through a biologically vital layer known as *cambium,* the tree is permanently damaged. On the other hand, unless the milk sacs are effectively tapped, the harvest of latex is incomplete.

The tapper makes his rounds during the very early morning, scraping all congealed sap into his scrap basket and clamping one or more small catch-cups, best made of aluminum, at the base of the spiraled cuts. Slowly the whitish milk oozes out into the cut of the superficial bark layers and drips into the catch-cups. A yellowish tree liquid protects the wound from air infection. The routine harvest is the simple expedient of emptying the catch-cups into buckets and carrying the milk and scrap back to the smoking sheds.

A few modernized plantations have pipe lines which carry the latex direct from the trees to a central processing plant; but a competent bucket man, or woman, working good trees, can collect about 100 pounds of the milk between dawn and noon—enough to make 30 to 35 pounds of "crude." Inevitably the average day's "take" becomes a decisive factor in the production costs of rubber.

At the smoking shed the raw milk is poured into open pans, treated with highly diluted acid (usually formic or acetic). Overnight it coagulates into a white pad, or "towel." A mangle man takes the pads and runs them through a hand wringer, then hangs them on racks in a tightly enclosed smokehouse, builds a smudge fire, and leaves the pads to drip and dry. The purpose of smoking is to preserve the rubber from deterioration.

Properly smoked, the pads become nut brown and are pressed into squat, 200-pound bales for convenient shipment to the mill or factory, perhaps in Akron or Boston. At the factory entrance it is likely that a hydraulic plunger forces these bales into a set of revolving knives, or "pie cutters." The chunks of raw rubber then travel on conveyors to the huge mixing machines which blend into it the many chemicals and compounds used in manufacturing finished goods. Chemists write the "prescriptions," or recipes, and compounders weigh out the ingredients, frequently with the assistance of electric eyes or other automatic devices. Indeed, the whole process is strikingly similar to that of making a cake by factory methods. It will later be described in some detail.

The Hevea is a beautiful tree which rises gallantly from the rich soil of the tropics. It offers a perpetual harvest, and because the milk flows best in the early morning, a good rubber worker usually tramps to the grove by lanternlight. When dawn sweeps in from the east he has already been long at work. With meticulous care he opens the wounds on the tree trunks and sets the catch-cups. Sometimes he goes home for coffee and breakfast. Then comes the collection of the milk, which is best carried to the shed room by noon or early afternoon—siesta time—because it quickly coagulates when exposed to the open air, which is always full of bacteria, and these will, in turn, quickly acidify latex. Thus, if the harvest is not taken promptly, it cannot be taken at all. After siesta there is time for brush and trail clearing; for budding, for work in farm nurseries and planting; for seed gathering and transplanting nursery stock to open fields; and for the unending, sweat-raising miscellaneous tasks of all tropical plantations.

Hevea is not necessarily a plantation crop. Many students believe it should, and eventually will, be a small-farm, one-family crop. Actually, about half of all the Hevea rubber grown in the great Netherlands island of Sumatra (before Japan's conquest) was produced on small farms of from one to ten acres and attended entirely or principally by the landholder and his family, from whom companies and traders bought it. Comparatively speaking, the results were good.

Herein seems to be the best solution to the labor problems involved in rubber production. There are valid grounds for predicting that, when and if Hevea becomes established as a great commercial crop of the American tropics, it will be preponderantly grown on such small farms or family plots. Such an agriculture demands many community or government instructors in bud grafting, correct tapping, and fungus and insect control, as well as regional experiment stations and qualified supervision of smoking sheds. These needs and their fulfillment cannot be called revolutionary; but they are not necessarily easy or simple.

Yet current successful operations of other tropical agricultures, such as the modern system for production of bananas, sugar cane, and coffee, have already proved that co-operative devices can be practical in the tropics. It is a fair estimate that improvement in Hevea agriculture can make it as efficient as these, or even more so. At first, intelligent assistance will be needed from all the American governments, including our own; but there is no real reason to doubt that such help would be repaid with interest.

Hevea farming is a work of infinite sweat and discomfort; of brightly colored sunsets; of innumerable flies, bugs, and mosquitoes. A rubber farmer goes to bed early both because he is tired and because lights attract amazing swarms of insect life. He eats supper at sunset, and very likely sips highballs, tea, or coffee. Then he goes to his room, or *barricone,* sheds his clothes and lies down upon his cot without cover. As always, the night is hot, and the moon and stars seem very close and bright and intimate. Though tired, he generally does not go to sleep quickly, for there are the heat and the multitudinous voices of the night. He drowses, and presently becomes aware that his bed is growing wet with sweat. But as the night grows later he begins to sleep. Sometimes, particularly if he is new to the tropics, he awakens suddenly, to be confronted with shapeless, reddish phantoms. These are called heat nightmares, and may be terrifying at first, until one gets used to them. After midnight, sleeping is easier. With late black night the air grows cooler. But dawn soon appears—suddenly as if shot from a cannon.

The dawn is welcome, and the farmer works rapidly, to avoid the late morning heat. He comes to know his Hevea trees with precise intimacy—to be able to judge rubber-producing values in terms of smooth bark and healthy leaves. He rejoices when young trees grow rapidly, and grieves over the death of fine old trees. In time he finds himself projecting incessant and imaginary diagrams of subsoils and root systems. He becomes accustomed to the feeble, flattish smell of newly drawn latex, and recognizes by its odor the type of wood being used to feed the smudge fires in the farm's smoking shed. He gets used to the smell and consistency of the white "towels" and the acrid, penetrating stench that pours from the shed. He comes to like the emphatic odors of a busy plantation, and to be an enthusiastic, even ardent, student of Hevea trees.

This study of Hevea is important, since experiments with other species of rubber trees merely underscore the importance of Hevea. Certain of them, however, are important enough to describe briefly. The Ceará or Mamcoba tree is also found in the Amazon country, in the wilds of northern and eastern Brazil. So far its record as a rubber producer is disappointing. The tree is related to the cassava, or tapioca plant. It has a tuberous root system, and flourishes in comparatively dry and rocky soil, and at altitudes as high as 4,000 feet or more. It is a rather small tree, rarely more than 30 feet tall, with a rounded head of grayish-green leaves somewhat similar in shape to the leaf of the castor plant. Ceará can be propagated either by seed or by cuttings, but in Brazil it is still almost exclusively a wild crop.

The method of harvesting is primitive. The free-lance tapper usually clears a space at the base of the tree and lines it with large leaves. Then he uses his machete to strip the outer bark from the side of the tree to a height of four or five feet. The latex oozes slowly down the tree trunk and presently coagulates into sticky ribbons or balls, which are gathered and pressed into lumps or cakes. The harvest is slow and toilsome, and though the clean latex provides fairly good rubber, in most cases its value is likely to be impaired by poor methods of harvest.

Castilloa (Castilla) rubber, often called ule in Central America and caucho in Peru, comes from a big jungle tree frequently three feet or more in diameter, with giant hairy leaves sometimes as much as two feet long. Castilloa trees, though native to great areas of central and northern South America, are most densely concentrated in the valley of the San Juan River of Nicaragua and Costa

Rica, lands which are still wild, fever-ridden jungles where rainfall is heavy and travel difficult. The Castilloa is usually found on riverbanks, and is best approached in a boat, and with a weather eye for alligators. Though the San Juan is its principal base, it may also be found along the rivers of Guatemala, Mexico, Honduras, Panama, and sometimes in Cuba and Haiti. In South America the Andes Cordilleras separate its stands from those of Hevea.

Current hopes and efforts to take wild rubber from the American tropics are being seriously directed toward the Castilloa tree, as well as the Hevea. But there are marked differences between these two principal species of rubber bearers. The bark of the Hevea is firm and granular; its structure therefore permits repeated reopening of the latex cells merely by removing a fine shaving along the lower edge of the tapping cut. Moreover, the latex cell system of Hevea is in the form of a network; consequently, opening its cells at any point drains the latex from a circular area averaging 18 inches in diameter. The flow of milk usually ceases in a few hours, but the cells in the area are rapidly refilled with latex, and the same cut can be reopened after a day's interval. This fact is the basis for the practice of tapping Hevea trees every second day, or for brief intervals daily.

The Castilloa tree, however, is distinctly different. Not only is its bark fibrous, which causes it to gape widely when cut, but its latex cells are almost vertical tubes, from which the latex pours like water from a pipe. When a Castilloa is tapped, its entire content of rubber runs out quickly. From four months to a year is required for the tubes to replenish themselves; thus there is no point in tapping these trees more often than two or three times a year.

Another point of difference is that the latexes of Hevea and Castilloa trees cannot be processed in the same way. Hevea latex is easily coagulated by almost any commercial acid, or by smoking; indeed, as its first users learned long ago, it is quickly coagulated by exposure to warm air, chiefly because the contamination of airborne bacteria acidify it. But latex from the Castilloa tree resists coagulation by acids and does not respond readily to the smoking process. The most effective way to coagulate it is to mix the latex with the juice of certain vines, such as the *nacta* vine of Southern Mexico and Central America, and the moonvine (*ipomaea bona-nox*), which flourishes throughout the American tropics.

Nevertheless, the unprecedented needs for harvesting wild rubber in the present crisis have produced a standard procedure for obtaining Castilloa latex. This involves giving each tapper 25 spouts made of galvanized iron; a large tapping knife shaped somewhat like a tire tool; an assortment of half-gallon latex buckets, or jugs; and a set of fine-mesh screens to cover the spouts and buckets during the tapping operation. In addition, each worker is provided with a step-ladder or rope ladder, though he is sternly prohibited the use of climbing irons, such as those used by telephone linesmen, as of course these would injure the tree irreparably.

The tapper places his latex bucket at the base of the tree and then drives a spout into the bark at a downslope immediately above it. Then he uses his tapping knife to cut a long vertical channel down the body of the tree to the metal spout. The tapper then begins a series of V-shaped lateral cuts, spaced about 18 inches apart and feeding into the central channel. If the Castilloa tree is big and well-bodied, he places one spout and bucket on each side and performs his bark surgery so that all the latex can be drained in a single operation.

The sap flows rapidly and the tapper waits ready to prevent overflow and to skin or press out the final cream rubber with his fingers when the heavy flow has abated. He must make certain, too, that his incisions do not injure the inner wood of the tree. Even so, the wounding is materially less exacting than in Hevea harvesting, where the first tapping cut is usually made about three feet above the ground, and is extended so very gradually that five or six years of daily or alternate daily harvests are made before the original bark structure at the base of the tree has been cut away.

Collecting rubber in the wilds is never easy. Rubber experts of the Board of Economic Warfare in Washington suggest the building of field stations at points convenient to all known and accessible concentrations of tappable Castilloa trees, each station to be equipped with four 1,000-gallon tanks for washing the liquid latex;

a 500-gallon hot-water tank and a boiler for heating the water; a series of fine-mesh sieves for straining the latex; a set of 500 baking pans (about 9 x 15 inches) for coagulating the latex; and a hand mangle or wringer for rolling the coagulum into sheets. For "working" the widely scattered trees, each tapper has a 50-gallon metal tub in which he washes the latex as place and circumstance permit. To remove dirt and debris, the latex is mixed with about three times its volume of warm water; the mixture is then strained through sieves and left to settle in the tanks. There the latex rises to the surface, and at the end of 24 hours or so the dirty water can be drawn from the bottom of the tank, clean water added, and the process repeated.

The washed latex is next poured into the baking pans, one gallon to a pan. About half a gallon of water, containing a small quantity of formic acid (about 3 cubic centimeters), is stirred with the latex in each pan, and the mixture is left to settle; the water is drawn from beneath the floating latex, which is then stirred until it looks and feels like soft clabber. Next, each panful is poured upon a table, and shaped by hand into a rectangular piece about 10 inches wide, ½ inch thick, and 30 inches long. The worker pats and fondles each spongy "towel" and runs it through a roller, from which it emerges as a "ribbon" of rubber, about 2 feet wide by 5 feet long. But the latex must still be coagulated by means of vine juices, for the use of which there is still no proven substitute. After the vine juice has been added, the sheets of coagulated rubber are washed, hung up to drain, and then taken to drying sheds, where they are allowed to hang upon smooth, sheltered poles for three or four weeks.

Other minor rubber trees include mangabeira, of Brazil, and sapium trees, of Colombia and Guiana, neither of which is of any great promise. Also, there is Rambong, or Assam, rubber made from an Asiatic tree sometimes grown as an ornamental plant and formerly cultivated as a minor plantation crop in India and Ceylon.

Wild rubber is inevitably costly. In order to procure it men must push farther and farther into hot, roadless wildernesses. This means great disease hazards and immense transportation costs. In fact, this is one of the principal reasons why rubber production has never been carried on systematically in Brazil. Notwithstanding these difficulties, this writer believes that our government is acting intelligently in its current endeavors to collect wild rubber from the American tropics; for our need is acute and will probably remain so for some years, regardless of synthetic products. At this time, when a comparatively few pounds of new wild rubber can mean the difference between life and death for a platoon of our fighting men, or a few tons of true rubber may well decide the outcome of an important battle, no price for real rubber can be termed out of reason. Aside from crucial military considerations (which cannot be put aside), the truth is evident enough that the American tropics, which are the ancestral home of the principal rubber trees, once more face the opportunity of producing rubber for a free world—plentiful rubber which can supplement our industrial production of synthetic or substitute rubbers. The wild rubber tree of the American tropics is still a reliable trail blazer to the bounties of plantation rubber. But our requirements of crude rubber are far too great to be met by it alone.

Meanwhile, the harvest remains a work for brave men, or desperate men, or for sons of the jungle who do not fear the ever-swarming mosquitoes, nor the virulent malarias and jaundices, nor violent floods, nor quicksands, nor the deadly coral snakes and other natural enemies which inhabit rubber-bearing jungles. Today men of many bloods and stations, most of them our allies in war, are harvesting a slowly increasing tonnage of wild rubber. That is important to all the Americas.

Besides rubber-bearing trees, there are many plants from which latex can be extracted. With the exception of one familiar bush—guayule—and one dramatic new development—Cryptostegia—they do not promise much. The principal African rubber plants are the vines called Landolphia. Obtaining latex from these vines, which usually grow widely scattered in dense and formidable jungles, is extremely difficult. Species of Landolphia grow in widely separated areas of tropical Africa, including the Sudan, Congo, and Madagascar. Their latex is taken out by means of stem incision, and is usually coagulated by exposure to heat and air. The difficulty of harvesting, coupled with traditionally bad preparation, have branded this a poor rubber.

In Portuguese West Africa there is the ecanda plant, from the tuberous roots of which a low grade of rubber can be obtained. The roots, or rhizomes, are chopped into pieces and the latex removed by means of hot water; more recently, by suitable machinery. But the harvest remains small.

Another potentially great rubber-bearing plant of our own hemisphere is the well-known guayule, which is really an enormous family of bushes, most of which are native to the dry highlands and mesas of Mexico. Guayule is neither stately nor impressive. It is a stubby bush, with grayish-green leaves and immense variations in size and shape. There are at least 800 different species which vary greatly in their content of rubber. But they all store a considerable amount of resinous, rubberlike material in their roots, leaves and stems. The harvest requires that the entire plant be uprooted and chopped to pieces so that the rubber can be recovered by washing. Unfortunately, the yields of guayule are lower than those of improved Hevea trees, and crude guayule rubber contains such a high percentage of sticky resins that it is by no means a direct substitute for Hevea rubber, even after most of the useless resins have been extracted at a high cost.

To date American consumption of guayule rubber has not exceeded 8,000 tons per year, which is less than 1 per cent of our rubber needs. Nevertheless, guayule is beginning to find a useful place as a cultivated crop, thanks largely to the efforts of Dr. William McCallum, Canadian-born botanist and pathologist who has spent more than thirty years in selective breeding experiments.

The Intercontinental Rubber Company has long been the chief "booster" for the increased use of guayule. At Salinas, California, it now operates a guayule milling plant with a capacity of about five tons of crude rubber daily; and at selected points in California, New Mexico, Arizona, and other western states it has planted more than 8,000 acres of the bush for use as seed. Meanwhile, guayule acreage of the United States is being increased, with the assistance of the War Department, the Department of Agriculture, and other federal agencies.

As the rubber situation becomes more desperate, the stories about guayule continue to grow and multiply. Early in 1942 President Roosevelt vetoed a bill to subsidize production of the rubber bush within United States boundaries, insisting that the Good Neighbor Policy obliges us to give Mexico and other Latin-American nations a status of parity in the production of rubber crops. Since guayule is native to Mexico, our nearest southern neighbor does not wish to have it snatched from her hands, as Hevea and other world crops have been taken from the Latin-American nations.

At all events, guayule is a noteworthy plant. It thrives upon land that is too dry for most other commercial crops. Its growing range extends well into our national boundaries. Also it is a legume, a nitrogen-restoring plant, and therefore particularly in line with new advances in dry-land agriculture. In its wild state, four or five years are usually required for the bush to reach harvestable age. Under scientific cultivation, this time can be substantially reduced, and it is said that guayule rubber yields, which now commonly range from 100 to 350 pounds per acre, can be impressively increased by better planting and harvesting methods and by selective breeding. It is said, too, that the seed can be sown by airplanes upon far-reaching, unfenced ranges, and that the germination can be greatly improved by means of mechanical sprinkling of the soil. Conventional irrigation does not seem desirable. But under the tutelage of skilled botanists like the brilliant but bashful William McCallum, who in 1937 cannily declined to establish guayule as a rubber crop for Ethiopia and Mussolini and refused all German and Japanese offers for improved guayule seed, the rubber bush is in a stage of rapid development, which is hopefully significant for our grave shortage.

With time and experimentation, improved strains of the homely bush of the Mexican drylands may become a truly important source of rubber. Obviously our Axis enemies have thought so for the past ten years, and many American rubber authorities agree. Though serious problems await solution, there can be no denying that in guayule lies a possibility of producing usable rubber from American earth that is otherwise unproductive. This possibility cannot be realized in a year—perhaps not in ten years, since an enormous amount of study, research, and development of guayule plants remains on the American list of imperatives. The same holds true for other rubber-bearing plants of the American tropics and for many other great crops which we do not ordinarily associate with the production of rubber.

There is another Mexican rubber plant which has only recently been given the attention it deserves.

Cryptostegia, commonly called "Mexican rubber vine," is the Greek name for a Madagascar plant originally cultivated in India and the Middle East, and later carried to Mexico where it was allowed to grow "wild." Today it may prove one of the world's most strategic plants. For this hardy, shrublike vine yields rubber of the highest quality—as good as any ever procured from Hevea or other sources. It reaches bearing age within six months after seeding and gives its maximum yield of rubber within a year or so. It flourishes in an astonishingly wide variety of soils and climates—in wet lands, jungle edges, dry lands, equatorial tropics, subtropics, as well as in large areas of the temperate zone. For these and other reasons the United States government has adopted this long-neglected rubber vine as an emergency crop. It is reported that the War Production Board has contracted for the immediate planting of an extensive acreage in Western Hemisphere areas where the best and quickest yields are to be anticipated. Meanwhile, farmers are hoping for an easier and more pronounceable name for the new hope of an immediate supply of natural rubber.

Cryptostegia is a milkweed vine the rubber content of which is concentrated in the leaves, seed pods, and stems. The more common species (grandiflora) is now being grown as a perennial well north of frost lines. It is known to have survived subfreezing temperatures—as low as 18 to 20 degrees Fahrenheit. Some plant experts feel confident that subspecies may be developed which will be suitable for propagation as a staple annual crop in the southern areas of the United States. So far, this belief is theoretical and unproved. But the vine's maximum rubber yields seem to occur at the leaf-shedding period, which in temperate climates would, of course, be autumn. It is also significant that the life cycle of the plant proves that it rapidly adapts itself to a variety of climates. For example, in Florida and northern India the seeds develop between May and June, whereas in Mexico the seeding time is early winter —December and January.

Scientific appraisal of the plant is impressive, but by no means complete. However, we do know that the vine is hardy and can be propagated easily from either seed or cuttings, and that seeding is rapid and easy. The seed pod is a milkweed-type pod or ball, each pod containing 400 or more seeds. One healthy vine usually produces at least 20 healthy seed pods within eight months, which is enough to plant an average of two acres at three-foot intervals, or roughly 4,000 plants per acre. The seed is exceptionally virile. Leaves and stems are intensely poisonous and therefore have few, if any, insect enemies. In current experiments, rubber yields vary from 200 to 500 pounds per acre yearly, 380 to 400 pounds being a good average. This is higher than yields from any other rubber-bearing annual plant. Moreover, Cryptostegia seems to be the fastest growing and hardiest of all rubber-bearing plants. For tire manufacture, its physical properties are excellent, on the basis of tests recently completed by the B. F. Goodrich Rubber Company, the United States Rubber Company, and the United States Bureau of Standards. Already it is being grown in widely scattered areas of the southern states—Florida, Georgia, Texas, Arizona, and California. It is also cultivated south of the Rio Grande under the auspices of the Mexican repatriation or resettlement administration in desert soils and in well-watered valleys. In the Mexican state of Tamaulipas first small harvests of rubber from Cryptostegia are in progress.

The Baruch Report,* appraising the rubber quandary of the

* See Appendix at end of volume.

United Nations, makes conspicuous mention of Cryptostegia as a promising and heretofore overlooked source. The confidence of the United States government in the success of such a crop is supported by emergency plans to plant it immediately in American nations adjacent to the United States—presumably Mexico, Central America, Cuba, and various others of the tropical islands.

The foremost reason why Cryptostegia is now being given one of the most spectacular introductions ever granted a commercial crop is that it reaches bearing age quickly. Canadians, Englishmen, Mexicans, Americans, and many others are now working together to effect that introduction. The Mexican Repatriation Service is developing extensive seed plots in the lower Rio Grande Basin. The United States Bureau of Plant Industry has seed plots in Lower California, Florida, Georgia, and other areas. The United States Rubber Company has developed a particularly important seeding and experiment center on the irrigated desert near Yuma, Arizona. Still larger quantities of seed are being collected from the Mexican wilds. British aircraft are flying seed from inland and coastal Madagascar. Fighting French planters of that huge, strategic island are co-operating with the democracies. The initial seed supply is already assured. It can be increased as planting progresses.

Present plans of the War Production Board direct that the first acreages shall be planted under official contract, with selected seed supplied to the greatest practicable number of independent farmers and planters in the widest possible range of countries and climates. It is understood that the majority of the first acreage will be planted south of the Rio Grande, in Mexican and Central American areas which are most readily accessible to railroads, highways, and other land transportation, and in certain Caribbean islands where a minimum of ocean shipping is required.

Agricultural history is crowded with human dramas and biological mysteries, but the story of Cryptostegia is unique. Here is a world crop which botanists have consistently respected, while governments and commercial rubber interests have equally consistently evaded it. As a matter of fact, the vine is not "new." There are references to its growth and use in India, Egypt and Madagascar for the past two centuries. Since only two species are known to exist—*grandiflora* and *Madagascar*—and only one known hybrid—*florida*—the actual botany is simple. So is the practical chemistry, which is almost identical with that of Hevea rubber.

In 1912 the British Imperial Institute made an official appraisal of the plant, with the assistance of a Canadian chemist, Dr. B. C. MacEvoy, a native of Montreal, a graduate of McGill, and later a resident of London and Bombay. The institute's studies showed that the latex of the rubber vine varies from ½ to 5 per cent of the total live weight of the plant, and that the resulting solid is about 90 per cent pure rubber. In 1912 this rubber was worth about 90 cents per pound as compared with $1.05 for Hevea rubber. Dr. MacEvoy's analyses mentioned several valuable by-products of the plant: the fluffy fiber of the seed pod, which can be used for stuffing pillows; the coarse stem fibers, from which rope and twine can be made; and the toxic factors, which can be used for commercial production of glucosides and digitalis.

However, the report of these investigations was forgotten almost as soon as it was published. Some commentators have contended that the evasion was deliberate on the part of British and Dutch rubber plantation companies, which chose to plant a standard and uniform rubber crop in the Far East and selected the Hevea tree for this purpose. Nevertheless, Cryptostegia found its way to the Western Hemisphere. By 1895 it was reported as growing wild near the ruins of the former estate of the Count of Sierra Gorda in the Mexican state of Tamaulipas, where the gray-greenish vine appeared to thrive in dry desert soil as well as in damp fertile valleys. Mexican Indians noted the rubber values of the plant, tagged it by various original names, such as bajuco, and harvested some of the rubber. They pinched off the tips of the vines and pressed out the white, sticky rubber milk. When the tips are removed, the latex oozes out and coagulates in globules about the size of huckleberries. The Indians plucked these globules by hand, and learned that the same vine could be made to bear three or four crops yearly.

Prewar surveys of North American rubber-bearing plants paid little attention to this newcomer. Its practical rediscovery was announced in 1939 by Dr. M. Castenedo, an authority on Latin-American plant life, in collaboration with Eduardo Chavez, director of the repatriation project of Mexico's Six-Year Plan. One of the first achievements of the Six-Year Plan was the opening of a flood control and irrigation program for the lower Rio Grande Basin, just south of the border near Brownsville, Texas. Here Dr. Chavez and his helpers have started cultivating about three-quarters of a million acres of fertile lands which up to now have been valueless desert and flood plain. About a third of this area is occupied by the world's best cotton farms—reclaimed at a cost of about $3 per acre!

In 1940 Peter Heinz, a Texan who is a technical consultant to the Mexican government, foreseeing the likelihood of a collapse of Far East rubber, began the systematic development of Cryptostegia as a Mexican crop. Prominent United States manufacturers told him that, although the vine rubber was excellent, the content per plant was too low for successful competition with Hevea. However, even before the fall of Malaya and the Dutch East Indies that opinion was not unanimous among rubber experts. Dr. E. M. McColm of the United States Rubber Company, returning from eleven years' supervision of Malayan rubber estates, examined the Mexican plantings and stated that a yearly yield of one gram of rubber per vine would make Cryptostegia more profitable than cotton. Heinz had claimed a yield of ten times that amount.

Even before this, another distinguished British and American authority, Dr. Charles S. Dolley, former professor of physiology at the University of Pennsylvania, had championed the neglected rubber vine. Beginning in 1925, he had made plantings in experimental plots of Mexico, Jamaica, the Bahamas, British Honduras, British Guiana, British East Africa, and India, always with the cordial interest of the respective colonial governments. His findings were promising, and his reports were respected. But the powerful and highly capitalized rubber plantations of Malaya and the Dutch East Indies naturally remained deaf to such findings, while rubber manufacturers insisted that they would continue to buy crude rubber from their regular sources. The Dolley findings showed 400 pounds of good rubber per acre as an average annual yield from Cryptostegia plantings and stressed the facts that the vine is free from insects and diseases and that it flourishes over a vast range of latitudes and rainfall conditions. They also proved that the seeds germinate extremely well.

After Japan seized the Pacific tropics and cut off the normal rubber supplies of the United Nations, Peter Heinz took himself, his samples, his Texas drawl, and his highly attractive personality to Washington and submitted samples of the Mexican-grown vine rubber to all principal manufacturers of the United States. There, for reasons unknown, but with a folio of maddeningly evasive letters as evidence, he was given the traditional bureaucratic run-around. Luckily those tactics were not followed by the high command in war production. Arthur B. Newhall, co-ordinator of rubber supplies, demanded a prompt hearing for the proposed rubber crop. Early in September, 1942, the President's Committee appointed to investigate the rubber crisis pointed to Cryptostegia as a promising rubber source, stating that there is nothing to be lost and much to be gained by vigorously pursuing its culture.

That proved the start of the newest lap in the race for rubber. From unjustified oblivion Cryptostegia leaped forward to military and commercial importance. Meanwhile, the Board of Economic Warfare states that seed and cuttings are now available at the University of Florida Agricultural Experiment Station; the U.S. Acclimatization Gardens at Bard, California; and in other highly favorable plantings at Yuma, Arizona, Indio, California, and other points within the continental United States.

As a wild climbing vine, Cryptostegia frequently grows 12 to 15 feet during its first year. In cultivation the seeds are usually "cross-checked" about three feet apart, like corn, and the vines are left to grow on the ground. Harvesting methods are not yet standardized. Some agronomists believe that the plant can best be mowed like alfalfa or other hay crops at the end of three or four months of growth. The alternate course is the tipping method, which consists of clipping off the stem ends with shears each day for ten or more successive days. This greatly stimulates the flow of latex and causes the outcropping of congealed globules which may be plucked by hand or sucked in by automatic devices which operate on the principle of a heavily powered vacuum cleaner. With such treatment Cryptostegia becomes a stocky, thick-stemmed plant which easily stands alone. The clipping process increases its production of seed pods, which are particularly high in rubber content.

For the technically interested reader, experts with the United States Bureau of Plant Industry of the Department of Agriculture offer the following approximations of rubber content by respective parts of the plant: mature yellow leaf, 6.21 per cent of gross weight; mature green leaf, 4.1 per cent; green pods, 5.12 per cent. The "haying method" of harvest involves mowing the vines when the leaves are mature and the green seed pods are most numerous, and milling the harvest. Without doubt the emergency expansion of the crop involves drastic developments in milling equipment. Engineers and scientists of the United States Rubber Company have already devised a fast-rotating type of gristmill to remove the latex from the clipped stems. Plans for other types of mills specify automatic choppers or chewers somewhat similar to types now used in the pulpwood industries. With such equipment, leaves, pods, and stems would be macerated, and treated with an anticoagulating and solidifying agent before the latex is removed from the leaf debris. Other plans favor the "hammermill" principle as employed in the paper industry, and still others propose the use of sugar-cane mills for grinding and extracting the latex, relying on such agents as benzine to prevent premature coagulation.

Meanwhile Cryptostegia is one of the simplest of crops—hardy, fast growing, bee pollinated, and quickly fruitful. So far as we know, it requires no routine of fertilizer. It cannot be killed by drought; nor can it be eaten by livestock or insects, since it is highly poisonous. Its growing range is tremendous and, as already suggested, there is a good chance that with time, skillful breeding, and propagation the range may be moved ever farther north. In terms of proved botanic fact, this possibility is not remote. But agriculturally Cryptostegia has several serious faults. Its rate of root development is inconsistent. No means of mechanical harvest or milling is as yet clearly and convincingly proved. The hand harvest is almost morbidly slow. Recent experiments in Haiti indicate that a nimble-fingered worker, in twelve hours, does well to harvest twelve ounces of the rubber. That means unreasonably costly rubber in excessively small amounts. It is definitely bad news.

Some years ago a survey of rubber-bearing plants of North America, prepared and published by the Carnegie Institution of Washington, listed in some detail 165 North American plants which are potential sources of rubber. Among these are dandelions, goldenrod, ordinary buttercups, and about a hundred other everyday plants which grow at our doorways, fence rows, or along pasture lanes.

None of these Temperate Zone plants has yet been proved practical as a source of commercial rubber; most of us can recall Edison's abortive work with goldenrod some fifteen years ago. Whatever their future may be, our crucial rubber needs must be filled immediately and in great quantity from effective sources now available. So far, one good Hevea tree is still capable of yielding more rubber in a year than five acres of dandelions, at perhaps $1/500$ of the over-all cost.

Outstanding progress has been made in developing synthetic rubbers from alcohol, which can be made from the grains, vegetables, stalks, and stovers which grow profusely in American fields and pastures. Some of the earliest patents for the manufacture of synthetic rubber were based upon the use of alcohol made from so-called "blackstrap" molasses—the residue after the sugar has been extracted from the cane. Although information of the rubber resources of Russia is zealously guarded, it is comparatively certain that the Soviet government has made tens of thousands of tons of substitute rubber from alcohol, which in turn is produced and distilled from rye, wheat, barley, sugar beets, potatoes, or whatever crop constitutes an available surplus in a given area at a given time.

Some of our own scientists are comparatively well informed about these methods of making rubber from alcohol, although the Baruch Report takes them to task for not going ahead faster with production. Chemists of the Bureau of Plant Industry have worked for years to develop methods for the practical manufacture of synthetic rubber from grains and other vegetables which are ordinarily surplus crops in the United States. At least three steps are involved, but they report that the two hardest steps have been solved and that the third is now near a practical solution.

As the Bureau of Plant Industry is one of the most respected divisions of the United States government, every finding reported by it is likely to be important. Unfortunately, commercial manufacture of rubberlike substances from alcohol does not fit in too well with the facts of the present emergency. War needs are not inclined to permit accumulation of huge cheap surpluses of plant materials suitable for making alcohol. Every available gallon of industrial alcohol, whether made from molasses, wood, grain, or other sources, is needed for the manufacture of smokeless powder, general explosives, and other essential war materials. For the duration, most of our synthetic rubber must come from sources other than food crops—chiefly petroleum.

Yet this does not eliminate the possibility that a substantial part of our future rubber supply will be made from waste or surplus agricultural products. Certainly it does not dispose of the fact that vast numbers of dependable rubber trees grow wild throughout Latin America and are only waiting to be tapped—among others millions of Castilloa trees in Mexico, Central America, the northern Andes, and the Caribbean islands, and many millions of Hevea trees which continue to dot the vast green wonderlands of the Amazon country. All these are vital resources, which may well be one of the keys to American survival.

For the past quarter century our own government, like many other American governments, has been tragically negligent of the natural rubber resources of this hemisphere. This neglect has been abetted by international rubber cartels and by the connections between American rubber manufacturers and British and Dutch rubber monopolists. More recently, American petroleum companies seem to have merged their talents in an effort to perpetuate the abandonment of our sources of natural rubber, so that they may secure a monopoly of substitute rubbers made of petroleum—a monopoly which they now hope to have subsidized by the United States Treasury via the Reconstruction Finance Corporation.

But the aspirants for petroleum rubber monopoly are not being assisted by career scientists of the Department of Agriculture, rubber experts of the Department of Commerce, or the Office of War Production, or by any other accredited rubber authorities. (Mr. Jesse Jones, speaking under oath, admitted that "in general" he did not consult technical or agricultural authorities in regard to his direction of the Rubber Reserve Company of the Reconstruction Finance Corporation.) Like most of his appointees, Mr. Jones, from deep in the heart of Texas—and the oil fields—has failed to study sufficiently the possibility of harvesting rubber from the natural sources within this hemisphere. More than sixty days after Pearl Harbor, the Rubber Reserve Company had a grand total of *two* rubber buyers at work in Brazil and all South America combined, and none at all in Central America or the Caribbean islands.

Whatever the future may hold, the truth is that most rubber still comes from trees. With all deference to the past, present, and future of synthetic rubbers, the fact remains that the scientific horticulture of Hevea rubber is far *newer* than either the concept or the practical manufacture of synthetic or substitute rubbers. Accredited patents for the latter date back to 1910. By 1915 German factories were synthesizing thousands of tons of rubberlike materials. By 1937 it is probable that no fewer than seventy thousand factories or processing plants in Germany, Poland, and Russia were manufacturing usable synthetic rubber. Yet in 1937 there was not one Hevea plantation in Java, Sumatra, or anywhere else in the world which could capably demonstrate how much good rubber Hevea trees can actually be made to yield.

Since men first saw milky latex ooze from the wounded bark of rubber trees they have sought to invent or to create substitute rubbers. Yet the horticulture and agriculture of rubber-bearing plants is even now only in its infancy. The skilled techniques of selective breeding of rubber trees are still damp with newness. During the past sixty years, yields of Hevea trees have been raised from 100, or at most 250, pounds of crude rubber per acre yearly to approximately one ton per acre. Today the Hevea tree is unquestionably the best propagated rubber plant. Yet the high-yielding strains, or clones, of Hevea are only now beginning to suggest the rubber-producing capacity which they may and almost certainly will show ten or twenty years hence.

RUBBER BEFORE GOODYEAR 2

THE derivation of the word "rubber" gives a clue to its early history. In 1770 Sir Joseph Priestley, the discoverer of oxygen, wrote: "I have seen a substance excellently adapted to the purpose of wiping from paper the mark of a black lead-pencil. . . . It is sold by Mr. Navine, Mathematical Instrument Maker, opposite the Royal Exchange. . . ." Thus he recorded one of the earliest and most common uses of this mysterious substance, the use which gave it the ultimate English name of rubber. Until quite recently "India rubber" was the common English term for the natural product. Of course, the "India" part was a misnomer arising from the early belief that Columbus had discovered India, which also led to the naming of the West Indies; in fact it was Columbus who had first brought rubber from the New World.

Antonio de Herrera, historian and propagandist for the imperial Spain of Charles V, reported that Columbus, in the course of his second voyage (1493-1495), saw natives of Haiti amusing themselves at a game which they played with bouncing balls made from the gum of trees. In 1521 Pietro d'Anghiera described such balls as "made of the juice of a certain herbe which being stricken upon the ground but softly . . . would rebound incredibly in the aire. . . ." No doubt the word "incredibly" was accurately used. Few, if any, white men had ever before seen this miracle of bounce.

The little that is known about the games which pre-Columbian Americans played with rubber balls has been gleaned from the ruins of the Mayan civilization in Yucatan. They must have been rather rough, exciting games, requiring tremendous skill. At any rate, the ancient Mayan game was played with a ball, presumably made of soft, solid rubber which must have been about the size of a modern basketball. Apparently this game, which the Mayas called *tlachlter,* was a predecessor of basketball. The players (probably between two and five on each team) toiled, jostled, and frolicked in an open, stone-paved court at one end of which stood a smooth stone wall. During the past decade at least three of these ancient playing courts have been uncovered, revealing ring openings, also hewn from stone, placed at right angles to the court walls.

Score-making apparently required that the ball be thrown or tipped through the stone ring. The players, so students of the Mayas tell us, did not use their hands or feet in playing the game; they made scores and kept the ball in play with their shoulders, heads, and hips. Apparently tlachlter was a warrior's game, and one can readily picture broad-shouldered, powerfully muscled Indians plunging, bending, driving, charging, and smacking hard against whatever got in the way, whether man, floor or wall.

The playing ball must have been heavy if, as archaeologists believe, it was ten or twelve inches in diameter and made of solid rubber. That would make it weigh about 10 per cent less than the same volume of water—at a rough guess, from 35 to 40 pounds. Unquestionably it was a highly prized possession, because on certain holy days rubber balls were dropped into sacred wells located in temples which the Mayas dedicated to their all-important rain-god. Indeed these astounding Mayas—who devised and used a distinctive written language, and a calendar more accurate than our own; who developed such staple farm crops as corn, potatoes, peppers, and peanuts; who built temples that defied tropical time and carved their great stories upon them—must have been comparably skilled in their use of rubber.

The fact is that manufacture of rubber balls still challenges the craftsmanship and ingenuity of the most skilled of rubber workers. Comparatively simple fabrication, such as bladders for footballs and basketballs, requires accurate compounding and first-rate handicraft. The same is true of good tennis balls, manufacture of which requires an ingenious technique. Even the cheap play balls which our children bounce so happily into our soup bowls require a great deal of manufacturing skill. A well-made golf ball is one of the most difficult attainments in the modern rubber industry. Its core is usually filled with sponge rubber, or with a liquid weighted with a heavy powder such as white lead. The core is vulcanized, or "cured," and then frozen in dry ice; while frozen it is mechanically wrapped with carefully stretched rubber tape. This in turn is built up by an automatic winder which adds several yards of tightly stretched rubber banding. Then a tough cover of gutta percha is molded around the ball, impressed, and enameled.

The principle of resiliency touched upon in the Foreword applies particularly well to the golf ball. When the ball is finished, the many yards of stretched rubber inside it constitute a perfect dynamo of potential energy, by means of which the ball leaves the head of a club at somewhere around 100 miles an hour. The hard cover returns the ball to its spherical shape, which facilitates well-aimed flight, even though the rubber-wound interior is pressed far out of shape by the impact of the club.

If a mere golf ball, created to satisfy the country club hours of the tired businessman, is so complex to manufacture, how difficult it must have been to make the huge balls with which the Mayan braves played their national game!

Many pre-*Mayflower* Americans besides the Mayas played games with bouncing balls, and also made crude shoes and waterproof garments. In 1615 Herrera explained in his superb *General History of the Voyages of the Castilians in the Islands of America:* "The ball was made of the gum of a tree that grows in hot country, which having holes made in it, distills great white drops that soon harden, and being worked and molded together turn as black as pitch. . . . The balls made thereof, though hard and heavy to the hand, did bounce and fly as our football, there being no need to blow in them. They rebounded several times one after another, insomuch as it looked as if [they] . . . were alive. . . ."

Astonished white men kept reporting that various Caribbean Indians, particularly at festival times, smeared themselves with sticky latex, in which they set brightly colored feathers. In 1615 F. Juan de Torquemada recorded that Mexican Indians were making shoes, headgear, jugs, bottles, and various clothing of the "magical tree gum."

By that time Europeans had begun to devise their own words for rubber. French explorers called it *caoutchouc* (kōō-chŏŏk), and this term remained in use for three centuries or more. It is derived from a South American Indian word, probably *cahuchu,* which means "weeping tree." The same root appears in other languages: Spanish, *caucho;* Italian, *caucceio;* German, *Kautschuk,* and so on. The almost foolishly simple word "rubber" had to wait for over a century to be coined. But the material itself, and the New World trees which bore it, was winning increased notice, not so much by Spaniards or Portuguese as by exploring Frenchmen.

In particular there was a young Parisian named Charles Marie de La Condamine, a scientist, mathematician, astronomer, and man of immense curiosity and bravery. In 1735 M. de La Condamine and four colleagues were commissioned by the Académie des Sciences to go to Peru and there measure an arc of the meridian by "astronomy and Civil survey." When they had finished their memorable assignment, La Condamine parted company with his colleagues and from Quito, on his own initiative, crossed the towering Andes by burro and afoot; using dead reckoning to steer his course through the Bolivian jungles, he finally reached the headwaters of the Amazon. By means of Indian canoes and log rafts he proceeded down its entire course. This daring trek took three years, during which La Condamine apparently learned more about rubber than any white man had ever known before.

From Pará the young Frenchman sent back to Paris samples of Indian-made rubber and descriptions of how the natives of the Amazon Valley used latex to make waterproof shoes and bottle syringes, and how they coated their primitive weaving with the strange tree milk, drying each coat over a smoky fire. "The natives prepare watertight shoes of one piece from this material. They also spread it over an earthen flasklike form, remove the fragments through the neck of the bottle, and thus obtain a light, unbreakable vessel. . . ."

The gold-hungry Spaniards had not been impressed with what they had seen of rubber, notwithstanding the fact that by 1615 Spanish troops in Mexico had been outfitted with garments waterproofed with it. At any rate, nothing of particular note had come of this. More than any other early explorer, La Condamine visualized the importance and possibilities of what Englishmen were later to call rubber. On his return to France he made an effort to awaken popular interest in the still almost incredible New World resource. We who are almost daily fed upon the miracles of the laboratory have come to believe that scientists can make almost anything happen; it no longer astounds us that fibers can be made from milk, or rubber from coal, air, and salt. The surprise of the Europeans of the eighteenth century at seeing a substance that would bounce was as great as ours would be if we saw water flowing uphill: both are instances wherein the law of gravitation is apparently reversed.

In 1738 La Condamine returned to Paris and pointed out the impossibility of carrying the latex back to Europe, because he had discovered that it had a most inconsiderate habit of coagulating when left exposed in warm air. But he was clever enough to suggest the possibility of using a solvent on the gum after it had been hardened in the sun. Other French scientists took up this ingenious suggestion and experimented with such substances as turpentine and petroleum; as a result, turpentine became the first generally used rubber solvent.

By the time of the American Revolution the general properties of rubber were known to scientific men throughout Europe. Botanists and naturalists had described both the Hevea tree and the Castilloa, as well as *Ficus elastica,* a lesser rubber bearer which still grows wild in Sumatra, Penang, and other Eastern tropics. In 1790 Jacques Fourcray discovered a means of preventing, or at least retarding, the coagulation of latex. By 1791 "Grossart tubes"—

drain syringes—were being used in surgery. These tubes were made of rubber which was first softened by heating and then made adhesive by treatment with ether.

With the coming of the nineteenth century the drama of rubber shifted abruptly to England. The year 1802 was a memorable one for British industry, particularly to rubber manufacture, for it saw the first practical use of coal gas as an illuminant—and the birth of the gaslight era. Previously, factories had been miserably lighted with lamps which ordinarily burned vegetable oils or whale oil, and smoked inordinately. At night London's streets had remained "foully dark." But coal gas was to change all that, and the history of rubber as well.

The scene of the first large-scale trial of the new source of light was Boulton and Watts's Foundry in London's Soho, the working floor of which was actually lighted with gas generated from coal. The discovery was largely due to a Scot named William Murdock, a pioneer mine machinist. Ten years earlier, while installing pumping engines in Cornish mines, Murdock had succeeded in lighting his home with gas piped from a tin mine. By the close of the War of 1812, gas companies were rising like evil-smelling mushrooms in towns throughout England and Scotland, and London streets were being lighted by some 4,000 Argand gas lamps. But the booming new gas industry was still confronted with certain troublesome problems, perhaps the most vexing of which was that of disposing of the then useless by-products, particularly tar and naphtha. By 1824 fashionable London streets were being indiscriminately smeared with coal tar; but there was still no use for the naphtha, until Thomas Hancock of Wiltshire hit upon its remarkable value as a solvent for rubber.

This particular Thomas Hancock was the son of a lumber merchant and cabinetmaker of Marlborough in Wiltshire; he was the third of twelve children, three of whom—Thomas, Walter, and Charles—were to find their way into British dictionaries of national biography. About 1815 Thomas, at the age of nineteen, and his brother John, twenty-two, went to London and set up a shop devoted to the building, repair, and servicing of stagecoaches. In those days rain was the nemesis of the otherwise flourishing stagecoach industry: it bogged the roads with deep mud, cracked and rotted harness leather, kept passengers at home, gave coachmen pneumonia, and caused the iron and timber of coach bodies and wheels to rust and rot. It is therefore not surprising that Thomas Hancock became interested in rubber as a waterproofing agent.

In 1813, or two years before the Hancock brothers opened their shop in London, the first American rubber patent had been secured by a Philadelphian named Jacob F. Hummel. This patent "yielded protection" for a "varnish" made of rubber—Hummel called it Pará—to waterproof leather shoes. Hancock began his business with experiments for using "elastic gum" to make waterproof cloaks for stagecoach passengers. He tried dissolving the rubber in turpentine; but the coating dried badly upon cloth and quickly deteriorated. Nevertheless, within four years, or during 1819, the diligent young handyman applied to his government for a patent on gloves, braces, garters, and shoe soles made of rubber. The author has been able to find no record of such a patent having been granted, but in any event the Hancock brothers opened an "elastic works" in which they made garters, shoe lasts, tobacco pouches, and other novelties—at first merely by buying rubber water jugs imported from Brazil and using sharp knives and probably heated irons to slice the "bounce bottles" into other shapes.

By 1820 Hancock had learned that the task of getting enough crude rubber was his primary barrier to quick and comparatively easy wealth. The thought occurred to him that he might augment the limited supply of imported rubber by utilizing scrap. The only difficulty—and it was a great one—lay in the complete absence of any machinery to grind it and thus make it suitable for re-use. Like the born scientist and inventor that he was, Hancock set about building a machine to "break down," or masticate, scrap rubber. It consisted of a hollow wooden cylinder studded with metal teeth; into this he fitted a rotating wooden core also equipped with teeth. Placing a few ounces of rubber scrap in the cylinder, he began to turn the crank. To his surprise, the longer he turned the harder the turning became. On opening the hopper he was amazed to see that the bits of scrap had been welded into a solid roll. By further experimentation he found that by use of a hand press he could force the rolls of lacerated rubber into solid blocks, from which he could cut thin or thick slices as his needs required.

Hancock called his scrap grinder a "pickle machine." He had built better than he knew, for it was a prototype of today's power mills, or "masticators." It is strange indeed that, with all the advances that have been made in rubber technology since Hancock's day, little real improvement has ever been made on the machine which he first invented. Modern mills are of chilled steel and are composed of two rolls set parallel and revolving in opposite directions, compressing and kneading the rubber between them. But the principle is the same as that of Hancock's "pickle." Quite literally its invention marked the beginning of rubber manufacture, which a century later was to take its place as one of our biggest and most enterprising industries.

At the time he invented this invaluable machine Hancock may or may not have known that other significant forerunners of an almost unimaginable age of rubber were materializing across the Atlantic. Purely by coincidence, the year 1820 marked the first importation of Brazilian-made rubber shoes into the United States. These shoes went to Boston, then as now the leather shoe capital of North America. Boston shoe manufacturers were naturally interested—sufficiently so that in 1823 they imported 500 pairs of "Indian rubber" shoes from Pará. Shrewd shipping men and Yankee clipper masters sensed an exceptionally promising trade in this merchandise.

But the "gum boots" from the Amazon were far from ideally suited to New England weather conditions. If left standing in the warm sun, or when placed too near a hot stove, the boots first became soft and sticky, and then ingloriously collapsed. On the other hand, in cold weather they became as stiff and inflexible as a board. As we shall see, this is the identical problem that confronted

Charles Goodyear a few years later. As if these troubles were not enough, the sizes were too small for most adult Yankee feet. Pará Indians built their shoes either on naked feet or on clay molds that were rough replicas of their own small feet, which were likely to be only a child's size.

But leave it to Yankee ingenuity to iron out a wrinkle like that! The New England merchants hit on the idea of sending wooden shoe lasts to Pará; and the Brazilian Indians, who were more versatile than most of their South American brethren, promptly put these to good use. For a quarter century the inter-American trade in gum boots continued to grow. By 1842 it had reached the astonishing figure of 462,230 pairs.

Back in the smoke-begrimed, money-mad London of the 1820's, Hancock had undoubtedly got wind of the thriving Yankee boot trade; but it is unlikely that he knew that a poor Connecticut tinker named Goodyear was even then interesting himself in rubber. His attention shortly became focused upon competition closer to home—a sturdy Scotsman named Charles Macintosh, a lanky, stern-featured citizen of Glasgow.

By trade this Macintosh was a maker and mixer of fabric dyes. At the same time that Hancock's "pickle" was born and the first gum shoes entered Boston Harbor, Macintosh opened an independent dye shop down the road from the Glasgow gasworks, where he proved his worth as a practical chemist by developing a process for separating ammonia from coal-gas residue. As he needed ammonia to make dyes, he arranged to purchase all the by-products of the gasworks at rock-bottom prices. But, having extracted the ammonia, he was hard put to it to dispose of the rest of the filthy, space-wasting coal liquor. He could sell the tar, but he wanted to find a profitable use for the naphtha obtained from distilling it. As a chemist and mixer of dyes the ingenious Mr. Macintosh knew a great deal about textile making; and as a victim of Glasgow weather he pondered, just as Thomas Hancock had pondered, upon the advantages and possibilities of a rainproof cloth.

In Connecticut, Goodyear was weighing the same question in a similarly wet locality; indeed, quite a case could be made for the statement that early advances in rubber manufacturing were directly due to the damp climate in which these inventive gentlemen lived. Today we do not consider the water-repellent nature of rubber its most valuable characteristic; but the idea of using it to waterproof fabric was the original seed from which all subsequent developments sprang. The idea was not new even in 1820. A generation earlier, in 1791, one Samuel Peel had been granted a royal patent for waterproofing fabric by means of a solution of rubber in turpentine. However, the resulting "Peel Cloth" suffered the same fate that hounded the early products of Hancock and Goodyear, and that overtook the Brazilian boots in New England: it was sticky in warm weather, hard in cold weather, and quick to deteriorate in any weather. By the time Macintosh appeared on the scene, it seemed as if the magic of bounce was to prove a snare and a delusion—a miraculous quality that defied the power of man to capture and subjugate permanently.

But the canny Macintosh moved the situation one notch ahead by discovering that coal-tar naphtha was a far better solvent than turpentine for preparing rubber coating for fabrics. In 1823 (note how nearly simultaneous all these incidents were) Macintosh received a royal patent for this discovery. He promptly established a factory at Campsie, near Glasgow; and, even more significantly, he set up a private laboratory on the roof of his cottage near by, where he succeeded in such remarkable achievements as the isolation of benzine and the purification of naphtha by means of distillation.

Like his fellow Scot, William Murdock, inventor of the gaslight, Macintosh found himself quickly possessed of both wealth and fame. Within a year the British government had swamped his shop with orders for rainproof cloth for the manufacture of tropical army uniforms. Finding his small "chemical works" unable to handle the orders, Macintosh hurried to Manchester, which was then claiming the title of cotton goods capital of the world. There in 1824 he joined three Englishmen—Joseph Street, R. W. Barton, and H. H. Berley—all of whom were successful cotton goods manufacturers, and together they built the first factory to make rainproof cloth.

Unquestionably Thomas Hancock, the young man from Wiltshire who was making good in London, was watching the moves of Macintosh and his associates. Appreciating the importance of the Macintosh patent, he promptly applied for license permission to use coal-tar naphtha in the preparation of rubber. The equally shrewd Macintosh was just as appreciative of the advantages of Hancock's masticator, without which rubber could not be processed on a commercial scale. Quite naturally, the Scotsman and the Englishman opened a series of horse trades which eventually made them partners.

In spite of his success, Hancock went on to bigger things. This is indeed the hallmark of the true seeker for knowledge: in his hands, money merely becomes a means of furthering ideas—a fulcrum for additional accomplishments. (Most great benefactors of mankind have been indifferent to it, as far as their personal wants were concerned: Hancock, Edison, Ford, Einstein—the list could be extended almost indefinitely.)

In 1822 Hancock developed a usable type of rubber tubing, from which he cut and sold profitable orders of rubber bands and mold-shaped "air-proof, water-proof articles for the sick"; waterproof tubes for life belts; air mattresses and air pillows; "drug belts—for easing pains from rheumatism and bladder sour"; rubber cushions for billiard tables. Soon after this he began the manufacture of surgeon's rubber, particularly tubes, syringes, and rubber blankets; then he turned his energies to the manufacture of rubber hose, which found still more customers waiting. During 1826 the Norwich Union Insurance Company substituted rubber for leather in its fire hose. Shortly thereafter Barclay and Company, London brewers, adopted rubber hose for their breweries. By 1832 a great many London taverns had beer or ale casks equipped with rubber tubing. Rubber was on the march!

The year 1826, incidentally, was the first for which the Brazilian government attempted to keep records of rubber exports. These records show that during that entire year about eight English tons

(2,240 pounds) of rubber and rubber goods were exported to the United States. The fact that exports to England are not listed may be a tacit reminder that Britain's merchant marine was still somewhat indifferent to cargo manifests and documents of port clearance.

It must be remembered that all the rubber products so far mentioned were extremely bad, by present standards. William H. Richardson, Esquire, of Boston, able commerce reporter of the 1830's, stated the chief difficulty most skillfully: "But the bubble soon burst. Goods manufactured in April became a sticky mass of useless rubbish in July. The warm weather literally melted hopes and expectations. . . ." Richardson was writing of American ventures in rubber making, particularly of the Roxbury India-Rubber Company, started in 1832 on the outskirts of Boston by Edwin M. Chaffee and his partner, John Haskin, both American shoe manufacturers who, despite their failures, were to write their names in the history of rubber. He was referring also to the early toils and failures of the puny Yankee, Charles Goodyear, and another impecunious tinker, Nathaniel Hayward, who tried to invent a waterproof blacking for shoes, and discovered, "as a result of a dream," that sulphur "admixed" with rubber gum and exposed to hot sunlight will assume a tough, durable surface! But, in speaking of the fleeting life of rubber goods, Richardson did not have reference to those made in England, where heat and cold are rather more evenly tempered than in Boston. However, it is probable that he had heard of Hancock and Macintosh, and that he regarded them with that always puzzling Bostonian blend of admiration, envy, and contempt.

British competition was definitely on the increase. One day, probably in 1829, Thomas Hancock journeyed to Manchester and joined the prosperous partnership of Charles Macintosh and Company. He was made a director, and his rubber patents were taken over by the company at an annual rental of £91 sterling. The Macintosh Company began to win fame and riches as makers of rubber cloth. The "Macintosh Coat," or simply, as called now, the mackintosh, became and still is a name known throughout the world. In 1834 fire destroyed the prospering Macintosh mill, but it was rebuilt. By 1837 Thomas Hancock, who spent a great many of his evenings at home in his "penthouse" workshop, had invented a mangle machine for spreading rubber upon cloth. With that invention the volume of "gum slickers" again spurted upward. The ingenious British partners coined more money from rubber sheeting and rubber thread; they also appropriated the good points of Bostonian Edwin Chaffee's memorable invention of the "calender," a machine which was designed for smoothing rubber into sheets of uniform thickness, and could also be used for impregnating fabric.

Hancock may or may not have heard of Charles Goodyear's first confused experimentation in compounding rubber with dilute acid and magnesia. Whether or not he did is not important, since Goodyear's early experiments were dismal failures. But there is absolutely no question that Hancock did hear of the Yankee's discovery of vulcanization, or cooking rubber with sulphur. In fact he not only heard of it, but actually held a piece of vulcanized rubber in his hands. He studied the sample which a homecoming Englishman, Stephen Moulten, had brought direct from Goodyear; noted the telltale "bloom" of free sulphur upon its surface; and in due course gained a British patent upon what was essentially Goodyear's epoch-making discovery. From that December afternoon in 1841, when Hancock carried foreign rubber samples to his home workshop at Marlborough Cottage, Stoke Newington, until today, the rubber industry has been an international one, defiant of political boundaries, but sustained and advanced by the genius and vision of a few devoted men. One of these was Charles Goodyear, whose name has become a household word throughout the world.

CHARLES GOODYEAR 3

A GENTLEMAN being inquired of how he [Charles Goodyear] might be recognized, said: 'If you meet a man who has on an India-rubber cap, stock, coat, vest and shoes, with an India-rubber money purse, without a cent of money in it, it is he. . . .'"[1]

That is how the greatest of all rubber inventors described himself. Unquestionably the description is embarrassingly accurate, for Charles Goodyear was as inept in financial matters as he was gifted with inventive genius. He was the kind of man who, whether he succeeds in coming by money or not, is perennially poor. This is not said in disparagement; indeed, his accomplishments are the more praiseworthy because of it, and he affords quite a contrast to Hancock in this respect.

Born in New Haven in 1800, he first intended to enter the ministry, and then elected the bitterly impoverishing career of tinker and inventor, losing much and winning little but posthumous glory while showing the way to a new world of rubber.

Goodyear's father, Amasa, was a Yankee tinker and minor inventor who dabbled in spoons, clocks, pitchforks, scythes, pearl buttons, or whatever "novelty" interested the whimsical American public of the early nineteenth century. Amasa led a humble and insecure life of drudgery. Both he and his son Charles were the true salt of frontier Yankee industrialism—both New Englanders of the old school, who worked with dogged but courageous deter-

[1] Footnotes for this and succeeding chapters will be found in the appendix, page 259.

mination and thought high and far. Amasa Goodyear had manufactured buttons for uniforms worn by United States soldiers during the War of 1812. He had set up a back-yard factory near Naugatuck, Connecticut—a humble workshop dedicated to making things and selling them, to losing heavily and partially recouping the losses, to dreaming of fame and fortune never to materialize, and to an unquenchable devotion to the new. In a word, it represented the spirit of early New England industry; and it is no mere coincidence that that also is the spirit of our current age of rubber.

Amasa Goodyear lived and worked before rubber was commonly known in the United States. In 1841, just two years after his eldest son discovered the process of vulcanizing rubber, Amasa died of yellow fever in what was then faraway Florida. He had heard of a newfangled Spanish crop known as oranges; believing that oranges would grow in that territory, he started Florida's first important orange plantation and planned to ship the harvest to New York and Boston by sea. Amasa did not live to see his last and most magnificent vision realized. Yellowjack saw to that.

The life of Charles Goodyear * was tragic but gallant—a life of resolute hope, of recognized success, of heroic failure; a life blockaded by the bleak walls of prisons. As Hugh Allen, one of his biographers, explains: "Money never meant anything to Charles Goodyear except to give him funds to continue his researches and enable him to demonstrate them to the public. And when at 60, his tired hands relaxed for the last time, he had demonstrated or visioned virtually every use to which rubber has since been put."

His story is basically an epic of American industrial science: it belongs to the heroica of our machine age. Only since Pearl Harbor have we begun to reflect on the problems of an industrialized society in which the consumption of rubber must be severely limited; and these problems will require a lot more thinking before they are solved. But it is something that we have before us the devotion of Goodyear to serve as an example.

* A chronology of its principal dates will be found in an appendix.

Goodyear was a pioneer on an industrial frontier to which rubber was almost unknown, but his discovery of vulcanization did much to make the Industrial Revolution possible. For example, the most significant mechanical invention of Goodyear's time was the steam engine; but for its efficient operation, airtight rubber sealings were essential. Fulton's steamboats were not of outstanding value until vulcanized rubber made possible the fairly efficient retention of steam. Rubber-insulated wiring was necessary for the development of telephone and telegraph. Again, the rapid expansion of railroads demanded far more powerful braking equipment than was possible with hand-setting devices. The operation of air brakes, which permits safe attainment of high speeds with heavy loads, is dependent on durable rubber hose connections.

A third of a century after Goodyear's death, the peculiarly American automobile industry grew great on rubber tires, tubes, parts, and fixtures; and for the automobiles in use, millions of miles of paved roads were built. Rubber was instrumental in speeding up our transportation and our national life. It removed the isolation of the farmer, and helped to knit the states together—to transform the country from a rough, generally impoverished, agrarian frontier into the greatest of all industrial nations. Surely the world was waiting for Charles Goodyear, though it did not recognize him when he made his unpretentious appearance. In fact, he was called a fool and an imbecile by most of those who did happen to notice him. As a debtor he served time in jails of the United States, England, and France. But he was endowed with all the golden stubbornness of genius: in taciturn Yankee grimness he fought indefatigably on. Ironically enough, the two nations which served him worst, the United States and Great Britain, have realized most from his inventions.

We have already spoken of the history of rubber before Goodyear. At the time he became interested in it, India-rubber erasers were being placed on the more expensive writing pencils. The ingenious Macintosh had already invented and begun to manufacture his raincoats of cloth smeared with a coating of rubber. In the Amazon Basin and other areas of the American tropics, Indians had proved their flair for making rubber shoes and boots, as well as syringes, hand sprays, solid and hollow rubber balls, and other miscellaneous rubber goods; and these were being exported to the United States. Hancock had invented the first practical machine for handling rubber commercially, and was busily engaged in further experiments.

The chief difference between Hancock and Macintosh, on one hand, and Goodyear, on the other, was that, although the former knew that the rubber products they were making were not especially serviceable and that something essential was lacking, they went ahead and made all the money they could instead of concentrating on the central problem—a better product. Goodyear, however, simply could not rest until he ferreted out the secret and satisfied himself that he had solved it. He never abandoned his search even in the face of several tragic failures which would have daunted a lesser man. Of course, Goodyear wanted to make money also; in fact he even established a factory before making his great discovery. But, like Edison with the electric light filament, he knew that somewhere there was a substance that would do what he realized had to be done before rubber would ever be of much use. It is this conviction, and the tireless courage that drove him to prove it, that lifts him head and shoulders above his contemporaries.

Goodyear's active entry into the field came about in this way. Edwin Chaffee had designed not only a machine for spreading dissolved rubber in a uniform layer on cloth but also a still more important device for impregnating fabric with rubber. As a result of his pioneer work, Chaffee founded the Roxbury India-Rubber Company, which he quickly built into a $600,000 enterprise. Rubber cloth factories soon appeared in half a dozen other New England towns. But all of them ultimately failed because no way had been found to make rubber impervious to the effects of heat and cold. Nevertheless, by 1832 the Roxbury Company was producing "rubberized" clothing, life preservers, and shoes. One day a timid, tousle-headed man, thin and yellow skinned, appeared at Roxbury to view the works and suggest improvements in the product.

"He [Goodyear] was passing the store of the Roxbury India-Rubber Company in New York and stopped to make inquiry about life-preservers with the view of purchasing one. On examining the tubes which were inflated, it occurred to him that he could improve their construction. . . . Some months after this he presented a specimen of his improved tube to the agent of the Roxbury Company with a view of disposing of it to that Company. Being pleased with his success in that, the agent advised him to turn his attention to the improvement of India-rubber. . . ." [2]

The events which directed Goodyear to Chaffee's factory outlet store in New York make a notable story. Finding himself too frail for the rigorous, though confining, life of the theological institute of that time, he went to work for his father, who had continued his career as a small-time inventor. The sickly youth had inherited his flair for invention; and even in his teens Charles had proved that he had a talent for salesmanship. His father was, not unreasonably, convinced that a Goodyear could sell Goodyear inventions better than anybody else.

In those days Philadelphia was one of the foremost centers of wealth and merchandising. Amasa Goodyear dispatched his oldest son thither to become an apprentice storekeeper. In early New England, hardware was traditionally a peddler's trade, a matter of wagon merchandise or heavily loaded backpacks. During the middle 1820's, soon after his marriage to Clarissa Beecher, Charles Goodyear violated this tradition. The feat of opening what may have been the first hardware store in the United States was motivated principally by the younger Goodyear's determination to sell his father's inventions. His long succession of misfortunes began here, for his business did not prosper. Many customers, most of them distant, did not pay their bills; debts mounted, and the store fumbled into bankruptcy. The young proprietor accepted all responsibility; but less scrupulous creditors promptly had him thrown into a debtors' prison. Here the frail Goodyear, by that time the father of three children, spent his thirtieth birthday. When released, he returned to New England to work as tinker, peddler, blacksmith, or anything else that might free him from debt. In 1832 a fourth child was born and two years later a fifth. The Goodyears remained desperately poor, drifting from town to town, while Charles struggled to perfect new kinds of pitchforks, knives, and harrows, and to sell them.

It was during the winter of 1832 that Goodyear passed the New York store of the Roxbury Company. Wearing a ragged coat, and a blacksmith's leather apron for additional warmth, he made his momentous visit to the rubber works, and met Proprietor Chaffee. Chaffee welcomed him, and confided the bad news that his goods were going "sour." It was true. Rubberized cloth was literally rotting in warehouses: Chaffee had actually buried $20,000 worth of it to keep it off the market. Quite obviously the Roxbury Company and its many imitators were headed for bankruptcy.

So was Charles Goodyear, for the second time. Arrest warrants had followed him during his frantic rounds of peddling. At Woburn, Massachusetts, they overtook him. But this time he took his equipment to jail with him: a marble slab, a wooden rolling pin, various compounds and chemicals, and a *pelle,* or biscuit, of crude rubber. He had become engrossed in the elastic magic and had already learned from firsthand experience that a jail cell can be made into a laboratory.

During this jail term Goodyear found that magnesium reduces the surface stickiness, or tackiness, of rubber. That was a noteworthy clue. Out of jail, he joined his starving family in New Haven, and began manufacturing rubber shoes. He and his wife, assisted by three or four hired girls, did the work, using a ramshackle house as their factory, baking the shoes in oversize Dutch ovens. For a few months all was well and prosperous—until Goodyear learned that his rubber shoes would not wear well. The magnesium "cure" was only superficial. Moreover, the neighbors were fighting mad about the foul smells pouring from the chimneys, doors, and windows of the Goodyear domicile. They suggested chasing the idiot out of town.

But Goodyear saved them the trouble. He sold all his household goods, placed his family in a cheap boardinghouse, and went to New York to seek capital. Meanwhile he had devised a formula for treating rubber with quicklime and water to remove the natural stickiness of its surface. With this formula he made rubber sheets and toys. Moreover, he had obtained the first United States patent for a rubber cement.

In New York he arranged an exhibit of his wares at the Mechanics' Institute. Nothing constructive happened. Again moneyless, Goodyear took a dollar-a-week room in Greenwich Village, located an abandoned mill five miles away and each day walked there and back, carrying his jugs and chemicals on his shoulders. He celebrated his thirty-seventh birthday with the discovery that treatment with nitric acid enables rubber to resist the degradation which results from heat, although this technique once almost cost him his life. Pooling his several discoveries he began to manufacture rubberized bandages, paper, and engravings. He printed letters on sheet rubber and dispatched one to President Andrew Jackson, first citizen of Nashville, Tennessee.

More important than this, he found a financial backer—a New Yorker with a pea-green cape, swallowtails, and a stovepipe hat of shiny green silk. The "angel's" name was William Ballard; he provided Goodyear with a Manhattan sales office and a factory and warehouse on Staten Island. Moving his family to New York, Goodyear extended his products to include rubber shoes, cloth, and life preservers.

But just at this time, as a result of Andrew Jackson's stubborn financial policies, the first really severe business panic of our history descended upon the country, cutting down Ballard in its swath. Goodyear searched frantically for another backer. His children went fishing in the bay in hopes of replenishing their empty larder. Clarissa Goodyear began making and peddling pasteboard bonnets. Charles hawked handmade aprons and piano covers. He pawned his household silver and borrowed dimes and quarters from tolerant neighbors. There is a story, possibly fabulous, that during 1837 he traded his umbrella to Cornelius Vanderbilt for a ferry ticket.

Stalemated in New York, Goodyear went to Boston. There he located the now bankrupt Chaffee and arranged to occupy the idle plant of the defunct Roxbury India-Rubber Company. By this time he had patented a process for making rubber shoes, and had sold the rights to a factory in Providence. By the end of 1837 he again boasted a bank account. His family was comfortably housed in Roxbury. He opened the Roxbury plant to manufacture tablecloths and piano covers. He acquired patents for processing rubber with sulphur, as well as with nitric acid. Impressed by the fact that rubber containers, when filled with air, float with great buoyancy, he undertook to make life preservers for steamship companies.

Then a great stroke of luck came his way: from the United States Post Office he succeeded in obtaining an order for 150 rubber mailbags. This progress encouraged him mightily; but the nemesis of unvulcanized rubber still pursued him, as it had others. One day he returned from a short absence to find his factory idle. Worse yet, the warehouse exuded an unusual stench. As with Chaffee before him, the rubber goods had gone "sour": the valued government mailbags and the life preservers had fallen victim to a sudden rise in temperature. The handles had come off the mailbags, and the floor was plastered with malodorous gum. Once more Goodyear was bankrupt! But he was far from beaten, for he stood upon the threshold both of a dirty factory and of a dazzling success. Within a year, he had discovered the magic of vulcanization.

The true facts about this momentous feat are open to question; but it is comparatively certain that it happened in Goodyear's home in Woburn, Massachusetts, during the bitter winter of 1839. On the statue of Goodyear which was unveiled at Akron, Ohio, "World Capital of Rubber," during the Goodyear Centennial Celebration, the date is listed as February 23, 1839. That may be correct; it is at least a reasonable guess.

At this point perhaps some mention should be made of just what it was that Goodyear found out about rubber that nobody had ever known before. What is vulcanization? The correct scientific reply is that, in spite of over a century of investigation by the most competent research workers, its exact nature is still a mystery. However, certain known fundamental facts will make sufficiently clear the revolutionary effect of Goodyear's discovery.

The reader will remember that rubber shoes imported from Brazil in the 1820's were so highly susceptible to changes in the New England climate that they were all but useless; and the tragedy of the mailbags was only one of dozens of such mishaps that had beset Hancock, Macintosh and other workers, as well as Goodyear. When gum rubber is heated, it first softens and then melts to a sticky liquid, and can never be restored to its original condition. On the other hand, it can be chilled to such fantastically low temperatures that it will shatter into a thousand fragments, just as if it were glass, when struck with a hammer; when it returns to normal temperature, it is as good as ever. This is equally true whether the freezing lasts for ten seconds or ten weeks.

Goodyear had wrestled for years with the problem of finding some treatment that would prevent this sensitiveness to temperature change—what scientists refer to as "instability." He had experimented tirelessly with dozens of ingredients, but only two—magnesium and nitric acid—had done the slightest good. He did finally hit upon the fact that, by adding a little sulphur to rubber and heating the mixture, profound and amazing changes occurred throughout the mass. Not only was the rubber no longer susceptible to heat and cold, but it was immeasurably stronger, more resilient, and more durable than the crude material. The chemistry of this remarkable transformation is superficially simple enough: under the influence of heat, the sulphur molecules bind themselves into the carbon structure of the rubber; the more sulphur the stiffer the product, until, when 32 per cent of sulphur is present, the rubber is as hard as a phonograph record.

The most important changes caused by vulcanization are these: (1) rubber is no longer sticky, but firm and dry; (2) its strength is tremendously increased, so much so that it can sustain weights of more than two tons per square inch, when properly compounded; (3) it maintains its strength at all normal temperatures; (4) its "permanent set," as described in the Foreword, is tremendously reduced—it does not fatigue nearly so fast as crude. Just why all these things happen is still an unsolved problem; the vital point is that they do happen. Thanks to the indefatigable Goodyear, rubber was changed overnight from an interesting curiosity to one of the vital substances of the modern industrial world.

Returning to the details of the actual discovery, the story has long been told of how the discouraged inventor, having promised his wife that he would give up experimenting, had one day been struck with an idea which led him, in his wife's absence, to attempt several new methods of treating rubber. Among other trials, he had mixed sulphur with a piece of gum rubber; hearing his wife returning sooner than he expected, he threw all his samples into the stove, to prevent her from knowing that he had resumed his interest in rubber. Some time later, so the story goes, he returned to find that the piece of rubber which contained sulphur had become firm and resilient.

There is little need to rely on such stories, which seem to grow up about every great deed or discovery. But it is well worth quoting Goodyear's own account, as given in his autobiography, *Gum Elastic,* not only for the account of the discovery itself, but because it reveals the qualities of mind that mark the true scientist. In refuting the contention that it was an accident, Goodyear states his case perfectly clearly and correctly; the actual heating of a rubber-sulphur mixture may have been accidental, but the significant fact is that it would have gone unnoticed by anyone with a less observant and intuitively scientific mind.

"At the factory at Woburn, and at the dwelling where he stopped whenever he visited the main factory at Woburn, the inventor 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 specimen, being carelessly brought in contact with a hot stove, charred like leather. He endeavored to call the attention of his brother as well as some other individuals who were present, and who were acquainted with the main factor of gum elastic, to this effect, as remarkable, and unlike any before known. . . . The occurrence did not at the time appear to them to be worthy of notice. . . . 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. . . . Upon further trial with heat, he was further convinced of the correctness of this inference by finding that India-rubber could not be melted in boiling sulphur at any heat ever so great, but always charred. . . . On ascertaining to a certainty that he had found the object of his search, and much more, and that the new substance was proof against cold . . . he felt himself amply repaid for the past. . . .

"It being now known that the results of the vulcanizing process are produced by means, and in a manner, which would not have been anticipated from any reasoning on the subject, and that they have not yet been satisfactorily accounted for, it has been sometimes asked how the inventor came to make the discovery. The answer has already been given. It may be added that he was many years seeking to accomplish this object, and that he allowed nothing to escape his notice that related to the subject. Like the falling of an apple, it was suggestive of an important fact to one whose mind was previously prepared to draw an inference from any occurrence which might favor the object of his research. 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. . . .

"It may, therefore, be considered as one of those cases where the leading of the Creator providentially aids his creatures by what are termed accidents, to attain those things which are not attainable by the powers of reasoning he has conferred on them."

In the light of this account it is a grave injustice to attribute Goodyear's great discovery to pure accident, as is so often done. It falls into the same category as Watt's discovery of steam power and Archimedes' discovery of the principle of specific gravity. All were precipitated by some chance occurrence, which would have passed unnoticed had not the mind of the genius who perceived it been prepared by years of studious thought on the subject to seize on the fact and interpret it. Indeed, Goodyear's right to be ranked among the world's great scientists and benefactors of mankind rests upon the fact that he, and he alone, was able to appreciate the importance of what he saw.

Though Goodyear's dawn had broken, the day was still unmercifully cold. During two bitterly impoverished years the discovery of vulcanizing went unnoticed. Goodyear was again destitute. Once more he sold his household goods to buy food. Then he hung out a shoemaker's shingle and began working with awl and jackknife.

In the meantime he undertook to make vulcanization patentable. First it was necessary to establish the exact degree of heat and the length of processing time. According to his memoirs, Goodyear baked rubber in his cookstove oven, boiled it in saucepans, hung it over the teakettle spout, and roasted it in ashes, in hot sand, over slow fires and over quick fires. Village neighbors regarded him as an imbecile, although relatively harmless. Bankers and other moneylenders spurned him. His health declined. He feared that death would overtake him before people could be made to realize the significance of his great discovery.

The winter of 1840 was a hard one. Goodyear's children were hungry. Undersized potatoes became the household fare. Goodyear sold his books, even his children's schoolbooks, for bread money. His family lived on the charity of neighbors until a gentleman of New England named O. B. Coolidge advanced him money with which to buy groceries for the five young Goodyears during the long and bitter winter months.

Then the frail champion of rubber received a check from a Paris manufacturing concern for the French rights to an acid gas process for improving rubber which Goodyear had recommended three years before. Some conception of the man's unswerving honesty may be gathered from the fact that he returned the check with the explanation that he had found a new method which made the use of acid gas obsolete. Bedeviled by debt and privation, the poor man tramped to Boston from Woburn to seek a $50 loan from an acquaintance. His request was refused, and Goodyear was unable to pay a five-dollar hotel bill. The hotelkeeper promptly resorted to the time-honored cure for loose fiscal policy: he had Goodyear jailed.

The victim was philosophical. He is said to have remarked, "This side of the grave, one resting place is as good as another."

After a month of this involuntary rest, Goodyear was again released. He walked the fifteen miles to Woburn, and on arriving home found his baby son dying of pneumonia. Penniless, he began writing letters. One recipient sent him seven dollars; another donated a barrel of flour. Finally, William De Forrest, Goodyear's wealthy brother-in-law, lent him $50 for a trip to New York. That was in late 1840, more than eighteen months after his discovery of vulcanization.

In New York, Goodyear came upon a merchant named William Rider, who showed an active interest in the "crazy tramp's" idea for pressing threaded rubber into cloth. Rider provided the money for opening a small factory in Springfield, Massachusetts. William De Forrest then joined the venture. Two years later the factory started the manufacture of "shirred goods." Charles Goodyear and his rather querulous financial backers installed two of Charles's brothers, Henry and Nelson, as foremen.

For a wonder, the venture began to prosper; but Charles Goodyear quietly withdrew and began investing his share of the profits in continuation of his research. He devised rubber walking sticks, hard-rubber combs, rubber handles for knives and forks, rubber watch cases, rubber book covers, and—believe it or not—rubber sails for clipper ships.

The invention of vulcanization was made at a time when steamships were beginning to prove their place as masters of the essential lanes of American coastal shipping, and of the rich spice-trade routes to the Far East. Goodyear himself was enormously interested in steam engines and the part to be played by rubber in their development. He could hardly have failed to realize the particular importance of the steam engine at sea. Yet he apparently believed that rubber sails could help preserve American leadership in sailing. He pointed out, with sea-captain customers in complete agreement, that a rubber sail, which is impervious to mildew and more resistant to weather than cloth, could do more work per sail yard and far outlast the best of canvas and would thereby justify its higher initial cost.

But rubber for sails was only one among hundreds of uses devised, recommended, and proved by Goodyear. With the asset of a modest royalty income from the De Forrest Company and pittances acquired here and there by releasing other of his rubber inventions, the jaundiced, hollow-cheeked Yankee spent happy years toiling with rubber in his home laboratory. He made rubber lifeboats and hip-length rubber boots; rubber teething rings and nipples (for an era of breast-fed babies); rubber coats, shoes, gloves, and sport boots; rubber knapsacks, tents, and blankets for use by the army (goods which were destined to play noteworthy roles in the Civil War). He also devised elastic cords, rubber sponges, and an enormous number of hospital and sickroom supplies. He projected solid rubber tires for buggies, chaises, and wagons, and even for wheelbarrows. He developed a cartman's bag of rubber, as well as rubber mailbags, doormats, carpets, window strippings, covers, and boat calkings. He invented much as Franz Schubert wrote music: shrewdly, rapidly, and with inspired opportunism, yet apparently with little understanding of, or interest in, the value of his inventions. He hurried incessantly, sick much of the time and fearful that death might overtake him with the greater part of his work yet unfinished. Unlike his father or his brothers, Charles Goodyear was not at heart a manufacturer; as soon as an invention was ready for the factory floor, he lost interest in it. He lacked any very clear idea of the value of one invention as compared with that of another. And he had heart-rending troubles in the matter of patent protection.

His bitterest patent fight involved the famous process of vulcanization. Our national Patent Office was not founded until 1836. Its earlier services were almost entirely concerned with New England industries, which were being stimulated by abundant water power and water transportation. Goodyear was among the Patent Office's first and best customers. But his patent for vulcanization was not granted until June 14, 1844—more than five years after his discovery of the process. Goodyear himself was partly responsible for the unfortunate delay. Instead of rushing to make a claim of whose value he was not certain, as is the modern practice, he waited to complete hundreds of home experiments with rubber and sulphur in many combinations and with varying degrees of heat. This fact marks him as an instinctive scientist rather than a money-getter. Remembering the unhappy venture in rubber mailbags and life preservers, which had fallen to pieces and become foul-smelling goo, he deferred the final patent until vulcanized goods had been proved in practical use. His more financially practical brothers had advised him to file patent applications simultaneously in the United States, France, and England, then the three most promising industrial nations. Lacking ready cash with which to file application for foreign patents, Goodyear had in 1841 filed at Washington a caveat, or statement of intention of seeking a patent on the vulcanization process.

On May 31, 1844, fifteen days before Goodyear finally received his patent certificate at Washington, the British government granted to Thomas Hancock of London and Birmingham a patent for a vulcanizing process substantially the same as Goodyear's. Later, under oath of British court, Hancock admitted that he had first learned of vulcanized rubber from samples Goodyear had submitted to a British manufacturer in an attempt to sell the manufacturing rights. But British courts and his Majesty's government declined to revoke the Hancock patent, pointing out that British law, justly or otherwise, confirmed patent rights to the individual who was first to receive a certification of patent.

Goodyear's struggles with patent infringement give proof of the Yankee's persistency, and showed, too, that at last a wealth-seeking world was awakening to the almost inestimable value of vulcanized rubber. Goodyear sold, leased, and gave away rubber manufacturing concessions to dozens of firms and individuals, sometimes parting with patent rights for a pittance and frequently accepting royalty rates that were absurdly low. Industrial piracy was rampant; patent laws were shot through with loopholes. During the twelve years between 1840 and 1852, the premier New England inventor, in proving his role as world pioneer in rubber technology, initiated and fought at least thirty-two cases in the Supreme Court of the United States, most of them to protect the companies or individuals to whom he had sold, leased, or given manufacturing rights to his inventions. . . .

A prime violator was Horace H. Day, a young manufacturer of New Brunswick, New Jersey, who was among the principal exploiters of the many flaws in early patent statutes of the United States. During the gold-rush days of 1849 and 1850, Day had manufactured and sold without patent rights both the rubber-inflated boats and the rubber tents which Goodyear had developed and patented more than a decade earlier. Then Mr. Day began the highly profitable manufacture of shirred goods, or rubberized cloth, for the immensely fashionable ruffled shirts worn by well-dressed blades of the 1840's. Insolently disregarding the Goodyear patents, he refused to pay any license fees, even though Goodyear had asked only three cents a yard for patent rights for shirred cloth which was sold for five and six dollars a yard!

Horace Day let it be known that Horace Day was a bad hombre and that the sickly Connecticut tinker would do well not to provoke him. Unintimidated, Goodyear went to court and entered suit against Day for infringement of patents, employing as his personal counsel the ablest lawyer of the times, Daniel Webster himself, who required a fee of $25,000. As his own counsel Day lured Rufus Choate—who, next to Webster, was probably the most famous lawyer of the time, and also one of the shrewdest. Day charged Goodyear with monopoly, intervened with Congressmen, and launched an audacious campaign to have all Goodyear patents annulled. The trial took place in the Federal Court at Trenton. Webster and Goodyear won. The court pronounced a decree of perpetual injunction against Day's use of the vulcanization process.

Webster made a superb summation and appraisal of the case. In part he declared: "This discovery will work important changes. It introduces a new material into manufacture, nothing less than elastic metal. That is as momentous a phenomenon as it would be to show that iron and gold could remain iron and gold and yet become plastic like rubber. It cannot be denied that somebody made this invention. Who is he? There is not in this world a human being who can stand up and say that this is his invention except the man sitting at this table [Charles Goodyear]."

The court's ruling was no less epochal. It questioned: "When genius and patent perseverance succeed, in spite of sneers and scoffs, in perfecting a valuable invention, how seldom is it followed by reward? Envy robs him of the honor, while speculators, swindlers and pirates rob him of the profits. . . ."

In previous years, Webster had been a personal enthusiast for rubber wares and for Goodyear's elastic creations. In fact, Goodyear had once presented him with a raincloak and hat and high boots made entirely of heavily rubberized fabric. The great Webster was deeply touched. It was summertime, and the rubber togs were too sticky to wear; but Webster promised to make good use of them during the cold weather of the coming winter. But when winter came the rubber wares lost their summer stickiness and became like cast iron—so stiff that they would stand alone. The story goes that Webster set up the boots and cape on his doorstep and placed the helmet upon the shoulders of the cape. Passing neighbors looked on, and when they saw the veritable pillar of cold rubber goods they said, "Shhhh. . . . Quiet. The Great Man is thinking. . . . Do not disturb. . . ."

Goodyear's historic legal victory over Horace Day did not mark the end of his strife in court nor of his restless and sometimes frenzied determination to discover more uses and fabricating processes for rubber. He described the patent laws of his time with typical Yankee terseness: "They do not protect the inventor. They merely give him the right to defend his inventions—at his own expense."

The expenses were great enough to keep Goodyear poor; sometimes in debtors' prison, frequently in beggary. Nevertheless, he continued to make discoveries and to announce inventions: that was his creed, his purpose, and his lifework. Five years after his discovery of vulcanizing, Goodyear was once more in jail for debt, this time in Springfield. When released, he transferred all his patents, both past and forthcoming, to the company controlled by his brother-in-law, De Forrest, and by his brothers, Henry and Nelson Goodyear.

At fifty-one the frail inventor planned a good-will trip to England and an exhibition of his principal triumph in Queen Victoria's World Exposition, which was housed in the Crystal Palace of London. It was the first of the great world's fairs. The Goodyears had been Englishmen. Charles pictured England as his second home, and the world's foremost stronghold of industry. He scraped together $30,000 to invest in his London exhibit to show the importance of rubber and perhaps to indicate how unjust had been the British patent granted to Thomas Hancock. The London exhibit was successful in that it was widely praised. But it brought no financial reward, and no step toward reversing the Hancock patent.

In Paris, meanwhile, Louis Napoleon was planning an exhibition intended to put Victoria's completely in the shade. Goodyear resolved to take part in this show of shows. His collection of royalties had improved under his brothers' direction, and he dug up the last dollar of his resources—and is even said to have pawned his wife's jewelry—and went to Paris. There he placed contracts for an immense rubber exhibit to be climaxed by displaying his own invention of a combination mill and calender which would produce rubber goods while the crowds looked on.

Paris newspapers and the French public generally were favorably impressed. So was Louis Napoleon, who made ready to bestow on the Yankee inventor the precious Cross of the Legion of Honor. Goodyear received a tremendous ovation, perhaps the most enthusiastic Paris ever accorded any American since Benjamin Franklin —a fact which could not obliterate the grim truth that he had overspent his resources and was unable to pay the contractors who had built his great exhibit. They soon began to wail, shout, and gesture after the manner of creditors. Goodyear pleaded with them to wait, to be patient, to understand that rubber meant more than mere money, that it meant a better life for all mankind. But the French creditors were not interested in these altruistic sentiments; they were not patient, and they did not wait. Instead, they obtained warrants for his arrest. In December, 1855, Charles Goodyear, sick and crippled, was pulled from his hotel bed by three gendarmes, taken forcibly to court, and most precipitately introduced to the Clichy jail.

Juliette Wardell, his second wife, pleaded with the constabulary to release him, pointing out that her husband was ill. In London, as a matter of fact, he had been stricken by a virulent inflammatory rheumatism, and was able to hobble about only with the assistance of rubber-padded crutches. But his wife's pleas were not effective. The gendarmes haled the sick man into night court and the judge pronounced an indefinite jail sentence on grounds of fraudulent evasion of debt.

The Clichy jail was notorious: its kennel-sized cells were entirely unheated; its walls were dark and without plaster; its floors of badly worn brick. It had no beds except piles of straw thrown hastily into corners. Mrs. Goodyear begged permission to go to jail with her sick husband, but that pathetic request was refused too. The December weather was bitter cold. The aging and enfeebled Goodyear spent sixteen days in the icy cell before an imperial order, resulting from a personal appeal to Louis Napoleon, set him free. During that terrible term the Cross of the Legion of Honor had been pinned upon "France's benefactor" from Connecticut—in jail!

Goodyear, now seriously ill, hurried to England with his wife. But the French creditors were in lusty pursuit and the inventor's welcome to Merrie England was another sentence to a filthy, bedless, cold jail cell. Then long-delayed royalty payments arrived from Boston. Still sick and almost completely paralyzed, Goodyear paid his way out of the London jail and with his wife proceeded to Bath.

He spent two years at that health resort, too feeble to travel farther, always hopeful of regaining health, yet thoroughly disillusioned and embittered toward both France and Great Britain, whose manufacturers had already realized great wealth from his invention, while their courts and sadly misnamed public servants had dealt coldly and unmercifully with him, whose superhuman struggles had supplied the world with one of its most indispensable commodities.

With little improvement in his physical condition, Goodyear returned to the United States in 1858, to find his affairs deplorably mismanaged. On every side his patents were being defied or pirated. Debts incurred in England and France had melted away his royalty checks. His brothers, and other agents and advisers, had managed unwisely. At fifty-eight the great Goodyear was again poor and homeless.

During June of 1860 he traveled to Washington to reopen the defense of his patents. While there he received a summons to New Haven, where his oldest daughter was dying. Too sick to attempt the trip by the jerky, rough-riding trains of 1860, he decided to travel by steamship. But the seas were unusually rough. The sick man grew sicker, and when the ship called in New York harbor Goodyear was taken to a hotel, where he died on June 30th.

By now he had become famous. New York newspapers published gracious obituaries of the "India-rubber man." Several financiers estimated his wealth at millions of dollars. Almost all the rapidly expanding rubber industries of 1860—and today—were built on Goodyear patents, inventions, or discoveries. The fact was that Goodyear died far poorer than most paupers. Probate inquiries showed unpaid debts of at least $200,000. In time Goodyear rubber royalties repaid these arrears and left a posthumous estate. But death, like life, was rather unkind to the man who made himself the prophet-creator of rubber, who had proved himself one of the greatest and most prolific of all American inventors.

AMAZON RUBBER

4

THE rubber which Charles Goodyear used in his work must all have come from the river-swept Amazon jungle of Brazil. According to the best available records, little or no crude rubber had been imported into the United States at the time of Goodyear's birth in 1800. Consistent records first began to be kept in 1826, when the genius from New Haven was running his pioneer hardware store in Philadelphia; at this time the United States was importing about eight tons of Amazon rubber per year —less than the amount required for "finishing off" one modern destroyer. When Goodyear died in 1860, this figure had climbed to about 600 tons.

Significantly, rubber had gained in value during those six decades. The first cargoes of biscuits of wild rubber had been taken on merely as ship's ballast, bartered from Brazilian Indians and sold to the highest bidder at New England seaports. By 1860, however, rubber brought about 70 cents a pounds at New York or Boston piers.

The wild rubber industry of the Amazon has been an amazing and tragic epic. After Goodyear's death, thousands of brave simple men were to devote their efforts and their lives to supplying the substance which he had learned to use so advantageously. We have never heard their names and we scarcely realize what their lives were like. And still are, for that matter. One man, for purposes of illustration, may well stand for all his comrades, past and present.

Call him Juan Fialho. He is a *seringueiro,* a harvester of Hevea rubber. In ancestry he is a *lapino*—the blood of colonizing Spaniard mixed with that of Juiloto Indian. For the Amazon jungle, that is a good blend. On the whole, the lapinos have survived the steaming heat more successfully than other seringueiros who were Negroes, mulattoes, or cholos.

Juan Fialho reminds you tactfully that on the whole his kind of seringueiro has outlasted all competitors, or rather all men mad enough, or sufficiently misled, to be lured into the Hevea jungles. Juan is broad-shouldered and square-chested; his scraggly black hair has now turned gray; and though he squints with watering eyes (the result of smoking rubber above enclosed smudge fires) he points out that the fact that he is not completely blind constitutes proof of the goodness of God and the effectiveness of the shiny teakwood crucifix which has dangled at his throat night and day for more than forty years. Indeed, God has permitted very few seringueiros to remain alive in the jungle for forty years, and still fewer to have eyesight, square shoulders, and comparative sanity at the age of sixty.

You would better appreciate the truth of this statement if you had ever seen a seringueiro at the end of a typical rubber-gathering day; if you had seen his eyes—tired, bloodshot, and sunken from excruciating hours in a densely smoky *fumador;* if you had heard his spasmodic, rasping cough; if you had beheld his half-naked body, gray and black with smoke, soot, and slime; if you had noted the conspicuous pallor which results from imprisonment in the reeking, miasmic jungle—marooned by high waters during floodtime and splashed with spongy mire and milk-rubber stains during the drier seasons which are the principal harvest periods for Hevea.

Such, senhor, is the man who harvests jungle rubber, who introduced the blessings of rubber to his fellow Americans and to the whole world. Such is an American whom almost all but God have forgotten: both the basic producer and the primary victim of an industry which has invited and tolerated much of the basest and cruelest persecution ever visited upon humanity.

But it is not enough to deduce a man's story merely by looking at him when his work day is ended. It is well to look earlier and longer, to see the past as an integral part of the present and the future. Forty years ago, when Juan Fialho first took to the jungle, the great rubber boom of the Amazon was only beginning. Yet even then it was easy to distinguish the seringueiro from other laborers by his pallid or jaundiced appearance and his "jungle slouch." Many seringueiros could once be seen tramping the old river-port towns, heavily burdened with the tools of their trade, especially *machadinos,* or tapping knives. These were thin, dull hatchet blades (dull because it was feared that sharp blades might destroy the wild Hevea trees which were making the rubber traders rich) with yard-long handles with which the seringueiro could reach far above his head and thereby increase his take of rubber milk, however ruinous to the tree. Seringueiros of earlier days also carried *baldes,* or galvanized-iron buckets for carrying home the milk, and *tichelas,* or catch-cups, to be driven at the base of the spiraled trunk wounds—from one to a dozen to each tree; they were also equipped with burlap shoulder saddles for carrying the pelles of smoked rubber, which weighed anywhere from 50 to 150 pounds.

Then, as now, most seringueiros were men of depressed silence, who rarely spoke except when they drank or fought—men dissuaded from even drinking and fighting by the isolation and infinite solitude of the great jungle. Like the open-range sheepherder, the seringueiro has remained an unsung citizen of great silence—a silence born of loneliness, of weariness, and sometimes of hopelessness.

Talk to a seringueiro two hours and he may say "Si, senhor" once or he may not speak at all. He may say "Estrado," which is a name for a section of forest containing somewhere between 75 and 150 rubber trees, preferably connected by footpaths and comprising the work assignment of one seringueiro. Or he may say "Seringal." That means a still larger stake of wild Hevea trees—from two to a dozen or more estrados. But uncounted millions of Brazilian Hevea trees do not grow in estrados or seringals, and have remained beyond the reach of what informed men until recently regarded as suitable for harvest.

He may speak of *defumador,* the small, tightly built room, or partition, of his shack which he uses for smoking the perennial "take" of rubber; or the *beyon,* an egg-shaped earthen flue which collects the smoke for coagulating the harvest of rubber milk. He may also refer to his *mango,* the wooden pole which he turns above the smudge fire in shaping the heavy pelles. If he speaks the word *reacción* he probably means the type of rubber milk procurable from the trees of his estrado: its odors, whether foul or sweet, and its color, whether honest white or sickly yellow. For when a tree is overbled, or sick, or sometimes for other reasons, a yellowish ooze appears along the edges of the trunk wounds, which seems to have a healing effect upon them.

Admittedly Juan Fialho is not in all respects a typical seringueiro, though many of his kin have been; in fact, the Juilotos were one of the first nations of Amazon Indians to harvest and sell crude rubber to Europeans. Yet he is typical of the men who spend their lives in tropical jungles to secure for man one of nature's most amazing products.

Brazil's great state of Pará was the nursery for an industry destined to gird the earth and to affect the course of great industries and empires. It is divided into some 50 municipalities, 47 of which were producing rubber by 1905. The oldest rubber seringals were located on an island—the Island of Marajó at the mouth of the Amazon—where grew the superfine, or "island," grades of Pará rubber. Other producing areas were opened, more than a century ago, at Camela and the districts of Rios Tocanta, Jurua, as well as along the lower Madeira and Solinaoes. But the blessings of free-growing Hevea trees were not stinted: thousands more seringals were latent in the valleys of less-known rivers; along the headwaters of the larger Amazon tributaries, in the state of Matto Grosso; along the lush frontage of the Acre and Purús; and in scarcely penetrable lowlands far back from the all-important rivers. Farther west, beyond the million square miles of low, rolling basin lands which are the home of Hevea, lie extensive supplemental stands of Castilloa trees, also called caucho and ule.

In Brazil the harvesters of this backland cousin of Hevea rubber are called *caucheros*. As Juan Fialho reminds us, the caucheros are by no means the equal of the seringueiros. As a rule the free-lance harvesters of castilloa rubber are merely tree hunters—not career harvesters, but occasional exploiters. The Castilloa tree, yielding latex much more rapidly than Hevea because of the structure of its cells, readily lends itself to the type of exploitation carried on by these hit-and-run gatherers. Most caucheros are roving Indians, or *mozos* (lowlier farm laborers), who vary their tenure of *milpas,* or garden fields, with intermittent raids upon Castilloa stands. The cauchero is usually in a hurry. Swift exploitation is his habitual working strategy: to snatch the latex at its place and time of maximum flow, frequently destroying the entire tree in the process. For a century the reckless tapping of Castilloa rubber has been ominously destructive of native resources and a practice which no worthy seringueiro condones.

There were and are bad seringueiros, as Juan Fialho readily agrees: tappers who build slow fires at the base of the Hevea tree and thus force the latex to flow rapidly into catch-cups, even though this perversion damages or even kills the tree. There are others who practice "high tapping" in an effort to take more than a reasonable quantity of rubber from each tree, climbing ladders and slashing the bark high into the limbwood area. This abuse also ruins the tree. On the contrary, like the somewhat fabulous North American lumberjack, the good seringueiro, however poor, lowly, and oppressed, respects the tree from which he takes his livelihood and regards it as a dependable crop to be harvested intelligently at the proper time.

While tossing away one long cigarette and hurriedly lighting another, Juan Fialho injects the comment that in the past many thousands of seringueiros never had a chance to be good ones. That, senhor, is a sad story, which goes back into an unhappy and heavily shadowed past—a past which most unfortunately is still part of the present and future of the South American rubber industry. It is the old, drab story of human greed, incompetent leadership, and unfortunate racial clashes; of peonage and rumswilling bribers; of bad food, bad housing, and a general decadence permitted to exist by a coterie of unscrupulous exploiters.

Speaking as a son of these productive lands, Juan Fialho begins his story in an understandably human way—with a discussion of seringueiro food. If food is the staff of life, the Amazon rubber harvester was left to lean on an exceedingly slender reed. *Xarque,* dried or jerked beef of the lowest imaginable quality; *farinha,* a flour made from the starchy root of the cassava; corn and salt; coffee, sugar, and lard (the latter only when conveniently available); and "jungle-kill," such as fish and sea cow collected by the seringueiro's own initiative and marksmanship—through the dark decades of rubber this has been the standard fare of the native tappers.

Seringueiro housing has been, and unfortunately still is, an intolerable disgrace to humanity—a dreary repetition of poorly built shacks improvised of logs, jungle palms, mud, or whatever building material happened to be most convenient and cheapest; they usually lack floors, windows, doors, beds, ordinary furniture, and privies. Ordinarily, a hammock swung between wall poles serves as a bed. The roof normally leaks, particularly during the long rainy season, and each shack has its customary complement of mosquitoes, lice, and other unwelcome callers. Insects are eternally ubiquitous, and there is rarely time, money, or energy to open the jungle to admit the cleansing sunlight. As a result, the air remains suffocating and water-laden.

Juan Fialho then speaks of his own people, the Juilotos, who were among the first victims of the great rubber rush of the Amazon. For centuries these Indians had remained a peaceful and honorable folk. We are apt to think of the coming of the white man's civilization as a step forward, culturally speaking. But the Amazon Indians, like the Fascist victims of Mussolini, have suffered from the white man's stupid attempts to impose a decadent concept of empire upon them. The Juilotos, too, have suffered from interbreeding with other races. They have witnessed the rise of the cholos, the mestizos or lapinos, mulattoes, and some measure of cross-breeding with Japanese and other Orientals. This miscegenation, perhaps inevitable, need not be considered deplorable simply because it occurred, but it has radically altered the outlines of the familiar Indian world.

Before 1825 a great many of the Amazon Indians were like the Juilotos—happy, agrarian people. They raised cattle, cultivated small fields, and built habitable homes. Then came the rubber rush. In 1825 it is probable that all Brazil exported less than 30 tons of rubber, which was most of the world's supply. By 1830 the total was 156 tons; by 1840, 388 tons; in 1850 it was 1,467 tons and in 1860 it was 2,670 tons. These were all small dribbles. But by 1897 there were being exported 21,260 tons of raw rubber, and the rubber rush was really under way. By 1909 it was in full swing, and for four years thereafter Brazilian rubber exports averaged 42,000 tons yearly. The borders of the jungle were being populated with English, German, Italian, United States, and Brazilian "rubber barons," *as well as saturated with fraud and peonage.*

The recruiting of Indian labor was off to an evil start—a system built upon slavery, usury, and other kinds of oppression. By 1907 Indian farm lands and villages were being abandoned. At Manáos and other river ports of the new rubber frontier, all commodity prices were soaring: eggs, when buyable, were $1.25 a dozen; bread, 30 cents a pound; farinha, or tapioca flour (often weevily), the staple food of seringueiros, was scarce at prices from $3 to $7 per 65-pound basket. Riverboats were hauling cargoes from Belém to inland riverports at fantastic rates. Fortunes were being made rapidly and easily; clans of middlemen were rising; self-constituted masters of men were out to recruit Indian labor, since the fabulous wonders of Amazon rubber inevitably depended upon the seringueiros.

On the whole, this recruiting process was thoroughly infamous. It usually began with bribery. The peon hunter, or *patrao,* went among the Indian villages and made advances to the desirable men, usually not in money, but in coveted materials, such as firearms and ammunition, sewing machines, ready-made clothes, musical instruments, and other merchandise attractive to the naïve Indians, most of whom had little or no money. Accordingly, the peon hunter priced his goods in terms of specified days or weeks of labor. For the Indian this proved a first step into peonage, for the specified periods of servitude were destined to stretch out interminably, even to death. The first stage was frequently the assignment of navigating the rubber buyer's canoe up the jungle-walled rivers. After that the peon was put to work clearing brush and trees for loading "spots" on the riverbanks, at locations convenient to the newly marked seringals. Then came the task of building houses and compounds for the exploiters. When these were properly built, the poor Indian was sometimes permitted to build himself a shack at a discreet distance from the master's place or, still more economically, to sling a fiber hammock between two trees and sleep in the open with the bugs.

That marked the transition from bonded service to slavery. Being still moneyless and far from his home and familiar surroundings, the Indian inevitably became a seringueiro. Escape from the deep jungles was all but impossible. Usually the peon was not permitted to own a boat or to build a raft. The *aviado* then sold his peon shoddy food, shabby clothing, and other "goods" for payment in rubber, demanding exorbitant prices for them and paying ridiculously low prices for the rubber. Meanwhile, the victim was held in debt which he could not possibly pay. He was beyond the reach of law or courts: jungle law was a law of stealth, brute strength, and death-dealing firearms.

It is a tragic, horrible story. But we *norteamericanos* did not notice: we wanted the rubber; we got it. Moreover, during all the bitter, humid years of the Amazon rush we were tolerating and more or less directly encouraging within our own boundaries a comparable peonage of the Negro sharecropper of the South. As a matter of hard fact, we still connive at a considerable measure of this peonage, even while the government of Brazil, under leadership of President Getulio Vargas, is making valiant efforts to blot out the peonage of the rubber jungles.

Juan Fialho, for whom eyes were made for seeing and ears for hearing, observes that behind the tyrant aviado stood other tyrants of Amazon rubber. There were the boss aviadores, who furnished the jungle exploiters with money, credit, and goods, all at fantastic profits. Next in line were the exporters of rubber, the smooth-handed hombres, who sat in the cool shade of cities and lounged at the *cantinas* while cheating both aviados and aviadores. These exporters controlled the banking business of the Amazon, and accordingly they made certain that their own profits were handsome and their risks small.

That was the Amazon rubber picture in 1903, when our Juan Fialho entered the trade whose control was being lifted bodily from the trusting and helpless hands of his people. At Pará and Manáos he beheld the huge commissaries, the great buildings—there was even an opera house, the shiny carriages, and the elegant raiment of the aviadores and their senhoras; he heard the get-rich-quick plutocrats explain how one healthy Indian seringueiro, when shackled by debt, was worth 1,000 milreis in gold, and how as much as 500 milreis was being offered for the "recruitage" of one harvester of wild rubber.

Among the river towns Juan Fialho, who even then spoke Portuguese well, witnessed still another act of the steaming, bloody drama of the Amazon rubber rush. That was the drab story of river transportation in the Amazon Basin, a story marked by a strong British accent. The first Amazon transportation system was the Booth Steamship Company, a shipping monopoly which plied from England, Europe, and the United States to Pará, Manáos and Iquitos, and was supplemented by coastal service to the south of Brazil. Second in power and extremely able in profitable "co-operation" with the Booth Steamship Company was the Amazon Steamship Company, which operated river shipping from Pará and Manáos to the principal tributaries of the Amazon, including river routes to Peru and Bolivia, to the distinct financial advantage of an absentee British directorate. As a further supplement, the Amazon Navigation Company operated fast, shallow-draft steamers which plied some of the smaller Amazon tributaries. But there remained hundreds of still smaller rivers and channels which could be navigated only by small launches, barges, canoes, or other hand-propelled craft.

Transportation is the lifeblood of the rubber industry. In most Amazon lands, rivers are the only channels of trade, railways and even poor roads being unknown. The exploitation of Amazon rubber faced the costly reality of great distances between ports. The trip by river from Pará to Porto Vilho on the Madeira is 1,718 miles; to Iquitos, in Peru, the river distance is 2,651 miles; to the ports of the Acre and the Purús, about 3,000 miles. Such long distances, combined with slow boat speeds, called for ship capacity that was never adequately provided. Great rivers, such as the Tapajós, Pinheiro, and Mosquero, had only decidedly intermittent boat service, and the Xingú, Coqueta, Guana and others had no shipping service at all, except by occasional private boats. Some of the larger seringals were equipped with small launches or motorboats to carry out the rubber and to bring in food and other necessary supplies; but the more distant and often the most productive ones depended upon canoes, rafts, *cayucos,* and human brawn for the final haul.

The tremendous distances and perennial uncertainties of the Amazon riverways spelled slow and costly transportation. They still do: and this is another important reason why the rubber industry was never scientifically developed there. But the shipping rackets of the great rubber rush made matters far worse than necessary. By 1910 Brazilian government experts estimated that between 20 and 60 per cent of the combined cost of rubber was incurred in transportation. The average river haul was about 35 days, with an additional five days for port calls and wait-overs. On the whole, the operation of riverboats was grossly incompetent. Boats were left to rot in idleness. Passenger and freight charges were exorbitant, and crew wages deplorably low. Accident and death rates among riverboat workers were cruelly high. Frequently the boats were poorly equipped and officered. Too frequently peon crewmen lost life or limb needlessly because of tragic inexperience and poor supervision. Thousands were killed in one way or another at the Falls of Antonio en route to Bolivia. Thousands more died while making portages. Amazon rivers are dangerous in flood and equally perilous in low-water season, when even small boats snarl and grind upon multitudinous sand bars, log jams, and floating islands. In such contingencies, crewmen and passengers alike frequently died of fever.

Juan Fialho points out that the fortunes, indeed the very existence, of Amazon rubber and seringueiros were and are interwoven with the vagaries of riverways and ships. Accordingly, he remembers the difficulties of river transportation as one of the graver complications of the dark years of the rubber rush. But he recalls even more distinctly other evils of those cruel times. Lack of sufficient boats and launches helped make the seringueiro an abject prisoner of the upriver jungles. Ridiculously high boat fare helped to sink him still more hopelessly into debt. But when the boat schedules, such as they were, had been opened, the rubber-seeking patraos and labor contractors went still farther among the Indian villages, painting extravagant pictures of the quick wealth to be gained from harvesting the flowing gold of the Amazon. They signed on hundreds and thousands by advancing boat passage to far-off seringals from which few amateur seringueiros lived to escape. For the total cost of the passage, plus the usual 15 per cent for brokerage, was written against the recruit's name, and the victim was never advised that a seringueiro would be lucky to earn the inflated price of his flour, salt, tobacco, and jerked beef, with a bottle of cheap whisky or rum as an occasional and very special luxury.

But Juan soon learned also that the arithmetic of wild rubber went far beyond the tricky contract forms ordinarily signed with X's; it was and still is an arithmetic of rubber trees. In a well-chosen seringal only about one tree in 80 is harvestable Hevea. As a rule the trees grow from 30 to 300 feet apart, the intervening spaces being crowded with other timber and with luxuriant and often thorny undergrowth, standing ten to thirty feet high, all heavily interlaced with creepers and vines.

These, mind you, were the *better* located seringals. Accordingly, it is probable that at no time during the Amazon rubber rush was more than 1 per cent of the Hevea growth of Brazil actually under harvest. Average yields in smoked rubber were approximately three pounds per bearing tree each year for big Hevea trees, 70 to 100 feet high and from 4 to 7 feet in circumference one yard above the ground. Thus, if a seringueiro worked two estrados, each with 100 bearing trees, his year's work might yield as much as 600 pounds of *borracha fina*—clean latex rubber, smoked so skillfully that the entire pelle from core to outer covering was pale brown, firm, and in stretchable layers, without soft rubber, or *entre fina,* in the center; and free from *grossa* (dirt, bark, ashes, etc.) and *seramby* or *scabe,* which are the stale drippings of latex.

Juan Fialho recalls most vividly that when the staple price for fine Hevea rubber was $1 a pound, prices paid to the jungle seringueiro for rubber in pelles ranged from 2 or 3 to 10 cents a pound. This meant that $15 to $30 a year was a typical income for a good seringueiro, and all these hard-earned milreis were usually required for the necessities of life, sold at enormous profits. The best seringueiros remained perpetually poor and debt-bound. Many went hungry. Uncounted thousands fell sick, died, and rotted in the jungle. Others were flogged to death by law-free patraos. Some were murdered by banditti that hovered on the edges of the jungle.

Indeed, senhores, it was a dark picture, which becomes even darker when one learns more at first hand of the seringueiro's working life. Jungle work is never easy; its disease hazards are terrific. Yellow fever, amoebic dysentery, yaws (a deplorable disease of festering flesh), sleeping sickness, elephantiasis, accompanied by grotesque swelling of the joints, undulant fevers, virulent types of malaria, painful and evil-smelling flesh sores and running ulcers—all these and more were real and terrible enemies of the seringueiros. All remain formidable enemies of man in the Amazon country today.

But deadly microorganisms are by no means all of the seringueiro's perils. There are many dangerous animals in the Amazon wilds, particularly panthers and jaguars; innumerable billions of mosquitoes, stinging gnats, and a hundred other pestiferous insects which swarm above the reeking earth, which may never once have been touched by open sunlight throughout a dozen centuries.

Juan Fialho remembers clearly that a seringueiro had neither time nor space for planting gardens or fields, and no free days for the tillage of mandioca, corn, beans, bananas, and other edible crops even had cleared land been available. It was left to the patrao to grant his rubber-tapping peons a dole of food, tobacco, and firearms. During 1913, when wild rubber of the Amazon was costing United States manufacturers 65 cents a pound (about three times the world price of crude rubber during 1940), seringueiros in the Amazon Basin were literally starving.

Under the best possible conditions harvesting wild rubber is hard, man-breaking work. During the *zafra,* or comparatively dry season in which the principal harvest takes place, a seringueiro could hope for about 70 good days for collecting latex. Those days were not blessed with union hours. As already pointed out, the latex of Hevea trees flows best very early in the morning. Thus the good seringueiro began his day's work by lanternlight; left his shack in black darkness and without breakfast; and, armed with a wounding knife, with buckets and catch-cups, and sometimes with a loaded rifle for defense against prowling animals or for acquiring edible game, he set out down the miry, winding footpaths which led to the scattered trees.

Collecting the day's take of sap, and carrying it back to the smoke room usually required eight or nine hours—provided it yielded as much as 25 pounds of smoked rubber, a minimum stint for a good seringueiro. In the old days much of the sap collection was ladder work; in the lower Amazon country, particularly along the basins of the Purús and Jurua, rubber trees were frequently tapped to heights of forty feet. That was damaging to the trees and dangerous to the men. But it was rarely the free choice of the tapper. Frequently he was assigned a quota of rubber, under threat of beating, starvation, or violent death to be administered by the patrao or his agents. Such threats were hard on seringueiros, and still harder on the Hevea trees. But once the seringueiro was located and effectively subdued, the patrao rarely visited the jungle estrado. It is entirely reasonable to suppose that his absence resulted from his general, if long-previous acquaintance with the typical Hevea forest.

Who should know better than Juan Fialho the life of the Amazon seringueiro, past and present? For he is a seringueiro who has survived forty years of Hevea jungles, and his testimony is therefore a human document valuable alike to the past, present, and future of natural rubber. But, as a simple man situated in a complex, jungle world, Juan is not aware of the beyond-the-jungle phases of Brazilian rubber. Accordingly his story is briefly supplemented.

To a great extent the history of natural rubber is Brazilian history—a page from one of the most significant of all national histories. Brazil still is one of the last huge frontiers left to man; rubber still is vitally important to the life and future of that frontier.

Brazil is considerably larger than the United States proper. Almost 80 per cent of its 3,250,000 square miles are still public, unclaimed lands. In a very real sense rubber remains a backlog of value to this greatest of all public domains. In 1822, when Brazil declared her independence from Portugal, her population was about four millions; now it is between forty-five and fifty million. But there are sufficient fertile and undeveloped lands, with climates tolerable to Europeans, North Americans, and other Temperate Zone peoples, to provide not only homesteads for several times that number, but, quite conceivably, rubber for all mankind as well. The land history of Brazil is clearly relevant to this possibility. The proprietorship of hundreds of millions of acres goes back to Portuguese grants of early colonial times—to the *sesmarias* handed by Lisbon's distant courts to favorites of Portuguese royalty, to army leaders, to politicians, and to spoilsmongers. These sesmarias were huge feudal domains. As a rule they were worked with enslaved labor—principally Indians, bound relentlessly to the land, prodded, flogged, starved, shot, raped, or hanged at the discretion of the owner. All this helped build deplorable traditions of maltreatment of Brazilian labor.

Brazil as a whole has repeatedly suffered the aftermaths of several migrations of frantic wealth seekers, beginning with the gold and diamond rushes of 1693 and 1729 and reaching a frenzied climax in the rubber boom of 1910. These rushes served to upset agriculture, to pull the preponderant coastal population to remote, jungle-strewn interiors, and to leave tens of thousands of farms and villages abandoned.

During 1823, Brazil's first year of sovereignty, only 11 of the 22 states comprising the United States of Brazil (in all about one-fifth of the vast land area) had a population density as high as two persons per square mile, or about the same as that of Arizona. During the half century that followed, frontiers were pushed back from the coast—particularly in the northeast and the southwest. The former move was a greedy extension of the feudal plantations, the latter a beginning of government and private colonization—of future empires of coffee and cattle.

Those were also the times of hirelings, or mercenary soldiers. The Brazilian government had employed police forces, made up principally of German and Irish mercenaries, to patrol its early southern frontiers. They were paid in land—small farms back in the hills, out of the way of the gentry of the coastlines or the huge cattle *fazendas* being opened in the adjoining fringes of plateau.

The Irish, on the whole, seeped away; but the Germans, at least a few of whom were the counterparts of Britain's Hessian mercenaries who had aided the British during the American Revolution, remained. They clustered about the early colony of São Leopoldo; they scattered through Rio Grande do Sul; they begot a progeny which has lately been the cause of the reported Nazi menace in lower Brazil. Also they supplied some of the rugged hombres who were to seek, and in some instances to collect, jungle wealth in the form of wild rubber.

Planters began the importation of African slaves. The Brazilian Negro, like his North American brother, came as an involuntary immigrant. Even so, he is important to the grand epic of Brazil, present and future, and incidentally to our hoped-for rubber supply. Also, as an answer to labor needs of large planters, a colonizing system of sharecropping sprang up, based upon a somewhat standardized contract called the *parceria,* which provided that the landowner advance the cost of ship passage or inland transportation and maintain the tenant until the first paying crop was marketed. Then the landowner recovered his money, and thereafter earnings were divided equally.

Thus the great coastal states came to have nine-tenths of the entire population of Brazil. By 1875 the governor of the state of Paraná had effected a public colonization scheme, whereby the government purchased large estates, divided them into small farms, and helped immigrants take over the land. Most of those immigrants were Poles and Italians. Nevertheless, four huge states—Goyaz, Matto Grosso, Pará, and Amazonas (all but Pará are inland areas)—continued to include about 63 per cent of the area of Brazil. These four states are still the great jungle frontiers and the chief sources of Hevea rubber; however important these states may be to the democratic world, they are still decidedly remote to the majority of the Brazilian population. When Brazil took over from Bolivia the vast Amazon headwater state of Acre, which included the fabulous lands of the Madeira, the rubber jungle frontier was still further enlarged.

The Brazilian census of 1940 showed a total population of about 44,000,000—about four and a half times that of 1872. The extravagant and sometimes bloody eras of rubber, gold, and diamond exploitation have abated; and the four huge wild rubber states of Brazil still remain sparsely populated.

Regardless of its basic source, the reliable recovery of rubber requires the presence of people—a great many people. Recently the author interviewed several of our government men who are seeking to organize agencies for buying Brazilian wild rubber; without exception, they complain of the continuing dearth of people in the Amazon Basin. The distinguished Dr. Henry A. Knight, chief of the Bureau of Soil Chemistry of the U.S. Department of Agriculture and a valuable champion of the Western Hemisphere as a rubber source, recently said:

"From Mexico we hope to get around 8,000 tons a year of crude rubber—principally guayule. From Africa, or more specifically

Liberia, we are already getting about 8,000 tons of Hevea rubber. From Brazil we hope to get somewhere near 50,000 tons of wild Hevea rubber. [We actually expect to get around 36,000 tons during 1943.] But our surveys suggest that the average frequency of wild Hevea trees, even the best favored localities, is not more than four trees to the acre, or 2,560 to the square mile. The most hopeful estimates indicate that at least 400 acres of jungle must be worked to recover one ton of wild rubber in a year. Getting out 50,000 tons will require that men reach into more than 20,000,000 acres of remote jungle.

"This is a scratch-pad estimate. It is a safe bet that the actual job will be infinitely harder than the figuring. Reaching into 20,000,000 acres of jungle will require the opening of at least 200,000 miles of trail and roads; the building of thousands of bridges and footbridges; the draining of tens of thousands of acres of swamps, the building of hundreds of piers, river ports, ferry services, airfields, and so on.

"When and if all these things were done we should still face the quandary of man power. Even with all these improvements, a capable wild rubber tapper will do well to take out 500 pounds of crude rubber in a year. This means that the feat of getting 50,000 tons of wild rubber from the Amazon country would take at least 200,000 seringueiros. When population is estimated, it suggests the necessity of moving at least a million people in order to supply our factories with 50,000 tons of wild rubber. And where would one find the needed million people?"

The United States of Brazil is pondering this same question. President Vargas has struck resolutely to break the hold of the Amazon rubber barons and others who have acted to lower the productivity of rubber-bearing jungles. The Brazilian government and various medical institutions of Brazil are experimenting with ways of diminishing the health hazard on the jungle frontiers. In spite of these efforts, the recovery of wild rubber from Brazilian forests can hardly exceed 28,000 tons during 1942, which is an increase of 9,000 tons over the 1941 output. This is barely enough to supply United States rubber factories for ten days.

With the help of United States funds (the Treasury has already earmarked $10,000,000 for the purpose), Brazil is now organizing a separate government department to make allocations of native rubber to Brazilian industry and to ship the remainder to the United States. More significantly, it is weighing a mass colonization scheme to supply labor to the sparsely settled Amazon regions. The execution of the plan is complex and its practical outcome is definitely doubtful.

In any case, United States taxpayers are providing a substantial part of the cost of the proposed experiment. The $10,000,000 just mentioned is only one item; the United States is also supplying Brazil with scores of government-employed experts in tropical medicine, rubber recovery, and plantation management, as well as experts in forestry and forest engineering, and still more civil, mechanical, and transportation engineers. These co-operative efforts may be substantially increased before this book is published. Even so, the future of Brazilian rubber production remains an enigma, largely because of the hazard of population. Though a vast frontier, perhaps the richest the world has ever known, Brazil is not yet impressively a melting pot of peoples.

In 1920, when 13 per cent of the population of the United States was foreign-born, only 5 per cent of Brazilians were immigrants. In 1882, when more than 20 per cent of our people were natives of other countries, only 4 per cent of Brazilians were not born there. Today more than half the foreign-born Brazilians live in one state, São Paulo (which is only 3 per cent of the area of Brazil), and about 92 per cent live in the four southern states of São Paulo, Rio Grande do Sul, Santa Catharina, and Paraná; in Minas Geraes, a south border state; or in the federal district of Rio de Janeiro—all far removed from the sources of wild rubber. Brazil's census of 1920 showed that 36 per cent of foreign-born Brazilians were Italians; 28 per cent, Portuguese; 14 per cent, Spaniards; only 3 per cent, Germans; Turks and Arabs, about 3 per cent each; and Japanese, Uruguayans, Poles, and Austrians, about 2 per cent. To repeat, Brazil needs tropical peoples—immigrants who are acclimated to hot lands. Most Brazilians continue to shun the wild rubber lands—the hot, wet Amazon states, the northeastern states, and even the Matto Grosso plateau. And rubber experts continue to declare: "There must be plenty of people before there can possibly be plenty of rubber."

Meanwhile, the average established farm of Brazil is very large—probably the largest rural holding in the world today: it covers an estimated 665 acres—more than a square mile—and is several times the area of the average farm holding in the United States. Furthermore, about four-fifths of all Brazilian farms are owned by native Brazilians. Among foreign-born landholders, present or former citizens of the United States are the *magnificos,* with farms averaging 10,262 acres and having assessed valuations above $21,000. (Japanese farms in Brazil average 91 acres; German, 188 acres; Italian, 172 acres.)

Brazil's perpetual scarcity of people is reflected by the cheapness of her land. Valuation of farms owned by native Brazilians averages less than $5 per acre; for foreign-born holders it is under $10 per acre. These values are all understandable when one notes again that even now only 20.6 per cent of Brazil's land area is privately owned. Meanwhile, the great wild rubber states, which cover some 57 per cent of the country, have fewer than two people per square mile.

Added to this hindrance to progress is Brazil's acute and widespread inadequacy of river transportation, which Juan Fialho noted as a casual river-port onlooker. But the shortage of railroads is no less distressing. In 1930 Brazil had only 20,182 miles of railroads—less than that of the state of Pennsylvania; less than ½ of 1 per cent of present rail freight haulage in the United States; and barely two-thirds of the United States rail mileage when Lincoln boarded the train for Gettysburg! Present development of waterways, highways, railways, and airlines in Brazil is in no way sufficient to supply rapid colonization or to carry Brazilian resources to market.

There is a comparable paucity of immigration. Between 1921 and

1930, immigration to Brazil averaged only about 87,000 persons per year. During the thirties it averaged less than one-third of that number. The 1934 Constitution of Brazil cut all immigration quotas to the bone, giving as a reason the need for "ethnic integration" of the immigrants. In 1936 the foreign nationals entering Brazil totaled only 12,773. The recent increase of Brazilian population is preponderantly natural. The distribution of people remains more uneven. In the Amazon Basin most of the population live within 50 miles of the riverbanks—and it is a distinctly riverbank society. During the past decade hundreds of jungle-edge and back-country towns and villages have been abandoned, and tens of thousands of Brazilian Indians have been completely divorced from white man's company.

The Constitution of 1934 was short-lived. In November, 1937, President Getulio Vargas promulgated a new one. By 1938 the Axis peril was too imminent for tranquillity in the government palaces of Rio. During that year the Vargas administration further clamped the brakes on immigration. By special decree Vargas ruled that 80 per cent of all quotas of immigrants must be bona fide farmers, and that not more than one-fourth of the immigrants in any colony or settlement might be of the same nationality. The maximum quota for all immigration was set at 79,000. The total during 1939 was actually only 22,668. Since that date it has fallen still lower. In March, 1941, another decree-law formally limited all immigration to farmers, technicians, and those who could bring with them at least $25,000 (400 contos of reis in tangible wealth).

Preston E. James, addressing the Brazilian Geographers' Association, made a pertinent summary of the view that Brazil must have more immigrants: "The process of transforming the potential wealth of the Brazilian interior into economic value will require the efforts of many men. . . . It would be necessary to change from the traditional system to a system of permanent colonization, an immigration like the one which took place in the United States between 1870 and 1890."

That is much easier said than done. During recent years the

Brazilian press and government have presented a growing opposition to immigration, domestic as well as foreign. Brazilians remember vividly how the rapacious and undisciplined rubber rushes upset farm establishment and orderly settlement during the amazing era between 1901 and 1920. Brazilian leaders cannot conveniently forget that, although less than 4 per cent of the land of Brazil is under cultivation, some of the best farm and forest lands have already been injured, and in some instances destroyed, by ill-planned exploitation.

Nor can they forget that surplus and unsalable crops remain as grim a reality as the crippling transportation shortages. For example, probably half the potential coffee lands of São Paulo cannot be used for growing coffee, because the world consumption of this product and the scarcity of railroads, highways, and cargo space seem to be in perennial conspiracy to hold down coffee acreage.

Such fabulously rich states as Matto Grosso have not yet begun to realize their possibilities for farm settlement, simply because, as a solemn, sun-shriveled Brazilian farmer recently said, "There is no market for what we grow and no way to get it to market if there was a market." Perhaps such fatalism is one good reason why Brazilian farmers seem to be more country gentlemen than frontiersmen or fighters finding the delight of adventure in matching muscle and wit with the treacherous jungle.

As a rule, Brazilians are distinctly aware of their great distance from world markets, and of the ironic piling up of agricultural surpluses, even as more and more millions of men go hungry—in other nations. Some believe that the solution to a considerable number of these problems of surplus may lie in expansion of Brazilian industries. But, quite regardless of their blood or background, the majority of them shy away from the steaming, flood-racked, pallor-producing jungles of rubber. They do not concede the possibility, much less the promise, of a solvent jungle agriculture. Extremely few rural Brazilians have even begun to realize the possibility of Hevea rubber as a plantation or a farm crop. They know comparatively little about rubber, and do not particularly relish the little that they know. They remember the abuses and ignominies of the wild rubber exploitation of former years; but in general they have not yet had an opportunity to learn of the advantages of scientific rubber farming.

In time they may discover that Hevea can more than pay its way as a permanent farm crop. For the present, on Brazilian farms, in cities and ports, and even in magnificent Rio, millions of Brazilians continue to believe that moving people into the great Amazon frontier to bring out wild rubber or establishing great Hevea plantations in Amazonas, Acre, or Pará would lower land values and otherwise injure the solvency of the Brazilian farm plant, and therefore the common national welfare.

This viewpoint may be entirely wrong; but its existence is a sturdy reminder that contemporary Brazilians are not eager to toil in wild rubber hells or on withering Hevea plantations merely for the chance to earn an occasional handout of half-rotten, sun-cured beef, weevily flour, or rank salt fish, while watching the master grow sleek and rich. Juan Fialho and many thousands like him are in complete agreement as to this. In terms of rubber production, Brazil, the home of the principal rubber tree, is still indecisively at the crossroads. The black, foul-smelling past of the wild rubber rushes must not and cannot be repeated. The comparatively liberal leadership of present-day Brazil emphatically stated this proposition at the Rio Parley and has since reiterated it. The day of the Amazon rubber barons, even if not completely finished, must end. Neither men nor nations can flourish in tropical slums or in dens of poverty; rural Indians can no longer be kidnaped or shanghaied, driven, exploited, flogged, starved, and murdered for the profit of a handful of "first families" or other self-seeking interests. That is true in Brazil and Latin America, exactly as it is true in the United States, Britain, or any other nation which hopes to survive. No nation can endure through the enslavement of many of its citizens for the infamous benefit of a few.

But the fading era of piracy in jungle rubber cannot easily be replaced by a major industry. There are hundreds of millions of acres of potentially productive soils. Throughout at least 2,000,000 square miles, both soil and climate appear to be adaptable to either small-farm or large-plantation culture of rubber trees. Widespread introduction of rubber as a semicultivated crop in the Amazon Basin would inevitably require the expenditure of billions of dollars for railroads, river landings, commissaries and medical centers, experiment farms and nurseries, towns, barracks, water supplies, and processing equipment. However difficult the procurement of these billions may be, such a development can no longer be considered impossible.

The truly formidable problem is one of people rather than of money; of the creation of a successful melting pot; of unprecedented integration of the Brazilian population; of intelligent and humanitarian liaison with Brazil's 20,000,000 surviving Indians; of remolding the unique and almost fantastic agrarian structure of Brazil, which involves co-ordinating the rubber crop (which the majority of Brazilians are inclined to abhor) with the complex economies of coffee, cotton, vegetable oils, and other great crops which they revere.

There is a superabundance of land. There is an ideal rubber-growing climate. But there are ingrained personal and traditional factors which are prejudicial to new enterprises in rubber agriculture. In part and with time these forces may be brushed aside. Mass education will help somewhat. Practical demonstration of Hevea rubber as a successful crop, on both a large and a small scale, will help even more. This accomplishment requires the laborious upbuilding of Hevea experiment centers or nursery farms, and skillful substitution of an exact horticulture for the botanical anarchy of the jungle. Meanwhile Brazil, with tens of millions of acres of superb coffee lands which cannot be planted to coffee bush; with other tens of millions of acres of excellent cotton lands which cannot be planted to cotton, and with still other tens of millions of acres of prime range or grasslands which are not permitted to support cattle, waits in understandable bewilderment at the crossroads of rubber.

Probably, some authorities say inevitably, the future of Brazilian rubber depends upon the demands and the fair play of the United States, which will always be the world's greatest consumer of rubber. A co-operative and equitable arrangement for growing and harvesting rubber is an essential basis of a widespread Brazilian industry of farm and plantation rubber culture.

This challenge faces Juan Fialho and several thousand more of his fellow seringueiros, whose place and importance in inter-American and world affairs is at last being noticed. It confronts the Brazilian government and people. It also faces us of the United States. We are engaged in a great war which we cannot win without rubber. Brazil is one of our largest American neighbors, and is deserving of our trade and our sincerest co-operation. And it is the greatest potential reservoir of rubber in the world.

MALAYAN AND EAST INDIAN RUBBER

5

IN rubber growing there is a division of interest. On the one hand is the workaday horticulture of Hevea trees, and the sweaty, realistic agriculture of rubber plantations. On the other is the high-finance or power politics of rubber, as exemplified by the British-Dutch rubber cartel.

In all the long history of agriculture the actual growers of essential crops have had only a penny-whistle voice in deciding the commercial destinies of those crops. Lately this unhappy situation has shown signs of being remedied. For more than ten years the operations of our own Agricultural Adjustment Administration have served effectively to grant the growers of staple crops a more active part in their distribution. For a quarter century (and in some instances longer), before the spreading sore of dictatorship, the birth and growth of producers' and consumers' co-operatives throughout Scandinavia, parts of England, Ireland, France, and other nations have helped grant the actual producers of crops a chance to participate in the disposition of the wealth which their labor and talents have raised from the soil.

For the most part, actual producers of rubber have had no voice in the international economy of their crop. They have constituted a necessary though almost unnoticed multitude of toilers—too often sufferers from diseases, malnutrition, and progressive degradation—a vast coolie multitude, oppressed economically and socially into subservience to absentee ownerships and coteries of power politicians. The latter, for their own profit, controlled the world destinies of rubber from vantage points well beyond the sight and smell of the Hevea trees and the laborers who worked them.

Now that Japan has conquered the rubber lands of the Far East, a situation long deplorable has grown even more so. We have lost all our principal sources of natural rubber—a grim calamity for any industrialized society, particularly during a crucial war. Already, many Americans are realizing what the penalty for their carelessness and apathy is going to be. Almost completely robbed of their desperately needed rubber sources, and shorn of tens of billions of dollars in rubber wealth, Great Britain and the Netherlands are now paying in national blood for their toleration of uneconomic, antisocial, absentee-owned rubber monopolies.

Long before Pearl Harbor, American consumers, like those of Great Britain, Holland, and other countries, had already paid dearly in cash to perpetuate the profits of the international rubber cartels, and to put up with the connivance of American rubber and automobile manufacturers with those cartels. Since the pompous christening of the first British rubber cartel, the United States public has received wholly incommensurate benefits from low prices of crude rubber, although it has repeatedly paid the high bounties demanded by high-priced rubber.

During the heyday of international rubber cartels, and indeed before they were organized, average consumer prices for most rubber goods were unjustly high in view of mass production advantages; too high to be compatible with quoted world rubber prices, with the fairly generous wages paid rubber industry workers in the United States, or with the reasonable costs of selling and distributing rubber goods.

In the past twenty-five years world prices of crude rubber have ranged from about $1.30 (1918) to 3 cents a pound (1932). The consumers did not realize the benefits of the latter figure, though they paid the price penalties incident to the former. In their diligent determination to hold on to an assured supply of crude rubber, our principal rubber manufacturers, who actually buy and fabricate almost three-fourths of the world's total tonnage of crude rubber, with supine resignation and with willful disregard of rational bargaining advantages, allowed themselves to be taken in by sharpers at the consumer's expense. As the world's principal buyer of rubber goods, the United States has long been paying the price of its own negligence, committed to the price policies of an international rubber monopoly. What is infinitely worse, it meekly permitted the hazard of a complete and abrupt shut-off of its principal sources of natural rubber—a hazard that is now a formidable fact.

It is entirely evident that the people of the United States cannot in justice blame or condemn the British and Dutch publics for what is now a mutual crisis in rubber supply. Few of the latter have grown fat from the rubber cartels, any more than the majority of us have grown rich from the interlocking patent agreements of certain American petroleum companies with the I. G. Farbenindustrie of Germany. The people of Britain and the Netherlands have shown comparatively little interest in the rubber empires of the Far East. Repeatedly during the past quarter century, however, the British Foreign Office and the Royal Netherlands government moved, not always successfully, to suppress the tyrannies common to so many plantations of the Eastern tropics. On the whole, the Dutch efforts were the more intelligent and effective; so was Dutch development of Hevea and other great tropical crops.

Inevitably the story of Malayan and Dutch East Indies rubber is largely one of capital investment and profits. Far Eastern rubber is a transplanted agriculture whose harvest is the result of the direct investment of between two and a half and three billion dollars. It was born as an issue of economic imperialism poorly fitted to establish regulations—imperialism of a kind that openly invited absentee ownership and interlocking directorates. And because of its size and political importance it was the kind of imperialism that encourages the growth of international cartels or, more bluntly stated, that well-known hydra of capitalism, the law-defying trust.

"Cartel" is a word not necessarily definable in terms of a given national economy. Neither is the agriculture of rubber, as simple a phrase as it may sound. Malayan and East Indian rubber is only a geographically descriptive name for an agriculture which is

Western Hemispherical in origin, since the trees themselves originally came from South America—the same *Hevea brasiliensis* that Juan Fialho spent his life gathering. British Malaya and the Dutch East Indies, abetted by British and Dutch capital, have made the most productive use of a potential rubber belt which includes many million square miles of tropical land in both hemispheres. But the fact that practically all Far Eastern rubber was lifted seed, root, and stem from the Amazon Basin, though trite, is a historical fact which remains salient in the rubber quandary of today.

The eastward trek of rubber began about 1875, when the British Colonial Office began to ponder the rising demand for rubber and the virtual absence of profitable rubber trees in British Malaya, India, Ceylon, and other tropical parts of the empire. Englishmen outside the government also considered the possibilities. One of these was Henry Wickham, amateur botanist and professional soldier of fortune, who had settled as a planter in Central America. The currently accepted story goes that one day in 1875 while he was in the vicinity of Pará, Brazil, Wickham was overtaken by a weather-faded envelope which, despite the Amazonian climate, still showed the seal of his Majesty's government. Having read the letter, Wickham commandeered a British tramp steamer which happened to be in port, hired a posse of river Indians, and began a diligent tour of the Amazon rubber jungles, during which he collected about 70,000 seeds from the biggest Hevea trees in the area of Boim across the Tapajós River from where the Ford plantations are now, and packed the seeds with extreme care aboard the boat. When the collection was complete, Wickham returned to Pará with his cargo and, with the co-operation of the British consul there, succeeded in getting clearance papers for "rare botanical specimens" required most imperatively by Kew Gardens of London.

He failed to say what kind of botanical specimens. He spoke, so it is said, in Spanish and English, neither of which the Pará customs master understood. A further probability is that Pará's port collector did not know Kew Gardens from Honduran tortillas and had long since abandoned any sustained effort to curb British soldiers of fortune.

The tramp freighter and its cargo arrived safe in England, and within six weeks the 70,000 seeds were being planted in the world's largest and most costly glass house, the $2,000,000 greenhouse of Kew. At least 2,800 of the seeds became plants. Most of these were transplanted to Ceylon. Wickham, shortly to be knighted in England and in Brazil to become permanently despised as a vandal, had made a historic haul. At the time of Pearl Harbor some of the original Wickham seedlings were still bearing latex along with about 8,000,000 acres of their descendants in the Far East.

So runs the common version of the beginnings of plantation rubber. There is, however, no actual proof that Wickham violated any law or embargo in taking these seeds from Brazil; indeed no such law existed at the time. Undoubtedly Wickham acted as if there *were* a prohibition on such activities; he couldn't afford to take any chances, and therefore may possibly be considered morally guilty of smuggling contraband. As a matter of fact, only two years previously James Collin, an English botanist, had been sent to Brazil to collect several hundred seeds, which he did without interference. Some of these were planted in Kew Gardens and others in Calcutta. The instructions to Wickham were a further extension of this experiment. It is undoubtedly true that Brazilians have resented this unauthorized removal of their rightful property, and it was certainly not an action that adds luster to the name of England. On the other hand, competent authorities do not authenticate the "smuggling" story.

There is money and power in growing rubber. Most principal colonizing nations have realized this; but the United States, the greatest consumer of rubber, did not. While British promotion companies were transplanting rubber seedlings which were to make the hot, mountainous peninsula of Malaya the primary source of the world's rubber, we had the opportunity to make the Philippine Islands into comparable rubber-producing lands, since Hevea has been found well suited to their climate. But with the close of the

Spanish-American War, after taking over Spain's ancient archipelago, American temperament was definitely not one of imperialism. In fact William Howard Taft, the first governor general of the Philippines, devised for that island empire a system of land and labor laws which was never wholly superseded. The legal humanitarian from Ohio skillfully avoided the imperialistic sanctioning of coolie wages. Even more effective was the Taft-written legislation which limited rubber plantations to 2,500 acres. In the fabulous era of Eastern Hevea planting, money-loving rubber promoters did not care to invest in holdings as small as this. The plutocracy of Hevea was not interested in peasant crops. For purposes of rubber growing, they did not choose to pay the Philippine average sugar wage of 50 cents per day, when tens of millions of Javanese and Malayans were thankful for the chance to work for a small fraction of that amount. Thus the boom in rubber planting passed by the Philippines, and the United States became almost completely dependent on alien rubber supplies. (In recent years, however, the Goodyear Rubber Plantations Company has been operating extensive plantations in the Philippines—at least, it was doing so until Pearl Harbor.)

The whole Far Eastern rubber boom took some time to materialize. Wickham's botanical legerdemain did not yield immediate results. As late as 1910, Brazil was still furnishing about nine-tenths of the world's supply of Hevea rubber, less than one-tenth coming from the Far East, from which, in 1905, the combined export was only 174 tons. In 1920 the grand total of rubber harvested in Brazil did not supply one-tenth of the fast-multiplying needs of the already enormous American automobile industry. Singapore was considered the crude rubber capital of the world.

Brazil's seringueiros were wretchedly poor, even though rubber speculators from many countries had grown rich from Amazon rubber. In 1906, rubber prices rose from 60 cents to $1.50 per pound. In London and Malaya, rubber plantation companies began to grow like tropical mushrooms. In 1910, world prices of crude rubber skyrocketed to $3 per pound. British colonial investors were in a lather of eagerness to start planting. In London alone more than a hundred rubber development companies sprang up. Some failed. Others merged. But more than a million acres were planted to Hevea, all unimproved seedlings, most of them planted too close together—400 or more to the acre (subsequent experiment has proved that from 150 to 200 trees per acre is about the ideal number). Coffee bushes and other staple crops were uprooted and burned to make way for rubber. Native forest timber was slashed and fired by the tens of thousands of acres. In those days rubber was the pot of gold at the rainbow's end; thus, largely as a result of a frenzy of speculation, Eastern Hevea became a plantation crop, which was at first enormously profitable. In Amsterdam and Paris more rubber plantation companies were formed to exploit the possibilities of French and Dutch colonies of the Eastern tropics.

Rubber manufacturers were establishing still larger plantations. Yankee enterprise also was entering the hot, sticky arena. The United States Rubber Company began leasing and clearing plantations in Sumatra and Malaya. Dunlop, the leading British manufacturer, followed suit. The French Michelin Tire and Rubber Company opened a plantation in French Indo-China. In the spring of 1916, the Goodyear Tire and Rubber Company of Akron ordered its rubber-buying department at Singapore to explore and begin a plantation in the hot, luxuriant island frontier, Sumatra.

World War I added new insistence to the demand for rubber. Germany, which had failed signally in developing rubber agriculture or any other principal resource in tropical Africa, was bringing home rubber by the submarine load. World prices of crude were about a dollar a pound. From heat-ridden plantations to tire molds and dealers' racks, rubber profits were high—for all but the plantation laborers.

Agriculturally, much of the ever-spreading Far Eastern rubber rush was notoriously bad. British and French companies continued to plant scrub trees, but failed to better the health and housing of native workers; but they amassed huge profits, even with latex yields as low as one-fifth of 1940 averages. Each year plantation profits of 100, 150, even 400 and 500 per cent were being entered in many a ledger. In Paris, London, Akron, and elsewhere the "rubber aristocracy" increased. Most of the world was at war, though one great neutral nation was getting its hands into the richest game of the times. That nation was the Netherlands, with its tremendous possibilities for tropical expansion.

The year 1920 was epochal in rubber history. Holland's Sumatra was taking its place as the most promising frontier of rubber. New Hevea plantations were beginning to make gigantic checkerboards out of the world's wildest jungles. Plantations were being assessed to provide money for constructive research. Dutch botanists in a hundred nurseries and experiment stations were bettering the vitality and yields of Hevea, and introducing a new era of selective breeding. Sumatran rubber also was a cosmopolitan venture. Americans, Dutch, English, French, and various races of natives, wearing pith helmets and little else, began attacking the black-green jungles—the home of orangutans, tigers and wild elephants; lands of stupefying heat, never before invaded by civilized man.

Sumatra lies immediately below the straggling peninsula of Malaya, across the Strait of Malacca, actually within sight of the headlands of Singapore. It is an elongated island, larger than all California, and completely equatorial, since the equator almost bisects it laterally. At the time of the Japanese invasion, it was still sparsely settled, having less than one-sixth the population of Java which, though only about one-fourth as large, supports more than forty million people. For centuries the jungles have been Sumatra's heritage; indeed, Sumatrans were the very children of the dense tropical wilderness. In general they were not farmers because there was no real reason why they should be. In their eternal summer they had been free to take most of their needs from the wilds.

But rubber growing requires that men be permanently tethered to the land. Quite logically, Sumatra grew to greatness in rubber agriculture because it was possible to import laborers from overcrowded Java. Here again, Dutch expediency began to appear. Royal Netherlands law required that Javanese could be moved to Sumatra only under a three-year work contract; that they could be moved only of their own free will; also that they should have the opportunity to return home at their employer's expense at the end of the three years. The standard labor contract further required that the employing rubber company provide hospital facilities as well as free medical treatment and shelter for labor; and 45 pounds of rice monthly for each Javanese, to be sold at not more than 2½ cents a pound (an exorbitant price, incidentally). Furthermore, it specified wages usually ranging from 6 or 7 to a common maximum of 20 cents a day—low enough to keep the coolies in status quo.

Under such conditions hundreds of thousands of Javanese were recruited and ferried to Sumatra to help in changing millions of acres of jungle into the most productive rubber lands the world has yet known. Having served their three years, some 80 per cent of the Javanese recruits elected to work on in Sumatra. Several thousand eventually became proprietors of small Hevea farms which they own, till and harvest, selling crude rubber to factory "bungers" or bartering it for necessary supplies.

The comparatively recent settlement of Sumatra involved many nationals besides Javanese. Imported Chinese coolies supplied much of the heavy labor to break open the trackless jungles. Bullock carts followed them on paths hacked out by bolos and machetes. Giant tree growths and vines were felled with long-handled axes swung by laborers perched shakily upon ladder tops. Work elephants were goaded to move logs and uproot stumps. Caravans of bullcarts drew in supplies, often covering only ten or twelve miles a day.

Under discerning Dutch leadership, roads were cut still deeper into the great jungles. Chinese pushed ahead, clearing the way. Javanese followed to build roads and villages and to plant rubber trees. It was big work, dangerous work: a toil of sweat, blood, sickness, and sudden death, of virulent diseases and other hazards which punctuated the fast-moving saga of rubber.

Of necessity heavy machinery was transported principally by coastal steamer or river barge. Frequently 15,000 workmen were required to open one plantation in the jungle, and accommodating such forces also called for rapid improvement in transportation; for building commissaries and hospitals; for highways and railroads leading to future plantation sites; for bicycle armies, for multitudes of trail slashers, for the ever-important *mandoers,* or native labor foremen; and even for professional hunters who protected laborers from nocturnal raids by tigers and other native animals.

Many nations and talents took part in creating the Sumatra rubber empire. Among others were the Bataks, or mountain nomads of the island, a Polynesian people who were among the last of the habitual cannibals. Whether or not certain Bataks are still anthropophagous is open to question.

The feat of making Sumatra the most productive of great rubber lands involved many age-old farm practices of the Javanese, such as leaving stumps and timber to rot and thus enrich the soil; choking out undesirable trees by planting quick-growing tropical vines which suffocated them close about their bases; the distinctive Javanese technique of terracing hillsides to hold moisture and thwart erosion; and of profitably disregarding the earlier British theory that Hevea trees grow best upon cleared lands.

East Indians were quick to learn that Hevea is usually extremely robust, and that the precious tree which had attained maximum size and age in the eternally crowded Amazon jungle could also grow in competition for space with most of the other tropical plant life of Sumatra. Earlier, in the days of Java's first rubber growing, tens of thousands of acres of Hevea had been planted merely as a catch crop, or more specifically as a shade crop to protect more delicate plants, such as coffee bushes, from the severity of the tropical sun. Repeatedly, in Java and elsewhere, these protective rubber-tree crops proved more profitable than those they were intended to shade. The canny East Indians saw the possibility of making Hevea a reserve or storage crop by planting seedlings as rapidly and economically as possible and letting them grow to maturity in competition with native stands of underbrush and wild growth. Then, in ten or twelve years, when the seedlings had grown to bearing age, the densest of the scrub growth could be cleared away and good Hevea latex harvested at very low cost, without long-term investment in difficult cultivation or continuous brush clearing, and without the expensive and troublesome upkeep during the unproductive interval between seedlings and trees big enough to tap.

For resources other than rubber, the frontier of Sumatra was soon to prove its importance. It was the nearest approach to a free and just society made by any principal rubber land. Wages were extremely low, to be sure, a fact that is not readily excusable. This is a chronic symptom of the greed and social shortsightedness for which most rubber-growing companies, and the colonial empires to which they belong, have already paid a terrific price. But Sumatra, at least before Pearl Harbor, was not a land of abject peonage and slavery. In matters of general administration, Dutch colonial policy was far more enlightened than that of Britain or France, and centuries ahead of the best shown by Belgium, Germany, or Italy. Rubber laborers in Sumatra were not slaves, since Dutch laws which permitted colonial planters to pursue and brutally punish runaway servants or field laborers had been stricken from the books before 1910. In both Batavia and Amsterdam, Netherlands public servants had given praiseworthy study to the medical problems of the jungle, including that always important part of the white man's responsibility, housing.

Motion-picture traditions to the contrary, people must be sheltered, even in the tropics. Rather oddly, indigenous styles of tropical housing are frequently not conducive to good work and health. Traditional Javanese housing is particularly bad. It produces a sort of ornate eagle's nest: a thatched house, mounted so high on stilts that it is attainable only with a ladder. These are usually built in rectangles, or *kampongs,* the central square being reserved for ceremonials, religious services, and native games.

In shaping Sumatra's rubber empire, Dutch authorities worked with natives to develop a modified style of kampong for workers. These are long, barracklike buildings, usually with wooden walls and sometimes with screening. They are built about a square, with living quarters for from 100 to 200 people in each. Their rooms are about ten by ten feet, and each room houses an entire family. In spite of appalling overcrowding, the building does provide decent shelter and the possibility of comparative cleanliness. It lends itself to gradual improvements, which better the lot of the dweller without upsetting his strong sense of custom and propriety. The more enlightened rubber plantations began building *pondoks,* not in rubber fields, which are strictly reserved for Hevea, but on river fronts or other sites, where space is available for screened porches in front, for outdoor kitchens, and for small garden plots at the back. A modest enough resource, by American standards, these gardens in Javanese eyes are a conspicuous step toward the more abundant life and have proved of great value to the health and common welfare.

The native word for a life with this background is *senang,* which means happiness or contentment, a quality more desirable than fame, wealth, or power. East Indian definitions of senang are specific and modest: more rice at lower costs—less than 2½ cents a pound, which bears no correlation with a daily wage of 14 cents; revival and continuation of the great folk arts of the Javanese, their traveling players and minstrels, their nights of music and dancing, and the happy days of picturesque ceremonial games.

Rubber may not maintain its place as the economic groundwork of Sumatra's senang. The Japanese occupation forces may destroy all rubber trees before they yield the great island. Yet the hopes of the East Indians do not die. Senang may come either from the shaded Hevea orchards or from other producing fields which may replace them in the event that the Japs destroy the trees. But they are sure that it will happen sooner or later. The very air of Polynesia promises it.

Meanwhile, the Javanese, whom smooth-handed white men call coolies and equally smug Japs regard as abused and benighted Asiatic brothers, continue to believe that men, by their very natures, will eventually seek the valuable things. Rubber, like sugar cane, cacao, spices, quinine, and a score of other great crops which have enabled the Dutch East Indies to make white men rich, is still immensely valuable. And the Javanese, down to the humblest coolie, see China as a feasible outlet for the great wealth of East Indian fields and groves—because she is the giant neighbor; because she has lived down infamous centuries of social and economic persecution by white men; and because she is great enough to fight on throughout the bitter years of Japanese rapine and pillage. Also, and more pertinently, because a Chinese is a true Oriental, living, fighting, and working in his own world. And a Chinese is strong. It was the brawny, thick-chested Chinese coolie who led the Javanese into the Sumatran jungles and helped reclaim its wastes to usefulness. Chinese also seek senang, which adds still greater strength to the growing Javanese and Sumatran belief that someday, not too far off, China will be not only the mighty friend and ally of the East Indies, but the great consumer of the wealth that will continue to rise from rich East Indian earth.

Under native scrutiny and with the toil, sweat, and craftsmanship of East Indians, great factories, refineries, oil fields, highways, and mighty buildings have already arisen in Java. They have begun to appear in Sumatra also. The East Indian onlooker has become reconciled to such magic. He believes that still more of the smoking monsters called factories may appear to make the good life more possible for Orientals. But China is the mighty continental hero of all Oceania, just as Mexico has long been the embodiment of the heroic state to the lapino, the mestizo, and other illiterate mozos who work in the sweaty fields and shops of Central America. China, biggest of the big, will also have great factories and great buying power. Peace, justice, and fraternity can live in the Orient.

It need not surprise us Occidentals when free Chinese celebrate the final collapse of Britain's stronghold upon Hong Kong, even though the conquerors be the despicable Japs. Chinese know that the defeat of Japan is inevitable—that Japs can be pried away from Hong Kong, whereas the British never could be. And it need not have caused us frenzy or anger, when peace-loving Javanese and Sumatrans watched resignedly from the roadsides as the Japanese invaders pushed aside the puny forces of such previous invaders as the British and Dutch. The colonial armies of Britain and Holland, indeed the Philippine army of the United States, however gallant their men, however devoted and unselfish their leaders, were feebly supported and equipped. The Javanese laborer knew of the vast wealth collected for East Indian defense in taxes laid upon rubber, petroleum, and other resources. He was not surprised to learn that Holland's enormous collections of defense money (such levies as 5¼ cents gold per pound on the 43 per cent of the world's rubber supply being grown in the Dutch East Indies) had not really been spent for defending the islands. Facing the impoverished, frantic attack of the Japs, East Indian defense forces were deficient in every essential tool: tanks, planes, guns, rifles, and ammunition; man power, leadership, and armed reserves; and equally important, vigilance against traitors.

What became of the defense money, of the huge tithes lifted from the productive earth of the Dutch East Indies? The Javanese is not the man to answer. He does not think in terms of gaining millions and billions of dollars, nor of spending them; he does know that the collectors of this wealth could not have been in harmony with senang. The verdict is stated without bitterness. Enduring truth cannot be hateful, ugly, or disloyal. Senang materializes only with an eternity of experience, and no man should be condemned merely for his ignorance—not the American, the German, Briton or Frenchman, nor even the Japanese.

A great many East Indians seem clearly aware that Netherlands sovereignty, despite its faults (many of which appear blacker since Pearl Harbor than the facts warrant), showed constructive merits. Dutch colonial policy at least did not arbitrarily depose the native sultans or any other landed aristocracy of the East Indies. The Netherlands delegated important powers to the colonial government at Batavia. It sponsored, in fact demanded, attention to sanitation, public education, water supply, road building, and many other civic essentials. Admittedly a "regime of business," the Dutch government dealt fairly, firmly, and impartially with corporate and private exploiters of her East Indies, honoring contracts and requiring as much of concessionaires, avoiding favoritism in nationality, discouraging cruel and unusual punishment of the weak and lowly, and winning at least some measure of the latter's respect and confidence.

Holland has reaped huge dividends from the East Indies, but her sovereignty has assuredly not been without benefits. As well as introducing Hevea rubber and other great foreign crops, Netherlands talent effected enormous improvements in their culture. For the professional agronomist, these improvements provide the subject matter of many important books. Netherlands leadership established in Java, and later in Sumatra and the lesser East Indies, the *proofstaatens,* or experimental farms upon which Dutch horticulturists, by masterly plant selection, cross-pollination, bud-grafting and inbreeding, developed types of cinchona and quince tree which quickly won and dominated a world market. They created disease-resistant, high-yielding strains of sugar cane, which not only perpetuated the cane-sugar production of Cuba, Hawaii, the Philippines, and most other principal sugar lands, but maintained supremacy over beet sugar or sugar cane grown inexpensively in the tropics. Even our domestic sugar cane industry of Louisiana and Florida, now definitely important to our war effort, owes its survival to Netherlands proofstaatens of the East Indies, particularly the world-honored Proofstaaten Oost Java.

East Indian research in tropical agriculture has been similarly important to others of our deficit crops, which we must import principally or entirely from tropical lands, for example, castor beans, tung oil, chocolate, coffee, and spices; it has been important also to many of the tropical fibers and palm crops. But it has been most important of all to the modern horticulture of Hevea rubber.

Dutch horticulturists were among the first to learn that about 30 per cent of Far Eastern Hevea trees were producing about 70 per cent of the world's tonnage of rubber. They noted that the plantation stands of Hevea ranged from 25 to 400 trees per acre; that in Malaya, where unimproved Hevea trees were standard, one tree would fill its catch-cups to overflowing while the next failed to yield enough latex even to dampen the cup. They noted the huge capital investment (averaging some $300 per acre, which characterized the British Malayan rubber plantations of World War I era); and they knew, as did any other experienced horticulturist, that a large part of this investment was uneconomic stockwatering.

As recently as 1920, Eastern rubber growers had arrived at no general agreement as to the most desirable orchard routine for Hevea trees. Some growers tapped each tree every second day throughout the year; others tapped all trees daily for periods of six to eight weeks, then permitted rest periods of the same length. It was at about this time, when all the Dutch East Indies together were producing less than 15 per cent of the world's supply of rubber, that Netherlands horticulturists and botanists were undertaking systematic Hevea research. They formed planters' associations to improve rubber yields by inbreeding high-yielding strains; sponsored uniform assessments for establishing and maintaining plant experiment stations for common public benefit in all principal farming areas; and invited foreign as well as domestic rubber planters to join the experiments.

Two American rubber firms were among the first to take part in the co-operative effort: Goodyear and United States Rubber, both of which had instituted their own Hevea research departments. In 1920, Goodyear's pioneer Dolok-Merangir plantation in Sumatra covered about 20,000 acres. The Dolok-Merangir staff, led by John G. Blandon, Goodyear's veteran Far East rubber buyer who until recently directed the Goodyear Rubber Plantations Company, had begun to study rubber trees with intense, devoted interest.

They noted the astonishing inconsistency of yield: how one tree would frequently yield well for a few years, then cease to produce; how a high-yielding tree would often inexplicably degenerate into a low-yielding or sickly one. They found that plentiful yields of latex had no direct relation to the inherent quality of the tree itself; that not one high-yielding tree in a hundred would reproduce itself true to type. They also observed, as had the Dutchmen, that even in 1920—eighty-one years after Goodyear's discovery of vulcanization, almost a third of a century after Dunlop's invention of the pneumatic tire, and twenty-one years after Seiberling founded the Goodyear Tire and Rubber Company, which has become the world's largest international system of rubber factories—all the commercially available wild rubber in the world was not enough to fill the needs of one principal rubber manufacturer.

At this time, horticulturally speaking, Hevea was still essentially a jungle grab bag. Its place in scientific agriculture was still untried and unproved. The Dutch, American, and East Indian horticulturists and plantation owners set about improving the crop. It was a slow, exasperating husbandry. When the scrub trees reached tapping age, the experimenters marked the high yielders for further use and ruthlessly slashed down the low-yield trees. They began planting from 150 to 250 Hevea trees to the acre, and reducing the final stands to 100 or more. They estimated the economical producing life of a plantation tree as twenty-five to thirty years, even though wild Heveas of the Amazon Basin continue to yield latex after they are two hundred years old. They learned that healthy trees, well planted in fairly fertile, well-drained, and slightly acid soil, usually reach the tapping stage in five or six years, with yields increasing steadily up to the fifteenth year. They developed immensely valuable assets in selective nurseries which became standard resources of the modern rubber plantation.

Hevea seeds do not always breed true; but cuttings taken bodily from superior stock usually transmit superior qualities rather faithfully. Accordingly, in the plantation nursery one plants the best available seed of what appear to be most vigorous, high-yielding, disease-resistant trees. Within a month, tiny, rich-green, umbrella-shaped trees have risen from the seed. These grow rapidly, and within a year their trunks are about the size of a heavy walking cane. The year-old seedlings are bud-grafted. A live bud, freshly cut from a high-yielding tree, is placed in a precise bark slit near the base of the seedling, the graft and wound being carefully bandaged. When the graft is completed, the top of the sapling is cut away. A new tree grows from the grafted bud—a tree which benefits from the virile seedling root. Then the improved seedling is marked, numbered, and transplanted to the field, where its growth rate, leaf development, and later its yields are carefully recorded.

But expert bud-grafting and nursery operation were only one assignment in the development of Far Eastern rubber farming.

Grafted trees duplicate the qualities of the mother trees, so long as the qualities are not the direct result of environment. To determine whether or not the high yields of a given parent tree are due to heredity or to favorable environment requires that progenies of the tree be tested under identical environmental conditions. This in turn requires infinite patience and years of time. So does cross-pollination. It is not possible to duplicate a given parent tree, strain, or variety of plant by means of its seed until the parent is bred to a pure line. As yet no botanist has developed a pure line of Hevea. Cross-pollination is an accepted means for emphasizing the merits and reducing the faults of two or more parent trees, that is, for effecting beneficial crosses.

The author is not a botanist, but he has had the good fortune to work with Walter N. Bangham, chief Hevea botanist for the Goodyear Company. A mild-mannered, drawling, long-strided Ohioan, Bangham is still short of middle age. But he has spent ten years at work in the great rubber lands of Sumatra and Java, where he has been successful in creating new and better families of Hevea, and has supplemented his East Indian experiences with Hevea work in Malaya and the Philippines.

Bangham works easily and speaks Dutch, English, Portuguese, or Spanish, depending on place and time. His working clothes are loose khaki, oversize boots, and a pith helmet considerably stained with rubber milk. He calls himself a scaffold man. He selects prospective mother trees and about them he has log scaffolds built and these are equipped with foot rungs to facilitate climbing. This technique is standard in the prize Hevea plantations of Sumatra, and Bangham himself helped make it so. He now directs Hevea research for Goodyear's new plantations in Costa Rica and Panama, serves as special adviser to Henry Ford's rubber plantation on the Tapajós in Brazil, and also as professional counsel to the United States Department of Agriculture's Hevea experiments in Central and South America. These personal items are encouraging omens for the future of Hevea as a plantation crop for the Western Hemisphere.

Hevea is a flower tree; to a layman its graceful blossoms are not particularly impressive, but to a rubber botanist they are principal tools of trade. Sexes are separate in these flowers. To accomplish cross-pollination, Bangham works in the morning; climbing the scaffold, he uses hand shears to clip away the old flowers and the premature buds. Then he opens the ripe female flowers (which would open under their own power about two o'clock the same afternoon) and inserts with forceps the entire staminate column of the male flower on which the anthers are beginning to open. Then he records the cross. That is the entire operation—botanically one of the most significant in the world today.

Selection and breeding have given economic supremacy to Sumatran and other East Indian rubber growing. They were and may long remain of extreme importance in the world's rubber supply. In 1920, the average yield of a rubber plantation was about 300 pounds of dry sheet latex per acre yearly, or between one and two pounds per tree. By 1927, the average yield with selective budding at Goodyear's Dolok plantation in Sumatra was 650 pounds. In 1940, average yields on this and comparably managed plantations had climbed to 1,200 and 1,500 pounds of dry crude rubber per acre, with yields of one ton a distinct possibility. During 1940, a Goodyear experimental plot actually yielded 1,960 pounds of crude rubber (which would be a good harvest of ten square miles, or 6,400 acres, of wild Brazilian rubber). Twenty years is not time enough to realize all the possibilities of this new era in rubber agriculture. Already prize "mother trees" in Sumatra have proved individual values of $50,000 per tree—one Hevea tree worth as much as a grand champion Holstein bull or a 28-ton tank.

At the end of 1941, Far Eastern plantations covered more than 8,000,000 acres, but of these barely 750,000 were planted to selected Hevea. Only about 9 per cent of the total rubber areas were of budded trees, and a great majority of these were (and let us hope are still) in Sumatra and Java. Even in Sumatra the newest and best directed stronghold of Hevea growing, about half the total 1940 harvest of rubber, or approximately 216,000 tons, was taken from small native holdings, virtually none of which are bud-grafted. This underlines the fact that, in terms of possible and proved Hevea horticulture, natural rubber has never yet had what it deserves—fair trial on a major acreage, and extensive propagation technique comparable to that long given to other great commercial orchard crops, such as apples, bananas, peaches, plums, and apricots. *Hevea brasiliensis* is still, for practical purposes, a primitive jungle citizen, whose aptitudes and possibilities in a technical world so desperately dependent upon rubber stores have only now become faintly apparent.

Hevea is still a new crop which waits to be made infinitely greater and more prolific. Now, of course, the majority of the most valuable mother trees of Sumatra and Java have been lost to the Japanese; but the knowledge and experience gained in producing them are still available for the American tropics. This is a phase of the rubber story that should be constantly borne in mind.

HENRY

FORDLANDIA 6

SEVEN hundred miles inland, fronting the Tapajós River of northern Brazil, is the largest Hevea rubber plantation in this hemisphere. Its name is Belterra, and its proprietor is Henry Ford. Belterra is probably the most significant farm property in the western half of the world.

In 1928 the Ford Motor Company began manufacturing automobile tires. Also in 1928, Henry Ford announced that he proposed to grow rubber on plantations in the Western Hemisphere and thus make an effort to restore to the Americas the production of an essential material which Brazil had first given the world.

Ford was, and is, well informed about the international rubber trade. Rubber is as essential to automobiles as iron or fuel. As we have already noticed, about three-fourths of the United States peacetime consumption of rubber goes into automobile tires and tubes. When Ford decided that something should be done about our rubber supply, the United States was importing about 500,000 tons of natural rubber per year. Most of it from British Malaya, which then produced about 42 per cent of the world's supply; some also came from the Dutch East Indies, which produced about 38 per cent, and from Indo-China and the Philippines, which supplied most of the rest. Meanwhile the total collection of latex from wild rubber trees in the Western Hemisphere had dropped to less than 2 per cent of the world's consumption.

Henry Ford is not a statistician, but he is a countryman and a believer in the productivity of the soil. On three continents he owns or leases no less than 4 million acres of land. Ford was raised on a farm in Michigan, where he absorbed his farmer father's conviction that soil can do "what nature intended it should do." He opposed extravagant use of commercial fertilizers and many of the machines and gadgets of modern agriculture. "The land knows what it needs. . . . A given soil is predisposed to a given vegetation, and fancy theories be damned. I say leave the land grow what it wants to grow."

In keeping with this theory, Ford believes that the Amazon basin homeland of Hevea rubber trees "naturally" chooses to grow Hevea rubber. In 1928 he tersely stated that he was tired of the British-Dutch rubber monopoly and meant to do something about it.

Monopoly has come to be a fighting word. It is so even to the dominant British and Dutch signers of the International Rubber Regulation Agreement, many of whom are eminent imperialists whose eminence and imperialism alike have been nourished in Malaya, Java, and Sumatra by Hevea plantation profits as great as 1,300 per cent annually, and seldom lower than 20 to 50 per cent.

At the time of Ford's first decision on the subject of rubber there was no international rubber cartel. The British-sponsored Stevenson Act, devised in 1922 to limit the supply and raise the price—or, as it was stated in public, to "stabilize" the price—of Far Eastern rubber, applied only to Malaya and Ceylon. The plan estimated the cost of producing a pound of Hevea rubber at 19 cents and sought to establish a world price of 34 cents. By 1926 the cartel had actually jockeyed the world price to a record temporary high of $1.23 a pound, while producing costs had dropped far below 19 cents.

In 1922, as today, there should have been excellent profits in producing Hevea rubber at 10 cents a pound; almost certainly there were, even on British Malayan estates, which on the whole were mediocre to poor. The collapse of the Stevenson Act, which was actually born at the instigation of Winston Churchill, then Foreign Secretary in the fast-failing Lloyd George coalition government, was not directly the result of rubber prices or profits. It was primarily the result of superior Dutch competition.

In 1921 all the Dutch East Indies produced slightly less than 15 per cent of the world's supply of rubber, and the British owners of Malayan rubber estates omitted the Dutch from the monopolistic plans they were making. Winston Churchill, cornered by a growing Conservative bloc in Parliament (which he later joined in the Baldwin government), plunged into the power politics of rubber. The British public and press was denouncing the war-debt claims of the United States government. Churchill took that cue and explained to Parliament in just what way a British-operated rubber control plan could be applied so that Britain might use British-grown rubber to obtain exchange advantages from the United States. In Akron, Harvey Firestone, Sr., saw the danger in the plan; but his colleagues yawned in boredom, preferring to pass along the shakedown to their customers. In England, as might be expected, Firestone was publicly damned.

Americans, on the whole, were easy victims. But the shrewd and capable Dutch were potent competitors of the British—a fact which neither Winston Churchill nor the British rubber companies appeared to recognize sufficiently in 1922. The truth was that the Dutch were better farmers and better traders than their rivals. Without fanfare they proceeded to prove it in terms of rubber.

In 1922 British colonial rubber was easily the majority of the available world supply, whereas Dutch East Indies rubber was barely one-seventh of it, so the planners of the Stevenson Act saw no harm in letting Holland have a commensurately minor share of the forthcoming profits. Rubber tonnages of the Dutch East Indies promptly went into an upward spiral.

By 1928 Java and Sumatra together were producing and exporting a full third of the world's supply of crude rubber. They were doing a better job of rubber growing than the British had ever done. They were also profiting greatly from British cartel operation and suffering none of the restrictions of rubber acreage or export quotas which British cartel members had necessarily assumed. By 1928 Britain's rubber trust had made monkeys of American rubber manufacturers, but the Dutch had just as decisively made a monkey of the rubber trust.

Thus, late in 1928, the Stevenson Act was repealed. Until early in 1934 the production of natural rubber went on without regulation. Meantime the depression had struck, and during 1933 rubber prices dived to a nadir of 3 cents per pound—again without reasonable benefit to United States consumers.

During June, 1934, the Dutch competitors shepherded the sagging British rubber trusts into the International Rubber Regulation Agreement, which undertook more capably to regulate acreages, export quotas, and world prices of the Far East Hevea crop. The scheme worked. During 1934 this cartel "caught" world rubber prices at 13 cents a pound; by 1937 it had jacked them up to 37 cents a pound. From 1938 until Pearl Harbor it held the price to 20 cents or better, roughly twice the legitimate production cost on reasonably well-managed farms or plantations. Once more the American public was the goat.

Then Holland fell to the Nazis, and the life of England was desperately imperiled. But even at this eleventh hour, when the crumbling cause of the democracies demanded a huge increase in rubber supplies, the Dutch-British plutocracy of the International Rubber Regulation Agreement was still permitting harvest and export of only about 53 per cent of the rubber stands of Malaya and the Dutch East Indies. The plantation owners were raking in the cash, and nothing was going to stop them.

Officially, this most profitable of all cartels chose to overlook the rubber-growing efforts of Henry Ford. But there have been comments from the sidelines. The gist of these comments—now hushed but likely to rise again—is significant to this story.

The British made the point that actual direction of the world-girdling rubber cartel is made up of consumers as well as producers. They admitted that rubber plantation wages in Malaya, Java, and neighboring Hevea lands were low—varying from 4 cents a day to as high as 45 cents. Although these wages were lower than those now common on prospering farms in the American tropics, with the exception of a few coffee *fincas,* they were probably not much lower than the net earnings of hundreds of thousands of sharecroppers in our own South. Therefore the propagandists spread the fable that general living standards, native arts, crafts, theaters, and public education, not to mention law enforcement and sanitation, were better in their own colonies than in the American tropics or the poor-land areas of the United States. As a matter of fact most of this was nonsense, but to a public both ignorant and apathetic it seemed perfectly reasonable.

More accurately, however, the defenders of the rubber cartel stressed the facts that wild rubber from the Amazon jungles had failed to keep pace with skyrocketing demands, that it had allowed crude rubber prices to boom to fantastic heights, and that if there had been no systematic control of Hevea growing the development of synthetic products would have long since robbed the world of a legitimate rubber agriculture. They added that they could not understand why Henry Ford should be so anti-imperialistic. The Ford Motor Company, they argued, is itself a sort of empire. Furthermore, Ford has diligently promoted and sold his cars throughout the Oriental "rubber empires," not to mention the United Kingdom as a whole and the rest of the world.

That was a hard argument to answer. But when British rubber publicists dwelt upon the importance of Malayan rubber concentration to our export trade, they were again talking nonsense. Before the war we were buying 58 per cent of all our rubber and 72 per cent of all our tin from British Malaya. From 1937 through August, 1940, our Malayan imports averaged $185,000,000 per year, and during the same period our total exports to Malaya averaged only $10,345,000 per year, or less than 6 per cent of the imports.

Actually, the Western Hemisphere offers much greater opportunities for profitable rubber growing. According to the latest surveys made by the United States Department of Agriculture, conditions suitable for growing Hevea rubber exist in at least fifteen Latin-American republics, extending from southern Mexico to northern Bolivia. In peacetime we usually sell many of these countries more than we buy from them. All are within the immediate scope of our Good Neighbor policy, and all are within 4,500 miles of United States ports by way of shipping lanes which we can protect, whereas Malaya is more than 12,000 miles from any United States port, and was virtually beyond Allied shipping control even before the Japanese took it.

In 1928, when Henry Ford began to speak seriously of rubber and Harvey Firestone had undertaken Hevea planting in Liberia, Brazilian wild rubber had been knocked into a cocked hat as a commercial factor. Singapore was the crude rubber capital of the world, and in Malaya there were 3,000,000 acres of Hevea trees; 2,000,000 of these were planted on about 2,500 plantations at investments ranging from $180 to $300 per producing acre.

Henry Ford started his Brazilian rubber venture in high gear. His envoys rushed to Rio de Janeiro and secured a free concession from the Brazilian government for about a million hectares, or 2,470,000 acres, of wildlands along the Rio Tapajós, which is probably the ancestral home of all the Hevea trees now in cultivation. That area is about five-sixths the size of Connecticut, but compared to the colossal Amazon Basin it is just a garden patch. Forthrightly enough, the concession was named "Fordlandia." On the whole it is good land, considerably above the average in the Amazon Basin; but it is more than 700 miles from a seaport, and much of the terrain is rough and steep. Moreover, the river is not very dependable for ship traffic; it floods widely during the wet season and sinks far below the docksites during the dry season.

The population of the Tapajós region is sparse, rural, and mainly of Indian blood. As a rule the people do not actually live in the country; they just build palm shacks, thatch-roofed villages, or log trading posts along the river, which serves as a highway, trade route, and sewage disposal system. When prolonged rains place the "under-table" lands beneath inches or even feet of water, the bank-combers hop into a boat or straddle a log and float to fairer lands. Under traditional circumstances, few of the natives work. They are principally squatters.

However, both people and topography of the Tapajós region are superior to those of Amazonia in general. Much of the adjoining land is above the water table, and as Ford's men have proved, much of it can be traversed by usable roads. Hevea trees grow best on flat, peaty soils, alluvial valley soils, or undulating foothills, and Fordlandia has plenty of all these.

Official Brazil was more than mildly pleased about the Fordlandia project, but some of the jungle-edge gentry, particularly in Manáos, once a world-renowned capital of the wild rubber rush, were both amazed and alarmed. Ford was carrying the spirit of River Rouge and Dearborn Commons into the heart of the jungle. He set out to build a completely modern jungle town, with sewers, a hospital, paved streets, electricity, and modern bungalows. He proposed to pay high wages for native labor, anywhere from seven to twenty times the former rubber-tapping earnings of the vanishing free-lance seringueiros. The local rubber aristocracy pointed out the demoralizing effects of spoiling jungle hoi polloi with exalted living standards.

It wasn't the amount of Ford's proposed spending that bothered the Tapajós and Rio Negro elite. Actually his total investment in Brazilian rubber properties is probably no more than $8,000,000—a mere pittance compared with the money behind the large rubber estates of Malaya and Java, and hardly an ordinary year's commitment for the United Fruit Company of Boston, which is by far the largest United States developer of tropical agriculture. Back in the wild rubber boom days, some of Brazil's independent rubber buyers had netted as much as $8,000,000 a year, and I am told that in 1910 the jewelry trade alone in Manáos, a city of less than 90,000 people, exceeded $8,000,000.

It was Ford's principle, not his money, that nettled. There remains in Brazil a permanent landed gentry who simply take no pleasure in seeing the Indians get ahead.

But Ford let it be known that he was not concerned with matters of race, color, or previous conditions of work (few of the first native employees at Fordlandia had ever worked before). His envoys led a fiercely energetic attack on the jungle. Ax strokes resounded and trees smashed to earth; machete swingers whacked away the underbrush and burned it. Within the first year more than a thousand acres were cleared and planted to native Hevea.

Draglines and bulldozers marked out the first roadways, for here, too, Ford workers were to have the opportunity to own and enjoy Fords.

The workers assembled a sawmill. Fordlandia timber was to build or help build hospitals, homes, and commissaries. Then the first major snag developed. Amazon hardwood is the very hardest hardwood in the world, and the sawmill soon confirmed this fact. The saws simply couldn't cut the logs: a round saw would scream halfway through a giant log and stop dead, a band saw would melt into smoke.

Then a Ford efficiency expert ordered that the saws be speeded up; when a power saw cannot function at normal speed, it can and must at double speed. But not the Fordlandia saws. Foremen speeded the gauges. The saws shook down their stations and almost wrecked the mill, but still failed to rip the incredibly hard jungle wood.

Even though the sawmill finally provided enough wood for floors, housing plans caused more trouble. A Temperate Zone style of architecture was selected and low-set bungalows, very like those in Greater Dearborn or Long Island suburban towns, were built. But housing in the tropics is different from Long Island. Throughout the brushier areas of the Amazon Basin most native homes are built on high stilts. Projecting thatch roofs keep the "under-decks" comparatively dry. There are no screens and usually no plumbing. Wives build their cooking fires beneath the houses, relying on the smoke to keep away mosquitoes and multitudinous other insects.

The United Fruit Company, which has spent millions of dollars in building employee homes and work camps throughout Central America, Cuba, and some parts of South America, has subscribed extensively to the house-on-stilts idea, because it helps ventilation, keeps the house cooler, provides more work space and offers considerable protection against earthquakes. In the Eastern tropics, on the other hand, most plantation houses are built on the ground without ventilation from beneath—but their ceilings are high.

Not so with the early houses of Fordlandia, which are consequently miniature infernos in which one lies awake and sweats the first half of the night, and then frequently suffers a fierce siege of heat-induced nightmares. The early houses of Fordlandia were methodically screened, which is likewise contrary to the customs of tropical living. As a rule, the natives loathe doors and leave them open, so that a screened house collects disease-carrying mosquitoes much as an old-fashioned flytrap collects flies.

Otherwise, Fordlandia dwellings are superior to most farm homes anywhere in this hemisphere. But, as usual in undertakings of this scope, final costs far exceeded the original estimates. That led to the next difficulty. Ford decided that the employees should pay a "reasonable" rent, and rents, reasonable or not, simply do not belong in the American tropics. Usually experienced operators do not attempt to charge rents for employee houses, since according to tropical tradition a house is merely something that providence, the boss, or the company is supposed to give one.

The native workers also had trouble with the Ford definition of living standards. They were earning enough to buy their wives silk stockings, but in the main their wives had not yet learned to wear shoes, and silk hosiery tends to deteriorate in mud. An intense jealousy arose among the workers' wives, and strange rifts and feuds took shape within the newly formed colony. And when a workmen's mess hall was set up, the native workers objected to the Detroit-style cooking and complained bitterly of indigestion. This was no indictment of the cuisine; a literal transfer of norte-americano fare to the jungle rarely pleases anyone. Furthermore, the natives had no inclination to square-dance on the village green, to sing the folk songs of Merrie England, to treasure Longfellow, or to revel in the Ford Sunday Evening Hour.

But from the beginning the Ford medical facilities were excellent. Within a few months the health of the Fordlandia colony was noticeably better than that of its neighbors. Skillful medication and energetic efforts at field sanitation thwarted or reduced the onslaughts of malaria and blackwater fever which usually harass new settlements in the tropics.

In spite of all the difficulties, the work went on. Most of the first thousand acres planted were native Hevea, either grown from local seed or transplanted directly from the jungle. The new planting didn't start well. After the wilderness was cleared, torrential rains washed off the surface humus. Droughts came and the young trees suffered from the fierce sun. Leaf-eating insects appeared, and so did the much-dreaded South American leaf blight. This leaf-killing fungus is the most serious enemy of Hevea in the Western Hemisphere. Its spore rides the wind, settles on the leaves, and sets up a quick cycle of reproduction. Leaves begin to vanish, sap ceases to flow, and frequently the tree dies.

The year 1930 found the Ford rubber men weary and discouraged. A prolonged drought almost halted river transportation. Much of the Fordlandia site proved too hilly for efficient cultivation, and they had planted the wrong kind of trees. Moreover, world rubber prices were on the skids. But Ford was determined to keep on, although he accepted a suggestion for a drastic change in plantation site. About 80 miles down the Tapajós River, his engineers picked another and better location, a 700,000-acre plot which is superb land from the standpoint of drainage, terrain, and sanitation advantages. The Brazilian government agreed to give the site in exchange for a like area of the original Fordlandia tract, and approved a 40-mile river frontage for the new Belterra location.

With this switch, Ford's jungle experiment was headed for practical production of rubber. Impulsive notions of creating a jungle utopia were shelved and Fordlandia was relegated to the status of an experiment farm and supplementary plantation. At present its population has fallen to about 150 workers. Belterra became the principal plantation.

Apparently the real turning point in the Ford experiment came about because Dr. James R. Weir, Ford's rubber biologist, was convinced that simply transplanting wild Hevea to cultivated orchards was folly. He had wide acquaintance with Far Eastern rubber culture and he knew that, whereas the best yields of ordinary scrub Hevea are rarely as much as 400 pounds per acre yearly and average as little as 200 pounds or less, the skillfully budded Hevea trees developed in Malaya, Sumatra, and Java frequently yield as much as 700 pounds of marketable latex to the acre, and have touched record yields of 1,900 pounds.

During 1933 Dr. Weir went to Singapore, where, after much shopping around, he purchased about 2,000 selected Hevea seedlings from some of the best managed Malayan estates. He brought these seedlings back to Belterra, planted them, and was delighted when nearly 1,200 of the high-yielding, disease-resistant young trees took root in Ford fields. Dr. Weir proceeded to develop a nursery for Belterra. As soon as promising parent trees could be selected, a renewed bud-grafting and planting program got under way.

That was in 1937. In Singapore the International Rubber Committee promptly locked the stable by forbidding further export of Hevea seed or seedlings from member areas; but the horse was gone.

Meanwhile Curt Pringle, a former sheriff of Kalamazoo, whom Ford had hired as assistant project manager, plunged into his difficult job with that determined gusto which seems to be a characteristic of many *norteamericanos* who at first don't know a thing about the tropics. Pringle began to iron out flaws and inefficiencies and to direct the building of cheaper houses more in keeping with native customs and needs. Ford and the Brazilians were still in disagreement as to matters of doors, screening, and height of ceilings, but the ex-sheriff proved himself an excellent arbiter and practical diplomat. He did not insist upon square-dancing or North American food, and he helped make available numerous modern conveniences, such as paved streets and electric lights.

Everything does not always go along smoothly, though. Recently Ford's rubber wages have come within competitive range of the higher brackets of Brazilian farm wages. In fact, Belterra has had considerable difficulty in holding its force of some 2,500 workmen. In near-by areas new cotton plantations are paying almost as much, and Brazil in general is experiencing a rapidly growing surge of prosperity and an improved labor market.

Ford's labor policy in Brazil, however, seems to have proved quite successful. My own acquaintance with tropical labor problems has shown me the many difficulties incident to recruiting, training, and maintaining permanent plantation personnel within the hot countries. The task involves enormous expenditures and endless details in matters of manual training, common schooling, medication, housing, and civic establishment. Certainly it is no conventional matter of hiring and firing, of being union or nonunion, or paying so many cents per hour for a 40-hour week with time and a half for overtime. In the rural tropics, when you hire a man you also adopt him, his family, his wife's family, and a considerable portion of his tribe, clan or village, for better or worse. They are yours to look after twenty-four hours a day, Sundays and holidays included.

Belterra is a bizarre creation, an arm of green wilderness suddenly made productive. It has many miles of roads. A visitor is not obliged to ride muleback in the lingering Latin-American manner; he can and probably does drive to the fields in a Ford. About the farm homes and labor camps are gardens and patches of coffee bush and spike-leafed pineapple. Orange trees bloom and bear at the doorways. Browned citizens doze in the shade and sometimes move rapidly in the sun. There are numerous plantings of *mandioca,* a standby food crop, as well as castor beans, cinnamon, and other "by-products." Verdant Hevea trees rise to cast new shade. After thirteen years, Henry Ford is beginning to win in his rubber venture.

The Ford style of rubber growing is technically complicated. Much of the new planting is of double-grafted trees: that is, buds of high-yielding varieties of Hevea are first grafted to hardy native roots, and then other buds of healthy leaf strains are transferred to the plant to develop disease-resistant tops or crowns. The grafting knife has become the most important implement of the establishment.

The spray pump also comes into use—a new departure in Hevea growing. Ford laboratory workers have recently developed rotenone insecticides which they make from timbo, a poisonous plant native to the Tapajós country. Entire trees are sprayed with this insect killer. But there are numerous dissenting opinions concerning tropical agriculture, and Hevea is no exception. For instance, the Goodyear Tire and Rubber Company does not favor spraying Hevea trees after they have been transplanted from farm nurseries.

Today the Ford rubber orchards are actually in harvest. At Belterra "test tapping" is in progress to determine the highest-yielding trees. At Fordlandia several hundred acres of the earlier scrub plantings are being put under the knife. The first latex yields are closely comparable to those of similar stands in Malaya. Certainly the tapping is profitable.

June, 1941, found Ford about 3,000,000 Brazilian rubber trees to the good. About 2,000,000 of these have been budded with stock from high-yielding, disease-resistant strains of Malayan Hevea. The budded trees will come into bearing during 1943. Seven years hence, Ford's harvests of latex should be between 12,000,000 and 15,000,000 pounds annually. In normal times the manufacturing needs of the Ford Motor Company require medium yields from about 7,500,000 mature trees.

Ford's rubber acreage is increasing all the time. The present total planting is about 16,000 acres, three-fourths of which belong to Belterra. Hevea acreage is not easy to compute, since the new style of propagation involves much tentative, or wait-and-see, planting. If the new trees start well, they stand; otherwise it is good management to discard them promptly. This means that the best gauge of a plantation's ability to expand is the status of its nursery and "parent trees." One well-developed parent tree, selected for superior yield and leaf development, provides enough buds to bud-graft several hundred acres of orchard stand.

As Ford's Brazilian properties have shown increasing promise, the U.S. Department of Agriculture has sprinkled Central America with ten new experiment stations. Also the Goodyear Tire and Rubber Company has launched two highly promising experiment farms in Central America. The first, at Gatun, Panama, is principally a nursery; the other, at Cairo, Costa Rica, first planted by the United Fruit Company in 1923, is now in commercial bearing.

All told, there is a reasonably good case for the prediction that large-scale Hevea production will soon be moving northward into Central America. The Department of Agriculture seems fairly certain that Central American lowlands have the space, suitable soil and rainfall, and sufficient native labor to furnish a large part of our rubber, and they are not far from our southern frontiers. It is undeniable, too, that Hevea trees can be grown successfully on small, independent farms; large, highly capitalized plantations are not essential. The stated goal of the Department of Agriculture is to help make Hevea available as a native farm crop within areas which promise the best results. The governments of Panama, Costa Rica, and other tropical republics openly approve this idea.

But Hevea will also be developed further in Brazil, its botanical homeland, in area the third largest country of the world (only Russia and Canada are bigger) and potentially the greatest agricultural nation the world has ever known. The Brazilian government has worked hard to evaluate and improve its rubber-growing possibilities, but so far Henry Ford has actually done the most to return American-born rubber to the Americas. The small new Hevea plantings of Central America seem to be about on a par with those of Belterra; the trouble is that there aren't nearly enough of either.

SYNTHETIC RUBBERS, OR ELASTOMERS

7

THE term "synthetic rubber" is not entirely accurate. Rubber itself cannot be artificially duplicated on a commercial scale. The strictly correct phrase is "substitute rubber, or rubberlike material"; that is, the products which ingenious chemists have conjured up from cornstalks and waste petroleum gases merely *resemble* rubber in their structure and properties, but are not identical with it. A general name for these new materials, useful because it is shorter, is "elastomer," and this will be frequently used in this chapter instead of the misleading "synthetic rubber."

Since white men first learned of the sticky, milklike latex which flows from wounds in the bark of certain trees and shrubs, they have sought to make substitutes for rubber, somewhat as the alchemists had tried to make gold from baser metals. In both endeavors the stories of failure would fill innumerable volumes, comprising a literature of pipe dreams, frustration, and not infrequently of deliberate fraud.

Chemically stated, the production of rubberlike materials involves a stringing together of long, slender chains of atoms similar to those present in rubber, that is, atoms of carbon and hydrogen attached to one another in certain definite ways. Such chemistry is laborious and almost endlessly complex. In terms of considerable American industrial research, petroleum, or products derived from it, has been regarded as a particularly good source of elastomers both because it contains the same chemical elements as rubber and because it is available in large quantities within our own borders.

As this book is written, the prospects for manufacturing elastomers from grain or sugar alcohols seem quite as promising, in terms of immediate and urgently needed results, as the enormously publicized petroleum processes. The remarkable fact is that laboratories in the United States and elsewhere have proved that at least 8,000 different types of elastomers can be produced from various base materials, including crop wastes and surpluses, petroleum, coal, limestone, salt, greases, soaps, and so on.

Obviously, not all these processes are practicable for our present needs. For purposes of this book only a few deserve mention. It is the author's belief that far too much purely technical exposition of processes of making elastomers has already been visited upon the United States public, whose very survival may depend upon adequate rubber supplies, and that the jargon of chemistry becomes unendurable when interspersed with legal phraseology, corporation propaganda, and commercial feuds. The lay public has for the past year been pelted unmercifully with obscure and technical double-talk—much of it from persons unqualified to discuss the subject—which may have a dozen different implications for a like number of reasonably intelligent readers. However, from all the welter of comment—some strange, some dishonest, and some unquestionably hysterical—a few salient facts are indubitable and trustworthy.

To begin with, rubber is a member of the hydrocarbon family of substances, which means that it contains hydrogen and carbon atoms grouped in certain precise ways. The crude natural rubber contained in latex as it is "bled" from the tree is about 95 per cent hydrocarbon. This essential portion is called *isoprene;* and it is this that has been found practically impossible to synthesize. When isolated, isoprene is a watery fluid having the chemical composition C_5H_8. The hydrocarbon family is huge, containing tens of thousands of different substances. Like natural rubber, petroleum is also a hydrocarbon, but it is not a single or simple one. Petroleum is a mixture of a great number of hydrocarbons; as many as 62 have been identified in the gasoline and kerosene portions alone, not to mention those contained in lubricating oils, fuel oils, paraffin, asphalt, and others of the huge assemblage of petroleum derivatives.

The formation of elastomers involves some extremely intricate changes in the structure of hydrocarbon molecules. The actual chemical elements concerned are usually not of decisive importance: what really matters is their *arrangement,* which governs the size, shape, and weight of the resulting rubber molecules. In simpler language, mankind moves on rubber because dumpy or roly-poly molecules can be transformed into slender, ropelike ones. Incidentally, much the same statement can be applied to high-octane gasolines.

Why and how does this transformation take place? Since I do not know, I submit this intriguing question to a capable scientific writer, Mr. Carl Dreher, who also does not know and says so rather interestingly:

"We do not know exactly what happens to the molecules when latex . . . becomes rubber in the solid, elastic form. But we do know that there are simple compounds called *monomers,* which have low molecular weight (the individual C_5H_8 molecules just mentioned), and more complex forms of the same chemical elements in the same proportions, which are called *polymers,* characterized by greater molecular weight and entirely different physical properties. The change from one to the other is called *polymerization.* . . . There is good reason to believe that a rubber band is elastic because it contains long, linked chains of thousands of monomer units, the linking being accomplished by the polymerization process. The chains appear to run roughly parallel and to be loosely twisted.

"The strength and durability of rubber are improved by *vulcanization.* Apparently vulcanization provides a cross-braced type of molecule, with sulphur atoms acting as tie-pieces between adjacent chains."

Natural rubber, when and if procurable, has always been and may always be the best source of these pragmatic and still poorly understood feats of chemistry. But the fact that substantially the same chemical tricks can be performed with other hydrocarbons, including petroleum, alcohol, and many plant substances, is fundamental to the production of elastomers. The intermediate base substance between the starting material—whether grain alcohol or petroleum gases—and the final product is known to chemists as *butadiene;* after this has been obtained, several different types of elastomer can be made by slight variations in processing. Butadiene is a colorless gas containing the chemical elements necessary for the formation of rubberlike substances.

The polymerization of butadiene was discovered by a Russian, Dr. Leopold Lebedev: that is, the way to make the molecules of this gas unite to form a much more complex chain of molecules. German chemists adapted this and various English inventions for the excessively expensive synthetic rubber which Germany was able to produce in some quantity during the World War I. This ersatz, though derived from German adaptation of basic processes, was in no sense a German invention. Neither was it good rubber; in fact, it was exceedingly bad. Auto tires made of it soon split and flattened: trucks had to be jacked off the ground when parked. It was poor rubber in hot weather and even worse in cold weather, for in winter chunks and slabs of tires on military vehicles would remain fast in the ice and slush after the vehicle to which they belonged had moved on.

Germany's disregard of the necessity of rubber in war was one of the blunders that cost her the decision in 1918. In some respects it was almost as stupid as our own recent failure to consider and develop dependable sources of rubber before Pearl Harbor. The Kaiser's fighting men floundered and died for want of rubber. While boasting the merits of ersatz, the Prussian High Command sought frantically and sometimes foolhardily to obtain natural rubber, even as our press and politicians declaim rosily about the potential blessings of synthetics, while other Americans are floundering and dying in tropical jungles searching for natural rubber. Ironically, some of the Niagara of press releases about would-be or might-be elastomers are actually replicas of the Imperial German rubber propaganda outpourings of 1918. In terms of rubber the Kaiser's Germany was caught sans-culottes. It paid the price and lost the war, and a quarter century later German rubber problems are still far from a satisfactory solution, even as our own.

The first problem in developing a substitute rubber is to obtain a base material each unit portion of which contains four carbon atoms in a row. There are many such substances—we do not yet know how many. However, at least three of the most important ones should be named. These are butadiene (C_4H_6); butylene, or butene (C_4H_8); and butane (C_4H_{10}).

All three can be derived not only from petroleum, but from many other hydrocarbons. The most advantageous sources differ with time, place, and national needs. In Poland and Russia, alcohol, made from plentiful or surplus crops, has been a more practical source than petroleum. In Germany, where petroleum is perpetually scarce, coal and acetylene, as well as alcohols, have proved important starting materials. In the United States, Venezuela, and other nations where oil fields spurt abundantly, the advantage of petroleum is obvious.

Petroleum chemistry vies with coal chemistry as the most complex, the most challenging, and the most productive of the physical sciences. In nature's subterranean laboratories, coal and petroleum have been slowly formed from the fossil remains of plant and animal life which existed millions of years ago. They contain primarily the elements carbon and hydrogen, and are therefore the starting materials for literally thousands of products which have become necessities of modern life. But we are still a long way from being able to supply our crucial needs for rubber by synthetic processes even with God's gracious superabundance of petroleum, alcohol bases, and coal.

It should be emphasized that these three basic substances are far from being finished elastomers; indeed, they are only the starting point. Before they assume any of the qualities of rubber, they must be converted into butadiene, which must then be polymerized, or united into long, chainlike structures of high molecular weight. This change may take place spontaneously just by allowing the butadiene in liquid form to stand for several days. The reaction occurs much more rapidly when sodium is used as a catalytic agent; by this the chemist means that sodium directs and increases the speed of the reaction without itself being consumed in the process. The widely used term "Buna," a German trade name for the most widely used of the so-called synthetic rubbers, is derived from the first syllable of "butadiene" and Na, the chemical symbol for sodium, which in Latin is *natrium*.

But the sodium process is costly and has several disadvantages, one of them being that it requires elaborate control of heat and pressure and a cooking time of several days. By early Hitler times German chemists had developed what is called "emulsion polymerization," by means of which a substitute latex can be produced within a few hours. The emulsion process was not new; it was merely a restatement of the industrial chemist's time-honored expedient of devising an emulsion, or soapy suspension, in water which, when treated with a catalyst under prescribed conditions of heat and pressure, undergoes polymerization.

One of the Buna processes now in use involves another long word—copolymerization—which means that other polymerizable bodies, such as styrene, are added to the butadiene and thereby become merged with or built into the molecule of the resulting elastomer. After further treatments the product emerges as a liquid, milklike in appearance and, like real rubber latex, capable of being coagulated by means of acids; it is then washed, dried, and used in the general manner of natural rubber, except that certain types are so tough and hard in the raw state that they have to be softened by heat before they can be processed. As in refining sugar cane, the current manufacturing principle for making elastomers is to fire up the works and keep them fired, thus facilitating accurate chemical control.

A simple statement of the varied processes of creating rubber via the test tube and pressure vat is likely to be misleading because prevailing synthetic techniques place ever-growing stress upon incidental compounds and ingredients. Many current processes are therefore inclined to begin not at the beginning, but somewhere toward the middle and to meander into devious and bizarre sideroads. For example, the chemical make-up of Buna-S, or Buna-styrene, which is now in the limelight of synthetic rubber chemistry, is a copolymer of 75 per cent butadiene and 25 per cent styrene, the latter being also a component of petroleum. There are at least 20 other substances which require economic as well as chemical consideration; and there also are many other "types," such as Butyl rubber, developed by the Standard Oil Company of New Jersey after years of rather discouraging setbacks. This is a copolymer of butadiene and isobutylene, and its greatest commercial advantage lies in the fact that eventual costs per pound are substantially less than estimated costs of Buna rubbers, though the latter are the better products. Isobutylene, at present an important ingredient of Butyl rubber, now costs only an eighth or a tenth as much as butadiene, the main ingredient of Buna. The estimated outlay for plant and equipment to manufacture one ton of Buna rubber per year is about $1,000; that for one ton of Butyl is about $700. Complexities in derivation and unpredictable changes in techniques of manufacture make these estimates somewhat indefinite.

Since butylene, one of the most important starting materials for making substitute rubbers, may be obtained directly from refinery gases, the close connection between the production of these substitutes and of high-octane aviation gasoline is obvious. The alternative source is butane, which involves not only laborious and uneconomic extraction from natural gas, but cash subsidies from the United States Treasury and appallingly large quantities of steel and other strategic metals, as well as crucially important time. Early in 1942 technicians employed by the Standard Oil Company of New Jersey disclosed a new refinery technique by which greater amounts of butylene can be released without corresponding losses in output of indispensable 100-octane gasoline.

The production of substitute rubber from petroleum must by its very nature be a significant and commanding phase of the over-all petroleum industry. For in practical petroleum refining, any plant which produces butylene is necessarily and by the same process making high-octane gasoline and toluene, the latter an indispensable explosive base.

By 1940 certain offices of the federal government had begun to work strenuously in support of synthetic rubber produced from petroleum. But six long and discouraging months after Pearl Harbor, there was no authority in Washington with the power to integrate or intelligently advise the production of these three essential strategic materials—butylene for substitute rubber, high-octane gasoline for aviation, and toluene for TNT—as one integrated production and financial problem. Production of butylene was within the supervisory province of the Rubber Reserve Corporation; toluene was under Army Ordnance, and aviation gasoline production was tethered to the Office of the Petroleum Co-ordinator.

Accordingly, chemists and real or would-be producers have been floundering in economic and professional quicksands. When one plants or taps a rubber tree one does exactly that: fate, soil, and climate willing, rubber is obtained. On the other hand, when one undertakes to develop substitute rubber from petroleum, one participates in an enormously complex industrial chemistry whose end products are derived from substances which are almost inseparably associated during manufacture.

This fact, which is as conspicuous and undeniable as sunlight, has been stubbornly evaded by many reporters, public officials, and corporation executives. As a result, by June 1, 1942, the techniques and correlation of processes necessary for producing substitute rubbers in large amounts had scarcely begun to assume workable or final form. Public money was being spent by the hundreds of millions for building plants which might well be obsolete before going into production—plants likely to be abandoned even before their completion. The entire planning was so befuddled that virtually any new process or refurbishing of an old process could change its direction overnight or halt completely. The problem of substitute rubbers had been "solved" only by a few ebullient politicians, by a handful of sensational and pseudo-scientific magazines and newspaper features, and by the extremely personal testimonies of a great many more or less fogbound inventors. The torrent of wishful words about new elastomers tended to drown rational interest, planning, and investment in proved sources of natural rubber. Just as destructively, it had served to bolster the traditional overconfidence in American "inventive genius" which, however real and admirable, has not yet solved all our dilemmas, including that of rubber supply.

Early in June, 1942, at long last, Arthur Newhall of Goodrich, Co-ordinator of Rubber for a nation fast becoming rubberless, began to "get tough and make sense." The news of allocations of federal credits and subsidies of about a billion dollars, for building plants for large-scale production of synthetic rubber with ultimate (somewhat optimistic) capacities of 1,000,000 tons per year, had "broken" in many a streamer headline. But construction actually in progress represented a total annual capacity of less than 200,000 tons. Petroleum and chemical companies which had accepted or avidly grabbed for the federal money, were still waiting "for the situation to clarify." The consuming public was in process of swallowing the bitter pill of drastic curtailment of auto mileage. Our armed services had endured further reductions of the rubber equipment which they had considered the minimum essential for victory.

But the time was growing late: the six irreplaceable months which followed Pearl Harbor had been lost. The national substitute rubber program was floundering helplessly and almost hopelessly. The rubber picture meanwhile had grown black enough to threaten not only the continuation of necessary civilian transportation, but the very success of the national war effort. The quandary in raw materials—steel, alloys, copper, and other requirements for building synthetic rubber plants—was almost as dire as that of rubber. The following figures [1] may be cited to indicate the amounts of strategic materials required in plants for making butadiene from alcohol and petroleum; they are given in tons of metal per 1,000 tons of butadiene produced:

	Alcohol Process (*Tons*)	*Petroleum Process* (*Tons*)
Copper	50.6	9.00
Nickel	1.0	2.05
Chrome alloys	2.2	5.00
Steel	140.0	165-194

Still politicians and petroleum and rubber executives bickered, quarreled, and sidestepped the issues. Small rubber companies were heckling and spitting at big ones.

By Presidential proclamation a nation-wide rubber scrap salvaging program went into effect on June 15th and continued until July 10th. It was not a particularly good one, nor was it very successful. Frantic plans were afoot for making tires out of doormats and girdles; indeed, the entry of the White House itself barely escaped violation at the hands of a scrap-rubber enthusiast. But the salvage campaign did result in arousing national consciousness of the desperate rubber shortage; and it did bring in about 454,000 tons of miscellaneous scrap—a disappointing total, far below previous minimum estimates. Most important of all, it helped a confused and truly Gordian entanglement of federal bureaus to seek an intelligent solution.

After prolonged wavering and executive dormancy, federal authorities in supervision of substitute rubber production swung into action with a sequence of moves to stabilize the techniques for deriving elastomers from the processing of petroleum, and to cause the program to gel sufficiently so that no further changes of processes however good or bad—except new discoveries leading to better production without changes in plant construction or allocations of materials for building the plants—could again upset or overthrow established plans for producing the elastomers essential to winning the war.

The most notable and praiseworthy move—which could and should have been made months ago—was the appointment (July, 1942) of two of the country's outstanding chemists, Conant of Harvard and Compton of M.I.T., and one leading financier, Bernard Baruch, as a fact-finding committee to investigate the entire field of substitute rubber, from both the scientific and the economic point of view. The gist of their report, which appears in full at the end of this book, is that the situation is even worse than had been generally believed; that it threatens us with the loss of the war; that more active efforts should have been devoted to developing alcohol-base rubber on a commercial scale; and that even our greatest production efforts, together with rigid civilian care of tires, will be likely to leave us with less rubber than we need for military uses in 1943.

The unprecedented striving now goes forward, with government agencies seeking—with rather indifferent success—to retard further competitive squabbles and industrial sideshows. The future of substitute rubbers remains clouded. In terms of technical and scientific reality, most elastomers are complicated products whose development is unavoidably broken into component parts not necessarily compatible one with another. But seven major petroleum companies insist that sufficient equipment is already at hand to produce about 100,000 tons of butadiene during 1943—about one-third of the absolute minimum demanded by our war effort. Meanwhile the United States stockpile of natural rubber, estimated early in 1942 as 700,000 long tons, continues to dwindle with alarming rapidity. Roughly one-third had vanished by July 1st of that year.

In the face of this, military requirements for rubber, which have already been pared dangerously low, must be met. For example, the approved schedule of 75,000 army tanks to be manufactured during 1943 calls for about 75,000 tons of good rubber: rubber treads can be replaced by steel only at a cost of 10 per cent of the tank's speed and maneuverability. The proposed output of 185,000 planes calls for at least 92,500 tons—an average of about half a ton per plane. Minimum shipping requirements are listed as 220,000 tons. These demands, still unfulfilled as this book goes to press, are far from being the total military needs for rubber, of which more will be said in a later chapter. They do not include apportionment of rubber to our allies or the requirements for army trucks, scout cars, troop carriers, gun carriages, pontoon bridges, gas masks, barrage balloons, pneumatic rafts, and hundreds of other items of essential military equipment. They make no allowances for essential civilian needs, which are an urgent reality in such matters as police and fire protection, sanitation, and repair facilities. With these facts in mind, one can only lament the complacency which was responsible for not providing months and even years ago for a contingency that might have been foreseen.

In the ever-puzzling field of rubber, American technology faces its maximum challenge. The challenge has two parts: getting the starting materials; processing them rapidly and efficiently. The first part is in itself gigantic, since the necessary recovery and transportation of raw materials is infinitely more costly and troublesome than the processing and treatment of the products themselves. For example, butadiene, the common denominator of substitute rubbers, is comparatively easy to store and to transport; though normally a gas, with simple compression it can be made a liquid for purposes of convenient transportation, storage, and processing. But most butadiene (according to processes which the Office of Rubber Coordinator has decided to accept as orthodox) is derived either from butane, which in turn is obtained from natural gas, or from butylene, a refinery gas. In business-as-usual petroleum processing, over half the available supply of both these gases is wasted; therefore the principal manufacturing source of butane and butylene is the absorption plants in which gasoline is produced from refinery gases.

For several years past, most gasoline refineries have been producing large amounts of butane for use in gasoline blending. When and if national consumption of motor fuel is substantially reduced, the amount of butane used in gasoline blending also will be diminished. Gasoline rationing not only prolongs the life and usefulness of the rubber already present in auto tires but helps to liberate an essential starting ingredient for the creation of the substitute rubber necessary to carry our armies to victory.

According to current plans, there are five principal steps in producing elastomers from oil. The first is that of accumulating butanes and other starting materials. The second step involves the treatment and processing of these materials to produce butadiene; in other words, the petroleum gases must be put through various catalytic processes and reacted with other substances before butadiene is obtained. The third step is purification; the fourth, polymerization of butadiene, sometimes with other petroleum derivatives, to produce rubberlike materials; the last is treating and fabricating these materials.

When rubber is synthesized from petroleum, the first three steps are plainly within the province of the petroleum industry. The fourth and fifth involve the transportation problem, which is one of the most acute difficulties confronting the entire nation. At present butadiene, compressed to liquid form, must be carried by tank cars from gasoline refineries to rubber factories. Distances and travel costs are formidable. Some disciples of efficiency, foreseeing even graver transportation problems during the coming two years, are urging that shipment of liquid butadiene be instantly stopped and that the polymerization be performed at or near the refineries. The resulting rubber substitutes would occupy much less space, and could be shipped by ordinary freight, thus involving transport problems no greater than those of crude natural rubber.

That is a suggestion which would go a long way toward easing this phase of the transportation problem, though it is not a complete solution. Supplies of suitable tank cars are already insufficient; within a year the tank-car shortage could well become ruinous. But the shortage of time and of materials for building new plants is also acute. On financial pages and in periodicals which depend on petroleum advertising, transport problems are pictured as comparatively simple; but this is far from being the case.

It is a fact that making substitute rubber from petroleum has never yet been easy or inexpensive, although as the economies of large-scale production are realized the cost of manufacture will decline rapidly. The minimum demands are formidable: huge quantities of steel and steel alloys for plant construction, large volumes of raw material from which comparatively small amounts of rubber can be made; extensive employment of high pressures and temperatures; and expert and diligent chemical and engineering supervision. Also there is the ever-present possibility of devastating accidents; some years ago one synthetic rubber plant disappeared from its foundations in about fifteen seconds!

Thus far, United States petroleum companies have appropriated most of the public money set aside for creation of an emergency rubber supply. Actual tonnage of substitute rubber made from petroleum has as yet been too small even for preliminary trials in wholesale production. During 1941 its total production was barely one-third the initial recovery of wild rubber from Central American and South American jungles, which in turn was less than 10 per cent of the urgent military needs of the United States.

In terms of actual practice, alcohol-base elastomers have had a more thorough trial than have those derived from petroleum. Throughout Europe the produced tonnage of the former is probably at least ten times that of the latter. This ratio is only a general estimate, as complete statistics are not available because of the strategic nature of rubber production and its entanglements with power politics. But rubber authorities are certain that during the 1930's thousands of small plants in Poland were producing elastomers from potatoes and cereals, and that even today a principal part of Russia's rubber supply is being taken from farm products by means of the alcohol-butadiene-rubber "cycle." Here, as in several other Temperate Zone countries, the chief source of these alcohols has been farm products, such as potatoes, wheat, and corn; indeed, the Baruch Report takes United States chemists to task for not benefiting from Russia's experience with this method.

Ordinarily the United States has substantial surpluses of wheat and corn, and though our per capita production and consumption of potatoes is small in comparison with those of Germany, Russia, and most other European nations, in ordinary times these also constitute a surplus crop. Moreover, we have exceptional facilities for growing other alcohol-producing crops, such as sweet potatoes, sorghum canes, rye, and barley. In Cuba and other Caribbean islands is the greatest potential supply of sugar cane in the world, and so far as we now know this is the cheapest, quickest, and from a refining standpoint the most expedient source of commercial alcohol.

Such a program would require comparatively small investments in processing equipment as compared with petroleum rubber. It is estimated that between 200,000 and 300,000 tons of substitute rubber per year could be produced from existing distilleries and alcohol refineries now operating within the United States. Also, it is possible for many of these distilleries to operate as individual units in localities near raw material supplies, which would mean important savings in transportation. Specialized plants and processing equipment are required for converting distillery output to substitute rubber; but this equipment requires only small amounts of critical materials, and it can be built and put to work in a third or half the time required for petroleum-rubber plants.

According to reasonably dependable authorities, total costs of refining plants to produce 200,000 tons yearly of synthetic rubber from alcohol would not exceed $30,000,000, with six to eight months as the necessary waiting period. Thereafter, the total cost of additional processing equipment should not exceed $200 per ton of annual rubber capacity as compared with plant investments ranging from $700 to $1,000 per ton and at least eighteen months of waiting time for the factories required for substitute rubber from petroleum.

It is noteworthy that the Rubber Reserve Corporation and the Co-ordinator of Rubber for the War Production Board have chosen to regard rubber made from grain or other vegetable alcohols as an untried experiment and rubber from petroleum as an accredited success—a view not only unsupported but flatly contradicted by the facts. It is also noteworthy that the placid continuation of an exclusive rubber-from-petroleum experimentation would succeed in giving unchallengeable control of the synthetic rubber industry to fewer than twenty corporations, including seven major petroleum companies and four rubber companies, namely Goodyear, Firestone, United States Rubber and Goodrich, which in effect are assigned the immensely strategic mission of fabricating butadiene into rubber.

In general, most of the news about synthetic rubber has been bad, so far as the United States is concerned. The presentation of that news has been still worse. During June, 1942, the President of the United States warned the people of the possibility that confiscation of civilian auto tires was possible and might even be inevitable. During July, 1942, such newspapers as the Washington *Times-Herald* and the New York *Daily News* were exploiting streamer headlines which in the first instance declaimed "Tire

Makers Call Shortage a 'Myth' "; and in the latter, "Rubber Shortage a Myth, Industry Will Tell Nation."

For good reason the rubber industry actually told the nation nothing of the kind. What the American rubber industry did announce, through A. L. Viles, chairman of the Rubber Manufacturers Association, was the "possibility" for the production of about 13,200,000 new tires and the recapping of about 30,000,000 used tires without interfering with military requirements for rubber. In making this number of new tires, "to carry America through until 1944," the rubber industry proposed to use 3,332 long tons of natural rubber, together with 97,420 long tons of reclaimed rubber, 32,475 tons of Butyl, and 33,188 tons of Thiokol, a new variety of an old synthetic previously unsuited for tires. That plan allegedly left for military requirements most of the nation's stockpile of natural rubber, about 85 per cent of reclaimed rubber capacity, and all the Buna rubber then "on schedule."

The announcement, made on July 22nd, was apparently a promotion coup to encourage the civilian tire industry and to express confidence in the forthcoming production of substitute rubbers which are substantially controlled by the "Big Four" rubber manufacturers. It was calculated to make headlines and to promote fur-stroking American self-complacency. It carried the small-print proviso that in order to achieve such a supply of civilian tires, every automobile, truck, and bus in the United States will have to cut its usual mileage (including essential war mileage) an average of 25 per cent and that a nation-wide speed limit of 40 miles per hour must be enforced.

Here again small print was more revealing than headlines, and less encouraging. During July, 1942, several petroleum companies had suggested the possibility of their supplying Butyl and butadiene sufficient for making 200,000 more tons of synthetic rubber than had previously been projected. But during that month, which may eventually be marked as the most significant month in the history of substitute rubber, the more important and less publicized news of rubber continued bad. The War Production Board completed a revised estimate which forecast no rubber supply whatever (in fact

5,000 tons less than none) by the end of 1943. The Bureau of Standards returned distressing reports on the quality and service values of auto and truck tires made of American Buna.

Also during that month the substitute rubber program was being shaken to its still flimsy foundation by dissenting voices of the wheat bloc and the midwestern farm bloc in Congress. On July 23rd, the United States Senate, with 9 of its 96 members present, passed legislation (bitterly opposed by the Roosevelt Administration) to strip from the War Production Board its authority over the manufacture of substitute rubber drawn from agricultural products and to create an independent agency to promote and control this phase of the war effort. The same measure, unanimously approved by the House of Representatives Committee on Agriculture, sped into final passage, with midwestern congressmen declaiming hotly that farm products had been frozen out of the picture in the interest of the petroleum industry, that the War Production Board was "under the control and domination of selfishness," and that "the rubber program had broken down." [2]

On the same day there appeared the McNary Bill to authorize Reconstruction Finance Corporation loans to distressed resort owners whose properties and businesses were being lost through the demise of rubber tires; also the urgent recommendation for a national speed limit of 40 miles per hour to save tires. Senator Brooks of Illinois lamented the inability of American farmers to secure tires for farm implements. The proposed new rubber authority openly duplicated the functions of the existing Rubber Reserve Company, gave power to a suggested "rubber czar" to enter into leases and contracts with nonprofit corporations and co-operatives, as well as other producing companies, and to prevent monopolies in the new industry by permitting no one concern to produce more than 10 per cent of substitute rubber made from agricultural or forest products.

In heat-punished Washington rubber and petroleum lobbyists were in a lather of perspiration. So were the bigwigs in the crowded offices of the War Production Board and the Department of Commerce. Mr. Jesse Jones philosophized, "We would never get any considerable synthetic rubber if we jumped from one process to another every time an oil company or an alcohol company or an inventor wanted the government to adopt their process." Donald Nelson echoed firmly, "Our decision has been made. If it's wrong, I'll take the blame."

Declamations of blame were growing. The official inventory of available rubber made preposterous the glib proposal of the Big Four rubber companies to manufacture and sell civilian tires. The petroleum lobbyists who had actually grabbed the greatest plum of a monopoly in United States history began to discover that the plum had ill-tasting worms. The farm bloc was at last in stride. The steel shortage had become more acute; and the whole future of rubber from oil was wavering in the balance of essential steel and plant-building materials. The chances for civilian tires before 1945 touched the bottom marker of the war-clouded industrial barometer.

The subject of synthetic rubber has become of the utmost importance to the American way of life. The time for talking of rubber substitutes as future possibilities, as theoretical technicalities, or as problems for research is long past. Yet in cold fact several general truths remain undeniable. One is that synthetic is still a trail which must be blazed into the future; a story which must grow out of the stacks, vats, working floors, pipe lines, power stations, and mixing rooms of hundreds or thousands of factories, only a few of which are now built or building—many of which do not yet exist even as blueprints.

The troubled future of substitute rubber is not brightened by the equally inescapable truth that its past record in the United States is remorselessly unimpressive, at least as regards the quantity produced. For example, reports made by the United States Department of Commerce indicate that since the year 1826 about 10,860,000 long tons of natural rubber have been imported and manufactured in the United States. Up to July 1, 1942, less than 60,000 tons of substitute rubber or rubberlike materials had been produced here, even though the production and manufacture of synthetic rubber has been described by American patents for a third of a century. This fact, of course, is largely due to an abundance of very cheap natural rubber, the extremely high price of the synthetic products available, and processing difficulties encountered in using them, which in many cases did not compensate for their specialized advantages. The history of substitute rubber in America is further burdened with many deliberate frauds, self-contradictions and corrections, and numerous outright failures, offset by comparatively few successes.

Before Pearl Harbor no American industrial concern had seriously considered the manufacture of substitute rubber in price-per-pound competition with natural rubber. The goal was merely to produce rubberlike materials for specialized uses, such as resistance to solvents and oils, and at prices which on December 7, 1941, averaged slightly more than 70 cents per pound, as compared with then current world prices of 22 cents per pound for natural rubber.

The current frenzied effort to create an immediate international war supply of substitute rubber by means of federal subsidy lacks precedent in American history. It also lacks background development. During 1940, the Council of National Defense began a study of elastomers and concluded that the synthetic production within the United States should be expanded to 100,000 tons per year, about one-tenth of current urgent needs, "but that it was not economically feasible for private industry to undertake such a program under present conditions. . . ." Meanwhile the Reconstruction Finance Corporation created a subsidiary, called the Rubber Reserve Company, which was instructed to build up reserves and stockpiles of crude rubber. This was deemed wiser than subsidizing costly factories for manufacturing synthetics at costs "at least 10 cents a pound" above prevailing prices of the natural product.

While the Rubber Reserve Company was in its rather moist infancy, it projected four "shadow factories," each to turn out an ultimate 10,000 tons of Buna-S, though the initial equipment would be sufficient to provide about 2,500 tons a year for each plant. Also during 1940-41, private industry's capacity to fabricate synthetic had arrived at an estimated possible 35,000 tons, though actual production had never approached that figure. The next step by the Reconstruction Finance Corporation was to propose that private manufacturers build plants to furnish the primary raw materials for synthetic rubber of the Buna-S type. The Rubber Reserve Company was to serve as purchasing agency for the entire output—either by direct purchase or on a basis of total cost plus an operating fee.

There arose the nettlesome issue of just how much synthetic rubber might cost. Actual estimates were, and still are, variable and contradictory. During 1940 some types of synthetic were being sold for $3 a pound, others for 30 cents. Defense Council members and rubber concerns gave 25 cents a pound as a reasonable price, with a 5-cent variation either way. It is probable that costs of German-made synthetics are considerably higher. The "reasonable" price of 25 cents a pound was predicated upon cheap and abundant raw material and lots of good luck.

Also the actual performance values of natural and synthetic rubbers in auto tires was unknown, and indeed it is still uncertain. All the first planning foresaw that synthetic rubbers "would work in harness with, rather than to the exclusion of, natural rubber"; hence that the commercial fate of the former would be bound up with the latter.

During 1940 the Standard Oil Development Company publicly announced its development and patent holdings of Buna and Butyl rubbers made from petroleum. During 1941 the Standard Oil Company of Louisiana built near the site of its refinery at Baton Rouge a plant capable of producing about 15,000 tons of butadiene yearly; the butadiene to provide part of the base material for a then proposed annual output of 40,000 tons of Buna-S, a synthetic rubber considered suitable for making automobile tires. The Baton Rouge plant was underwritten by the Defense Plant Corporation and the Rubber Reserve Company, both subsidiaries of the Reconstruction Finance Corporation of our national government. Accordingly, all of us were partners in these then little noticed plans and expenditures. The Standard Oil Development Company served as engineers and architects and the Standard Oil Company of Louisiana, by no remarkable coincidence, agreed to supervise building the plant.

These details were released to the press during October, 1941, when butadiene and Buna-S were merely two more alien-sounding words. During that month, too, the greatest of world wars was spreading like wind-blown fire into the dead grass of a decadent Asiatic imperialism. Our great rubber factories were importing about 88 per cent of their tonnage of crude rubber from the war-clouded Hevea lands of the Far East; about 8 per cent from other far-flung corners of creation, and about 3 per cent, some of it from guayule bushes, from all Latin America.

The propaganda department of the Standard Oil Company of New Jersey observed sagely during October, 1941:

"Nor is there any immediate prospect of increasing the Western Hemisphere's yield of crude rubber. Ford has developed some commercial production in Brazil and Goodyear in Central America, but at best this is a long-range program. Regulations of the rubber-producing countries in the Far East forbid the export of the best seeds, seedlings and cuttings which might result in setting up rival producing areas in other lands. . . ."[3]

This refers correctly to British and Dutch conspiracy in barring export of planting stocks of a crop which the former had literally lifted, not too ethically, from South America, whose remaining rubber production the British-Dutch cartel was avidly seeking to destroy. But Standard Oil propagandists failed to mention that during October, 1941, the Philippines were still able and eager to supply superior Hevea rubber seed and planting stocks for use in Central and South America, and that these facilities were not being used except in Goodyear's small-scale rubber-growing experiments in Costa Rica and Panama.

During 1941 the total United States production of all types of substitute rubber was about 17,000 tons. During 1940 it was about 5,000 tons, and during the previous seven years it had varied from 900 to 3,000 tons. Speaking quite impartially, the greatest of industrial nations was lagging carelessly in a field of enterprise which several other industrial nations had come to recognize as supremely important. In particular Russia, Germany, and Poland, all keenly aware of the strategic necessity of domestic and emergency sources of rubber, were pressing far into the realm of synthetics. Standard Oil of New Jersey experts estimated Germany's 1937 production of Buna-S as 25,000 tons, with expansion plans for producing 75,000 tons, or about three times the estimated total United States production of substitute rubbers during 1942. In addition, before the Third Reich's invasion of Poland, German imports of natural rubber had been reported as being in excess of 65,000 tons yearly. (Some commentators contend that the Dutch-British rubber cartel faked their figures on crude rubber sales to Germany and actually delivered to the Reich a great deal more than the tonnage reported.)

Both Russia and Poland had taken equally realistic approaches to the imperiled situation of rubber supplies, and both had developed variations of Bunas which were represented, perhaps truthfully, as being superior to German-made Bunas. The Russians patriotically called theirs Sovprene. Great Britain's manufacturers of substitute rubbers, though supported by a long and distinguished background of research chemistry, had been retarded and in some instances squelched by empire politics and quasi-official sponsorship of the now fallen Hevea empires of Malaya.

Meanwhile, principal American rubber manufacturers, except Goodrich, like the United States government, had remained cold, or at best lukewarm, to industrial development of substitute rubbers. The researches of Dow, du Pont, Goodyear, Firestone, and others, though scientifically noteworthy, had been independent, small-scale enterprises directed toward the development of elastomers for specialized uses, and as such they had been comparatively successful.

But from a standpoint of source materials and standardized processes these American ventures had been individualistic and diverse. Significantly, they did not attempt commercial manufacture of substitute rubber from commercial crops. In terms of domestic economy there was no good reason for the use of crop alcohols as starting materials. Crop prices were comparatively good during the late 1930's. The nation-wide forces of the Agricultural Adjustment

Administration were serving to reduce surpluses and to hold up farm price levels. Liquor distilleries were busy, and demands for commercial alcohols were steadily growing without the benefit of any demand from the rubber industry. Even though six pounds or more of synthetic rubber can be derived from the alcohol procurable from one bushel of wheat, there was no bright or immediate prospect of cheap production of substitute rubbers from crops, and there is still no such prospect.

With excellent cause, the recent American pioneers in the field doubted the possibility of ever arriving at low-cost production of elastomers. They had good reason to know that the whole rubber program of the Third Reich had been comparatively blind to cost, and that Hitler's men had never spared either their own horses or the public's in the matter of rubber prices. They also knew that basic materials procurable in the United States, however plentiful, are in the main subject to high taxes, wages, and operating overheads. They knew the hazards of changing technologies and obsolete investments; also the forces of capital depreciation, which are always inevitable.

During October, 1941, the propaganda department of the Standard Oil Company of New Jersey explained rather convincingly:

"From the long-range viewpoint—since the present outlook is that synthetics will be used in conjunction with, rather than to the exclusion of the natural product—one of the principal headaches of the synthetic industry is the uncertainty of the world markets for the natural product.

"Suppose, for example, the synthetic producer accepted the present world price of about 22 cents a pound for raw rubber as standard, and made large investments to increase his production so as to be able to meet that competition. Natural rubber has sold for long periods below 10 cents a pound and has gone as low as 3 cents. The domestic producer could not hope to meet such competition because he is faced with a certain irreducible minimum in current out-of-pocket expenses, notably labor and taxes."[4]

This is a typical business outlook; and until December 7, 1941, it was, for better or for worse, the accepted opinion of American business in general. But it would be unfair to blame business for this. The vital importance of a dependable rubber supply to our national economy and hemisphere defense, and the perilous status of Middle and Far Eastern rubber were well known to the national government. It was our government's duty and obligation to act; instead of doing so, it turned thumbs down on the idea of stepping up synthetic capacity.

Inevitably the story of substitute rubber, like that of natural rubber, is inextricably involved with politics, and will undoubtedly remain so. The dangers incident to allowing the supply of our most essential import to be controlled by the monopolists of Holland and Great Britain is a fantastic instance of misgovernment. Before Pearl Harbor, American rubber manufacturers were continually faced with a plutocratic hierarchy in control of rubber supply in a remote and perilous corner of the earth. As corporations, they sought to meet this deplorable situation in the manner of business expediency. For one thing, some of them started plantations of their own, notably Goodyear in the Philippines and Firestone in Liberia. Moreover, they held to the belief that rubber is rubber regardless of source, and that natural and substitute rubbers should be considered complementary rather than competitive products. American petroleum and chemical companies, more or less of necessity, shared this viewpoint. They sought to develop elastomers and other rubberlike materials to fulfill specialized, premium-price functions without benefit of government subsidies. Such developments were costly in time and talent, as well as money. Having spent heavily of all three in order to produce limited quantities of a usable substitute rubber, they sought repayment.

For this they can scarcely be blamed. But as one onlooker, the author contends that American business concerns can and should be blamed and duly punished for participation in antisocial collusion or conspiracy, or for entering or seeking to enter trust agreements with actual or potential enemies of the United States; also that commercial organizations are surely culpable for forming industrial blocs and setting forth in a more or less deliberate and common effort to employ government affiliations and subsidies for creating industrial monopoly of so indispensable a material as rubber when American survival swings in the balance of world war.

Assuredly the petroleum industry has the right to develop rubber from petroleum. In view of the crucial military needs for rubber in time of war, it is hardly unreasonable for a given industry to seek benefit of public subsidy. Certainly the agricultural bloc has not been backward about so doing. But, again, the effort of certain petroleum companies and related organizations to establish a monopoly on petroleum-base substitute rubber by way of Treasury subsidy seems, to this writer at least, a contradiction of established principles of legitimate competition in business enterprise.

This is only one man's point of view; but it recognizes the fact that the story of synthetic rubber, which basically is similar to, and a part of, the story of natural rubber, is also a story of social and ethical values which can no longer be measured in terms of test tubes, mixing room formulas, or dollars and cents profits.

OUR RUBBER-DEPENDENT WORLD

8

ABOUT a month before Pearl Harbor, I talked with an automobile sales executive who took occasion to speak of the toils and triumphs incident to the second greatest auto manufacturing year in American history. Smoking a slender black cigar, he talked discursively, but with the gusto of a man who loves his subject, of a world which moves on rubber tires:

"American highways and byroads are carrying between 29 and 30 million passenger automobiles and nearly five million trucks and buses—enough vehicles to take every man, woman and child living in the United States for a ride at the same time. . . .

"My job deals mainly with pleasure cars. Americans own enough of them to maintain a demand for 50 million tires a year, which would provide around 500 billion miles of driving every year—or as far as light would travel in a month at 186,000 miles a second! This unthinkably vast mileage requires about 33 billion gallons of gasoline; that in turn helps pay for building a quarter of a million miles of roads and highways, helps create usefulness and value for maybe 80 billion dollars' worth of suburban or country homes and business sites, and gives jobs to at least 13 million Americans. Besides that, automobile and gasoline revenues run into the billions every year. They help pay for roads, schools, police, and for national and local government. They do most to determine our population centers. They underwrite retail and wholesale selling, carloading, port figures and bank clearings. . . ."

His eyes were bright. "You are talking about rubber. . . . I'm telling you the life of the rubber industry rides with the automobile. The automobile, in tires, tubes and fixtures, uses around four-fifths of the world's entire output of rubber. . . . American automobiles have already run through ten millon tons of tire rubber. We can run through another half million tons a year . . . here in this country where we have about 6 per cent of the world's population, 7 per cent of its land surface and better than 80 per cent of all the motor vehicles on earth. . . ."

What is true of the automobile industry is only slightly less the case with many other phases of a mechanical civilization. During the year that preceded Pearl Harbor, I listened to officials and employees of our largest electric companies explain how manufacturers of electrical goods and appliances were helping to save and stabilize the American rubber industry—meanwhile overlooking the fact that the electrical goods industry is dependent upon a supply of rubber.

Modern mine operating, which uses thousands of tons of rubber for conveyer belts, air drills, and working and carriage equipment, is also vitally concerned with rubber. So, to a very substantial degree, is modern railroading, as well as large-scale agriculture, retail and wholesale merchandising, baking, brewing, roadside catering, and thousands of other American enterprises of which more than one is interrelated with your life and mine: our bread, meat, clothes and home; our past, present, and future and those of our children.

In 1932 the rubber industry spread to the farms with the introduction of tractor tires. By 1940 nearly nine-tenths of all tractors made and sold in the United States were equipped with huge, heavy-treaded rubber tires. To accomplish the same amount of work, a rubber-tired tractor consumes about one-fourth less fuel than a metal-tired one of the same size. Moreover, it moves about 25 per cent faster and wears longer, because of the vibration-absorbing properties of rubber already mentioned. About 20,000 tractor and implement tires were sold to United States farmers during 1933. During 1936 this figure reached 375,000, an increase of almost 1,800 per cent in three years. During 1937 the sales of tractor and other farm implement tires climbed to 800,000; during 1940, to about 1,100,000.

More and more the story of rubber underlies the chronicle of American transportation. There were 1,100 motor trucks in the United States in 1906; a third of a century later there were about 4,750,000. Until 1916 trucks had been mounted on solid tires; in that year pneumatic tires for trucks were perfected. During the following five years the number of registered motor trucks in the United States increased fivefold; since 1921 it has grown twenty-fold.

Goodyear, the largest United States rubber manufacturer, has made and sold more than a quarter of a billion pneumatic tires for motor vehicles since 1908, eight years before the successful development of new methods for compounding tires. In the past twenty years the working life of these tires has been increased an average of ten times, and their cost has been reduced to about one-fourth. Since 1926 the life of the best quality tire for light automobiles has increased from 14,200 to 26,500 miles, or from a year and ten months to three years; and the average rubber content has increased from 6.1 to 10.8 pounds.

These figures, quoted at random from estimates by the Goodyear Tire and Rubber Company, are arithmetical reminders—if any are still needed—of the vivid reality that we of the United States are citizens of the most rubber-dependent of all nations. Ordinarily the United States uses about 77 per cent of its total imports of rubber for making tires and tubes; about 10 per cent for general molded goods, hose, and insulation materials; about 7 per cent for footwear; and about 6 per cent for all other uses, of which there are thousands!

The following figures, prepared by the Rubber Institute at Akron during the three years before the world exploded into war, show the net imports of crude rubber:

NET IMPORTS OF CRUDE RUBBER BY COUNTRY

(Long Tons = 2,240 Pounds)

	1937	*1938*	*1939*
U.S.A.*	592,394	406,343	486,372
Great Britain	92,701	133,079	69,133
Germany	98,170	90,200	56,591 †
Japan	62,311	45,836	48,800
France	59,871	59,660	56,718
Canada	36,088	25,696	32,028
U.S.S.R.	30,462	25,650	25,000
Italy	24,733	28,170	20,024
All others	58,620	56,715	55,010
	1,055,350	871,349	849,676

* United States annual imports of liquid latex, here calculated in corresponding weight in solid rubber, averaged about 43,000 tons per year.
† First 8 months.

For more than a century our dependence upon rubber has continued to grow. Here briefly, is the proof:

Year	*Estimated World Total Rubber Production*	*Net Imports into the United States (Long Tons)*	*Per Cent of Total Consumed in the United States*	*Annual Average New York Crude Rubber Price per Pound (U.S. Dollars)*
1826	....	8	...	....
1830	....	160	...	....
1834	....	540	...	....
1840	....	260	...	....
1845	....	400	...	....
1850	....	615	...	....
1855	....	2,150	...	....
1860	....	1,675	...	.62
1865	6,000	1,700	28.0	.87
1870	8,500	3,500	41.0	.99
1875	9,000	4,586	51.0	.66
1880	17,000	8,109	48.0	.85
1885	22,500	11,354	50.4	.60
1890	30,750	15,336	49.9	.84
1895	37,000	18,646	50.2	.76

Year	*Estimated World Total Rubber Production*	*Net Imports into the United States (Long Tons)*	*Per Cent of Total Consumed in the United States*	*Annual Average New York Crude Rubber Price per Pound (U.S. Dollars)*
1900	44,131	20,308	46.0	.98
1905	56,053	27,021	48.2	1.28
1910	94,013	42,210	44.9	2.07
1915	170,826	98,999	57.9	.66
1920	341,994	249,521	73.0	.36
1925	528,485	385,596	73.0	.72
1930	821,914	457,423	55.7	.102
1935	872,413	455,756	52.2	.123
1939	1,002,768	486,371	48.5	.176
1940	1,390,469	818,102	58.8	.201

Since the birth of the rubber industry in 1826, or thereabouts, the United States has imported and consumed an average of more than half the world's entire output. About 1850, when Goodyear's discovery of vulcanization was finding its way into practical use, United States consumption of rubber began to climb. The forward spurt of 1855 can be explained in terms of new applications of rubber introduced by the shoe industry. During the nineties the bicycle era was at its height, and tires for this purpose were absorbing an amazing tonnage of rubber. The use of rubber in boots and shoes was continuing at a high level. By 1898 approximately 77,000 different styles of rubber footwear were being sold on American markets!

Military uses for rubber were meantime becoming of increasing importance. The Franco-Prussian War had proved that the captive balloon, with its gas bag protected and made durable by rubberized fabric, can serve as eyes for artillery (particularly when a mile or so of rubber-covered wire connects the onlooker in the balloon basket with ground observers). Earlier, in our own Civil War, Union forces had made use of observation balloons, but not very effectively. By 1890, the balloon ascension, sometimes with a parachute jump from the basket, had become a classic feature of the distinctively American circus. The Germans were manufacturing rubber-coated "sausage balloons" as forerunners of the Zeppelins, while in France the Montgolfier brothers had attracted tremendous attention with their hot-air balloons, to which they hogtied and sent aloft sheep, roosters, and ducks as proof that life could be sustained without contact with the ground.

Long before the fabulous era of the automobile tire, rubber had invaded the American home: hot-water bottles were being advertised as a boudoir essential of the discriminating female; rubber garters and sleeve bands were in flower, both figuratively and literally; rubber carpet sweepers were trundling across Victorian carpets; hats were being built and pressed on rubber forms; and washing machines and steam mangles were pummeling laundry with relentless rubber rollers. At the same time, industrial applications of rubber were rejoicing in spectacular growth, particularly hose for fire fighting and for spraying orchards, gardens, and lawns; medical, surgical, and drugstore supplies; jar rings and similar sealing devices for canning fruits and vegetables; and the ubiquitous "rubbers," boots, and raincoats. As long ago as 1878, a patent had been issued for a vacuum-suction milking machine, made preponderantly of rubber, and warranted to work "like a calf sucks." By 1900, almost two thousand rubber goods patents had been issued in the United States.

In 1896 there were at least three domestic brands of cars—Ford, Haynes and Duryea—as well as a few imported models; but it was not until April 1, 1898, that Alexander Winton made the first actual sale of an automobile in the United States—the quickly to be forgotten Winton Single Cylinder. Cars had previously been sold in France and England, but up to that time the presence of "gasoline buggies" in this country had been for purely experimental or display purposes.

During 1905 the manufacture of automobile tires became a notable addition to American rubber inventories. It gave world prominence to rubber and supplied an almost incredible and never entirely satisfied demand. The United States makes and uses about four-fifths of all automobiles and more than four-fifths of all automobile tires. More and more, every auto, truck and airplane wheel, indeed every train and carriage wheel, helps to measure and to accent our dependence on rubber.

A visit to the working floor of a rubber factory is probably the best way of understanding this industrial miracle. One of the revelations of such a visit is that almost every rubber product is made of a great many substances in addition to rubber. The word "rubber," as commonly used, really means rubber mixed, or compounded, with several of hundreds of raw materials and chemicals which are essential to proper service for the infinitely varied uses to which rubber is put. The selection of the proper materials to be added to a given "batch" is dependent on the type of service for which the product is intended. The rubber industry has always been an amazing saga of practical (and sometimes impractical) chemistry. Its mixing rooms, testing yards, laboratories, and work floors are meccas for chemists and experimenters.

For instance, a great many rubber products require the insertion of layers of cotton (or rayon) to lend strength, stiffness, and durability; tire casings, hose, overshoes, boots, machinery, and conveyer belts, and a hundred other items fall into this category. The cotton is used in the form of closely woven duck of various weights, or sometimes individual strands; it is coated on a calender with a soft rubber compound, known in the shop as "friction," which contains resins or pine tar to make it sticky enough to adhere to the fabric. When the tire is made, successive layers, or plies, of this rubber-impregnated fabric are laid on top of each other to form a strong, yet flexible, side wall. In the case of hose and other fabricated products, the process is similar, although for comparatively light articles cotton sheeting is used instead of duck. Tiremaking requires more than a ton of selected cotton fiber for every three tons of crude rubber. In 1939, the American rubber industry used 412,670 long tons of rubber for automobile tires and tubes; and to provide strong carcasses for those tires it consumed 145,023 long tons of selected cotton. Thus the American cotton farmer, the cotton broker, and our entire hemisphere's prospects for cotton production are closely related to the present and future of rubber manufacture, though of late, rayon is being substituted for cotton, with some degree of success.

This interdependence continues to grow as tire fabric requirements are extended and liberalized. Tiremaking calls for a long-staple cotton. For a good many years it looked as if manufacturers' demands for Egyptian or Sea Island (Georgia) cotton (fiber lengths from 1.2 to 1.6 inches) would not be satisfied with the standard grades of the king crop of the deep South, and would cause cotton-producing centers to shift to the Nile Valley, the Rio Grande Basin, or the great rich fields of Brazil, all of which are suited to growing cotton of extra-long fiber. But this particular dilemma is abating, now that tiremakers have learned to make better use of the good cotton staples which can be grown in the United States.

Consider an ordinary passenger automobile tire—a four-ply "600-16"—upon which most of us usually ride when and if we still drive. Here, approximately, are the materials which this tire contains—a more or less average estimate as of 1941, when tires for civilian use were still being made:

Materials Used	*Variation*	*Average Parts (by Weight)*	*Weight for One Tire Complete (Pounds)*	*(Ounces)*
Crude rubber	40-60	50	11	6
Reclaimed rubber ...	0-10	5	1	1
Fabric	12.5-17.5	15	3	3
All compounding ingredients and bead wire	25-35	30	6	6
			22 pounds	

About one-half the weight of a tire is crude rubber; about one-sixth is fabric and one-third compounding ingredients and wire. More specifically, here is a reasonably typical recipe for making tire casings for a light passenger automobile:

	Tread *Pounds or Parts*	*Carcass* *Pounds or Parts*
Crude rubber (smoked sheets)	100	100
Sulphur	3	3
Mercaptobenzothiazole	1	1
Stearic acid	4	1
Pine tar	3	3
Zinc oxide	5	50
Carbon black	50	....
Antioxidant	1	1.5

And here is a run-of-the-mill recipe for inner tubes:

	Pounds or Parts
Crude rubber (pale crepe)	50.0
Crude rubber (smoked sheets)	50.0
Sulphur	.6
Mercaptobenzothiazole	.5
Tetramethylthiuram disulfide	.5
Stearic acid	1.0
Zinc oxide	10.0
Soft black	40.0
Antioxidant	1.0

The rubber industry has become the standby of the sulphur industry. Sulphur is its "basic compound" in vulcanizing—for soft rubber goods 3 parts of sulphur to 100 parts of crude rubber; for hard rubber, from 40 to 45 per cent sulphur. Both soft and hard rubbers are cooked to order at a temperature of around 287° F., usually at a steam pressure of 40 pounds per square inch. (There are processes by which rubber can be vulcanized chemically without the use of sulphur and heat, but as yet these have little practical value.)

The time required for vulcanization and the proportion of sulphur used have been progressively reduced as rubber technology has advanced, especially after the introduction of organic accelera tors about 1914. Rubber-sulphur mixtures require three or four hours of baking at 247° F. or higher. But most modern compounds can be vulcanized in from five to seven minutes, depending on their thickness and the amount of sulphur and accelerator present. The principal accelerator—or "speeder-upper"—used in tires and other high-grade products goes by the name of mercaptobenzothiazole, which means that its molecule contains sulphur and nitrogen, both of which are essential for vulcanization. One of the chief antioxidants—which retards the ravages of oxygen mentioned in the Foreword—is phenyl-beta-naphthylamine; many accelerators, however, also have antioxidant properties.

The rubber industry has literally "made" the carbon black industry. Carbon black is the best reinforcing agent for rubber and is indispensable in tire treads and other products which have to resist abrasion. During 1939, along with the 412,670 tons of rubber and 145,023 tons of cotton and tens of thousands more tons of wire, copper, and chemicals, our rubber factories used 141,349 long tons of carbon black in the manufacture of that year's total of around 60,000,000 auto and truck tires.

Carbon black is made simply by causing flames of natural gas (a waste product of oil fields) to burn against iron channels, from which the residue in the form of soot particles is automatically scraped and molded into pellets or bricks. It is about as pertinaciously filthy stuff to work with as one can imagine, especially in powder form. Its particles are the smallest of any substance known—so small in fact that they fly about like smoke, and penetrate both clothing and the pores of the skin. One cubic inch of carbon black, if spread one particle thick, would cover an area of 35,000 square feet! It is this tremendously fine particle size that allows the black to insert itself in the rubber matrix and thus make the joints between the rubber particles just as strong as the main portion of the matrix—somewhat as cement is used to fill in the open spaces between rocks in a stone wall. Many theories have been advanced to explain the mechanism of its action; but on this, as on the vulcanization problem, the truth is still undecided. The cement analogy is probably as good as any.

The discovery that carbon black vastly improves the wear and abrasion resistance of rubber came about accidentally. It happened in this way: Back in 1915, the chief ingredient used to furnish stiffness and wearing qualities in tire carcasses was zinc oxide—a white pigment. Such a tire might be expected to give about 5,000 miles of wear at the then dizzy speed of 30 miles an hour. But the use of zinc oxide made it inevitable that the tire would come out white, or at least a dirty gray. Since this was considered undesirable from an aesthetic standpoint, research workers began experimenting with black pigments, than which there is none blacker than carbon black. They found that increasingly large quantities of carbon black were necessary to overcome the effect of the high loadings of zinc oxide they were using. So they kept adding more and more—until, lo and behold, up went the tensile strength values to heights previously unheard of: 3,000, 3,500, even 4,000 pounds per square inch, compared with the maximum of 2,500 they had been getting with zinc oxide! As a result, the latter was retained only in quantities necessary to activate the accelerators (nothing else will do it), and carbon black took over the burden of helping tires to withstand the sharp pebbles of the nation's detours and the grueling ravages of its superhighways. The fact that a stock tire will generally run 25,000 miles at high speeds is largely due to the properties of carbon black, although modern accelerators, introduced at about the same time, must be given some of the credit.

It is remarkable that these two technological discoveries were made just as the automobile industry stood on the brink of its sensational development. Rubber was now ready to say to automotive engineers, "Go ahead and make the finest, most high-powered engines you can; the tires can take the punishment."

A great many rubber compounding materials are far more expensive than crude rubber, even in these times of desperate rubber shortage. Some accelerators, for example, cost as much as $5 a pound. However, most of the ingredients used as "fillers" and reinforcing agents, such as carbon black, clay, whiting, and the like, have always been cheap. Organic dyes, necessary to obtain bright color effects, are rather expensive, some of them costing upwards of $2 a pound. In the case of these more expensive ingredients, such a small quantity is required—1 per cent or less—that their use does not add greatly to the cost of the finished product.

Rubber manufacture also requires a great many "specific purpose" compounds, such as talc (the usual dusting agent); aluminum powder, which helps to reflect light and heat from rubber tires and balloon fabrics; pumice and silicas, used as abrasives; asbestos, which is standard in rubber brake linings; and many types of glue, which help stiffen rubber mixtures for certain specialized purposes.

There is probably no better way to appreciate the cosmopolitan qualities of rubber compounds than to glance through a compounder's formula book. It convinces one that rubber goods made only of rubber would be as useless as a cake made of nothing but flour. Here, for example, is an extremely simple recipe for making a "pure gum" stock for surgeon's gloves or dental dams:

	Pounds
Crude rubber (pale crepe)	100.0
Sulphur	2.5
Mercaptobenzothiazole	1.0
Stearic acid	1.0
Zinc oxide	5.0
Antioxidant	0.5

And here is a recipe for those classic red hot-water bottles:

	Pounds
Crude rubber (pale crepe)	100.00
Sulphur	0.75
Accelerator	0.51
Stearic acid	1.00
Zinc oxide	10.00
Whiting	60.00
Barytes	70.00
Organic red color	1.00
Antioxidant	1.00

Rubber stocks designed to resist heat in service require a very low percentage of sulphur. This is true of hot-water bottles, some types of conveyer belt covers, steam hose, and numerous others.

The art of rubber compounding can never be explained in any book; it is acquired only by years of intimate experience in the laboratory and factory, and sometimes seems to be as much a matter of intelligent guesswork as of theoretical knowledge. Enough has been said to indicate the complexity of the problems facing the manufacturer in formulating compounds for hundreds of specific purposes, often while keeping within absurdly rigid specifications. Many interesting stories might be told, if space permitted, of the discovery and development of antioxidants, and the means for evaluating them; of the beginnings and subsequent expansion of reclaimed rubber; and of laboratory "tragedies," some of which are not without their humorous aspects. Life in a rubber laboratory may be dirty and tiring, but it is rarely dull.

There are good reasons for thinking of American manufacture of rubber goods in terms of the Big Four: Goodyear Tire and Rubber Company, Firestone Tire and Rubber Company, United States Rubber Company, and B. F. Goodrich Company. In gross output, as in research and sales promotion, these four companies hold dominant places. Goodyear alone ordinarily manufactures about one-eighth the combined national total of rubber output, which means that this company ordinarily turns out a greater tonnage than the average totals manufactured in France or Japan, and almost as much as the entire German manufacture, as of 1937. But it is also to be remembered that the existence and production of thousands of American factories, most of them in other industries, are immediately dependent upon the existing supply of crude and reclaimed rubber in the United States.

A recent edition of the Rubber Red Book [1] records that at least 29 United States factories and firms were manufacturing rubber bathing apparel in 1940. At least 21 were making rubber dental goods; 60 were making rubber mats and other flooring; 32, pure rubber gloves; 266, drug and surgical sundries of rubber; 58, hard-rubber goods; 67, shoes, heels, and soles; 121, rubber cements; 121, household goods (such as jar rings, bottle caps, casters, aprons); and 46, rubber-insulated wire and cables.

The list continues approximately as follows:

Rubber Goods	*Number of U.S. Manufacturers*
Laboratory supplies (rubber tubing, acid aprons, etc.)	35
Latex products	20
Mechanical goods	46
Hose	51
Rubber mountings	62
Other mechanical goods (rubber)	75
Plumbers' specialties (rubber)	70
Rolls and tapes (rubber)	96
Tubing (about)	100
Miscellaneous "mechanical" rubber including windshield wiper blades	261
Rubberproofed fabrics	21
Rubberized clothing	26
General rubber fabrics	88
Sponge-rubber products	72
Sporting goods (rubber)	62
Stationers' goods (rubber)	77
Rubber thread	11
Tire accessories and repairs	85
Bicycle tires	7
Pneumatic tires	29
Solid tires	27
Inner tubes	34
Toys and novelties	80
Artificial flowers	4
Ash trays	15
Rubber buttons	7
Coin mats	13
Ear stoppers	5
Rubber goggles	14
Can closures	5
Mannequins and display figures	16
Masks	4
Plastic rubber	21
Road expansion joints	7
Rubber paints	19
Rubberized curled hair	4
Stoppers	22
Table tops	6

In the United States at least 394 factories are manufacturing machinery and equipment required for the fabrication of rubber goods. Two are making bead chains for tires, two make burrs, and two more make buckles for rubber goods. Twelve make hose couplings; 8, clamps; 8, eyelets; 10, fasteners; 10, ferrules; 12, mouthpieces for toy balloons; 7, hose nozzles; 4, air valves; and 11 specialize in wire required in rubber manufacture. About 223 firms manufacture industrial chemicals used in compounding rubber, 11 specialize in the manufacture of equipment for reclaiming rubber, and at least 290 manufacture dyes and coloring agents for use in the rubber industry.

Rubber factories are in operation in 29 states. Many of these, however, are extremely small, employing only about half a dozen workers.

State	*Number of Rubber Goods Manufacturers*
Alabama	3
California (42 in Los Angeles area)	66
Colorado	1
Connecticut	39
Delaware	2
Georgia	4
Illinois (67 in Chicago area)	84
Iowa	5
Kentucky	3
Maine	3
Massachusetts (40 in Boston area)	127
Michigan	32
Minnesota	6
Missouri	16
Mississippi	1
New York (65 in New York City, 26 in Brooklyn)	132
North Carolina	4
Ohio (20 in Akron area)	122
Oklahoma	1
Oregon	2
Pennsylvania (26 in Philadelphia)	68
Rhode Island	21
South Carolina	2

State	*Number of Rubber Goods Manufacturers*
Tennessee	3
Texas	5
Vermont	2
Virginia	2
Washington	2
Wisconsin	21
Total United States rubber factories approximated March 1, 1941	779

In a rubber factory, amid the incessant rumble of ponderous and expensive machinery, the visitor quickly infers some of the reasons why our principal rubber companies have not made greater investments in rubber plantations or devoted more time and talent to the agriculture of Hevea or to the elusive chemistry of synthetic rubber. Rubber executives are generally factory men; they have to be. The great bulk of their capital investment is in machinery, factory equipment, and (before Pearl Harbor) in sales promotion, stocks, and wages. Whatever he may say to the contrary, the India-rubber man, 1943 model, is an industrialist—not an agronomist nor a searcher for the new horizons of synthetics. The factory must run. It is a community of machines into whose creation and development has gone most of the capital investment, most of the accrued earnings, and most of the talent developed by the rubber industry of the United States, which is by long odds the most advanced and efficient in the world.

No matter what they say, off the record or on, American rubber executives remain factory men. The great majority of our rubber workers—machine tenders and designers, mill-room supervisors, laboratory technicians and test-tube agronomists—also are factory men and women. The lush, hot Hevea lands seem infinitely remote from the smoky shops of Akron. So do the flat, derrick-covered oil fields. In cold statistics, and hot machine rows, Akron, Ohio, justifies its claim of being "Rubber Capital of the World."

About half a million Americans earn their livelihoods in rubber factories. Most of them are skilled laborers. For a third of a century they have been among the highest paid of industrial groups, the freest from strikes, the most steadily employed. Even during the worst depression years, wages in rubber factories held either at or near the dollar-an-hour level. Improvements in technology have helped to raise them. They have once more disproved the contention that bigger and better machinery diminishes man-hours and manual skills. In rubber manufacturing, increased mechanization has done exactly the opposite. Most of the basic crafts of rubber manufacture endure. Thus, despite complex extrusion machines that operate on the meat-grinder principle, human skill is still essential in making inner tubes; and a better workman is required to manage a 1942-style mixing machine than a 1836-model Chaffee mill.

The tiremaker is one of the most impressive as well as the most typical of American craftsmen. Building a good tire continues to require outstanding manual skill. The tiremaker literally builds up each casing, beginning it with the flat strips, or plies, of rubberized fabric, which are fed to him by an automatic carrier. These he places carefully upon a collapsible revolving drum, so that each ply forms a complete circle, with its cord or fabric structure at a right angle to that of the ply below. Having placed the first two plies in position, the builder inserts the wire beading for structural support and adds plies as specified, from four to eight; most passenger automobile tires are now four-ply. He next places chafing strips around the beading to protect the tire from rim wear, and lays a "breaker strip," or cushion, around the center of the bead. Finally he puts on the tread and rolls the assembly down with a metal roller to assure good adhesion of the plies during vulcanization.

Then he removes the "green" tire from the collapsible drum, places an air bag inside, and inserts the tire in a shaping machine. This compresses the edges, pushes out the center, and thus creates a huge "doughnut," which is then placed in a "watch-case" mold and "cooked" with steam pressure. During this process the tread design is implanted by the shape of the mold; the casing is effectively heated from within by means of the heated air bag—or sometimes a water bag—a thick-walled tube which can be filled at prescribed pressure with steam or hot water. The cooking requires from 45 to 60 minutes. The vulcanizer opens automatically when the tire is "done"; it is taken out, the air bag extracted for further use, and the tire passed along for trimming, inspection, and wrapping.

There are variations in this process—"trade secrets," which in Akron are usually about as secret as Mrs. Mulrooney's washing. There are numerous "kinks" and specifications for types of fabrics to be used. There is "gum dipping"—which involves immersing the fabric cords in latex—and various other specialized processes.

The sweat-soaked, dirty-faced men who process tires are indispensable builders of our modern world. They underwrite the employment and directly affect the livelihoods of nearly all the population of the United States. Their work makes possible the delivery of goods in trade, the transport and migration of our people, modern agriculture, the care of the sick, the burial of the dead, the employment of millions of automobile drivers and workers, salesmen, cabmen, motor patrolmen, and special workers, official and private; in other words, the unending work and recreational pilgrimages of Americans, who are the most migratory of all peoples.

Like many other specialists of the rubber factory, the tireworker is the cornerstone of an almost fantastically interdependent employment structure. He is another industrial worker who is far removed indeed from the source of his essential materials. As a rule he knows little or nothing about how rubber is grown and harvested, or devised by synthesis. That is distinctly "out of his field." Probably he has never known the hot nights and sultry dawns of a Hevea plantation, or the noontime lull of a cotton field. His knowledge of the physics and chemistry of synthetic rubbers is usually nil.

During the two decades just past, the profits reported and dividends paid by corporate proprietors of Hevea plantations in Malaya and the Dutch East Indies have exceeded the dividend earnings of all United States rubber factories combined. It is worth noticing that the wage scale in our factories is among the highest in the world, while that paid on rubber plantations has remained approximately the lowest.

For generations, the United States and the rubber-dependent world at large have shown willingness, even eagerness, to pay fair prices for rubber. In general, none but American rubber manufacturers have been ready to pay fair prices for essential labor and craftsmanship. The tireworker of Akron and his tens of thousands of factory colleagues earn and receive good wages; but their employment is, and long has been, desperately imperiled by the serfdom, peonage, and bitter poverty of the hundreds of thousands of unknown, dark-skinned workers on the other side of the earth—those other men of rubber whose sweat, toil, and suffering have made possible most of the indispensable motion of American life and trade, as well as the existence of tires and the tireworker of Akron.

Just how, in the world of the future, can we go about bettering this disgraceful condition wherein about 80 per cent of the essential producers of rubber have been paid less than 25 cents a day?

In Akron recently, during a twenty-minute "lunch hour," I discussed this point with a career tire builder who was eating his lunch beside his molding machine. He finished his apple, drained his vacuum bottle of the last swallow of coffee, and expatiated:

"This world has been built by the common man, with God's help and grace. If it's ever going to be worth a damn it's got to be run by and for the common man, who ain't necessarily interested in seeing Mrs. Richbitch make 200 per cent on her Malaya rubber farm, get her ugly mug in the society column, or clip six million dollars in petroleum dividends.

"Brother, this is war—to decide the lives of us all. This is a war that's got to be won with rubber—if it's won—by us. We're working and fighting to save democracy. That means the right of the common man to live and earn and buy. Neither rubber nor any other industry will ever be worth a good goddam until it pays decent wages for the goods and services it's got to have, and by that I mean from the ground up.

"What are we going to do about it? Brother, in a democracy we can do plenty. . . . We boys here on the factory floors can take it up with our unions and affiliated unions. Yes, sir. . . . We can plant the idea of a union-made stamp on every auto tire. Maybe we could plant the notion around that the big shots here in the factory had just as well not put on that union-made tire stamp till they've made damned sure the rubber they buy is not produced by starved coolies.

"Can they do that? Suppose I'm a British or a Dutch rubber grower. . . . The customers that buy three-fourths of what I have to sell come out flat and tell me what to pay my hired help, and send over men to see that it's done. Do I do what the big customers tell me? Yes, sir, I do, or else I go broke. . . .

"Any dumb cluck knows there's been plenty of rubber conspiracy between big business of the United States and big business in Britain, Germany, France, Holland, and other places. . . . But it takes government license to export goods and government approval to import. With enough heat put on Congress and Washington we can see to it that some nice fine print goes onto those export licenses—print that says living wages have got to be paid rubber workers all along the line. . . .

"You say we can't do that? 'Can't!' We *are* doing it in some cases. It's our job to do it in all cases. Wage rates can be written into every trade agreement that our country makes from now on. . . . That's democracy, brother. . . . That real democracy is the right of the common man, regardless of place and color, to work and to live. Play fair and pay fair with the rubber worker, and you'll get the rubber that you need."

Rubber has become essentially pegged to the wage levels and living standards of the United States, but it demands international parity in wages. We are going to have to recognize the right of the farm laborer who produces crude rubber to earn wages which are compatible with those earned by the final manufacturer of rubber goods. The future of rubber requires an international fraternity of labor. Spilling over national and territorial boundaries, it demands economic justice—the need for an international justice of tomorrow. Of all the commodities essential to mankind, rubber, planted, grown, and processed by men of all races and colors, is foremost in its opportunity and need for the extinction of racial prejudices. Introduced by Indians of the American tropics, exploited by white men, popularized through the ruthless persecution of Indians, more recently grown in many tropical lands by brown men, yellow men, red men, and black men as well as white men, the economy of rubber is stamped with particular social importance.

In everyday American life the extent of our dependence on rubber is focused upon the automobile. During 1941, the national total of revenues procured from the sale and licensing of motorcars, from gasoline taxes, automobile property taxes, oil taxes, and taxes on replacement parts and accessories was around $3,000,000,000. Though harried and threatened by a rubber shortage and temporarily out of manufacture, the American automobile remains our most versatile taxbearer. Automobile taxes maintain or help maintain most of the roads of this nation. Each year they help to educate some 20,000,000 young Americans in public schools. They help pay deficits incurred by almost every other phase of American government. They pay, or help pay, for water coolers in legislature lobbies, for political campaigns, for the support of prisons and public asylums, for state and local police, for township, city, county, and national governments.

Each year since 1921, the American structure of automotive taxation has gained in volume and importance. It is now far beyond the point of accurate statistical "breakdown." The results of its partial or complete elimination can no longer be competently described even by our most able automotive tax authorities.

In spite of war, our American economy still rolls on rubber tires. One of the best current appraisals of this fact is contained in a publication entitled *Automobile Transportation in the War Effort,* published by the Brookings Institution, and compiled by Charles L. Deering of the institute staff and recently of the Office of Defense Transportation. Mr. Deering and his associates find that approximately 34 per cent of all automotive vehicles registered in the United States expend between 70 and 100 per cent of their total mileage in business pursuits. For this and other reasons, he believes that 20,000,000 such vehicles (requiring perhaps 800,000 tons of tire rubber) is the minimum that must be kept running. According to the Brookings Institution, this can be accomplished only by heretofore unknown sacrifices of transport convenience by the American public as a whole. The summary declares that, if normal driving habits continue, all civilian tires will be completely worn out by 1945, and that the number of cars in service by June, 1943, will be substantially less than the necessary 20,000,000. Accordingly, the report declares that nation-wide gasoline rationing and stern restriction to five tires per car are essential to maintaining the mobile economy which is in turn essential to winning victory for the United States. Both these restraints are now in effect.

Other capable realists reiterate our absolute dependence on rubber. Inventors roam widely in rubberless experiments. At Akron, and elsewhere in the United States, engineers and research men for Goodrich and Firestone are experimenting with rubberless tires, some even being made of wood. At Dearborn the Ford Motor Company has under trial production a fabric-built tire which contains only one-sixteenth of the rubber normally used. (Most of the rubber content of this tire is in the form of adhesives or rubber cement.) Goodyear test cars scoot over the Akron countryside on rubberless tires. "Sandals" made of asphalt-impregnated fabric are being manufactured. An improved type of reclaimed rubber has recently been announced. Dependence involves necessity, proverbially the mother of invention.

The quest for natural rubber gains rapidly in scope and frenzy. At the same time, senators paint glowing, romantic pictures of rubber from poinsettias, dandelions, and goldenrod. Early in June, 1942, the Secretary of Agriculture reported that about 80,000,000 bushels of wheat or corn will be needed to produce 200,000,000 gallons of alcohol, which in turn could produce 220,000 tons of butadiene for synthetic rubber. Never in man's history has so much scientific effort been directed toward creation and development of rubber substitutes. By August 1, 1942, war agencies of the United States government had examined and rejected more than 600 patents or formulas for rubberless tires.

This startling, sometimes terrifying, dependence settles grimly upon all American business. It clouds the future picture of city trade; but it is somewhat less appalling to urban than to rural America. As federal regulations now stand, cities have distinct advantages in priorities for rubber goods. They also have the best railroad and transport accommodations, and better facilities for pooling delivery and collection of essential goods. They have the principal concentration of public utilities, the maximum ratio of public servants, and the best facilities for getting the most use of the tires available. Nonetheless, some of them have already stepped back forty years in their transportation methods. Horse-drawn cabs of the nineties vintage are a common sight in Boston today.

Rural dependence upon rubber is actually greater than urban dependence, and though city tires keep wearing (at a still prevalent rate of about 3 per cent a month), the fatal puncture or blowout is more calamitous to the country than to the city dweller, who can usually use a streetcar if he has to. In terms of practical use on country roads, and considering the greater distances involved, rural tires, trucks, and automobiles are shorter-lived than those of the town, since the countryman must take his produce as well as himself to market and back over the two to seven miles of comparatively inferior road which separates the average American farm or country home from its local trading center.

There are many angles to rural dependence on rubber. One of them involves the annual automotive migration of harvest labor, the "Okies," "Arkies," and their kin, who comprise a caravan totaling as many as 2,000,000 workers. They take to the road from early spring to late fall and earn their "vittles," "gas," and "grub" by helping to harvest perishable crops, particularly fruits, vegetables, and cotton. These migrant workers are essential to the still decisive "big farm" structure of the United States. A 1,000-acre orchard of prunes, peaches, pears, or apples is likely to require from

50 to 500 or more pickers to harvest its crop, after the proprietor, his family, and perhaps two or three "steady" hired men have "made" it. With modern machinery one man can produce vegetable crops the brief harvest of which requires a hundred men. As farm production becomes more imperative to victory, so in general do the services of migrant harvesters. Repeated studies of these farmworkers prove that as a group they are good people in their best working years. Recently the United States Employment Service, with more than 4,500 public offices scattered throughout the country, the Farm Security Administration, which has opened well-managed tent camps for migrant workers, and other federal departments have ably championed the cause of the Okies.

Now, partly because of booming labor markets and partly because of the present dearth of tires, the ranks of the Okies and Arkies are fast dwindling. Here and there throughout the nation valuable fruit and vegetable harvests have already rotted for lack of pickers, and American agriculture is paying dearly for the growing immobility of our once great harvest army. Thus far, tire-rationing authorities have been unable to solve the dilemma which seems to have settled upon us for the duration, or at best until 1945.

The first calamitous rubber shortage in history grimly disregards individual needs and principal trades and professions. It defies national boundaries. It makes our dilemma that of our allies—of all Europe, both free and conquered, of much of Latin America, of Russia, China, and India, and most of the tortured East. It does not except Great Britain, which in the past has profited most from rubber production. In England today no vehicles except those vital to war effort are permitted to have new tires. The Ministry of Supply issued an ultimatum on April 1, 1942: "The Government's attitude is one of complete ruthlessness. We have simply got to save rubber. The position is so critical that the Government has made up its mind that the time for appeals to the public has come to an end. Henceforth every one must accept whatever is issued to him—new, retreaded or second hand. A discarded tire must be surrendered without payment. . . . The next step may be the requisitioning of tires from cars that are laid up. There will be a gap to be bridged between the exhaustion of stocks and the big flow of synthetic rubber that we are hoping to get, mostly from the United States. We will be able to tide over the intervening period with extreme difficulty. . . ."[2]

The rubberless quandary of London and a score of other world capitals settles impartially upon Pelican Lake, Wisconsin; Farmington, Arkansas; Leonora, Indiana; and tens of thousands of other crossroads villages of the United States. It settles just as impartially upon the principal rubber-tired carriers which serve those villages.

One of the most straightforward documents of proof is the proceedings of the 1942 Chicago convention of the American Trucking Association, which is famous for its blunt statements of unpleasant truths. The membership of this association agreed that half the 4,750,000 trucks now traveling United States highways will be forced out of service before the end of 1943 for lack of rubber, and that "without a miracle" the American trucking industry cannot last into 1944. This testimony is hair-raising, in view of the fact that, even in this age of transportation networks, about 48,000 towns, villages, and other small communities of the United States lack railroad service and are therefore vitally dependent upon motor-truck transportation. Department of Agriculture economists estimate that about 75 per cent of all farm crops grown in the United States go to market by truck. In 1941 motor trucks carried about 18 per cent of all freight moved in the United States.

The trucking industry includes about 2,500,000 privately owned trucks, more than 1,500,000 farm trucks, and about 700,000 licensed common carriers. The Office of Defense Transportation has already ruled that none of the latter can leave on any trip without being fully loaded, or return home with less than a 75 per cent capacity load. Supplementing this ruling, commercial truck operators have effected elaborate systems for pooling equipment and cargoes, for increasing commercial loads and reducing the number of trucks in operation on a given run, and in various other ways enforcing drastic control.

But the truth is that in the year 1943 this great and indispensable industry is facing possible extinction for want of rubber. Proprietors of trucking lines are grimly intent upon driving every good truck an additional million miles and recapping every available tire to assure a maximum working life of 125,000 miles. Nevertheless, without a miracle, there will be few trucks on American highways during 1944. And the 48,000 American communities without railway facilities will inevitably be face to face with supply and transport wants never before dreamed of—even in the mud-splashed and romanticized days of stagecoach and prairie schooner. The stagecoach and wagon age is over, too. The status of our horse and mule population is about the same as that of buggy-whip manufacturers. And replenishment of the equine population takes time—four or five years at least, and ten years at most.

A shortage of rubber naturally turns the spotlight upon our railroad system. Hundreds of millions of additional tons of freight must roll upon the same rails; tens of millions of additional passengers must ride upon the same hard-pressed cushions. Cars must be crammed and schedules upset, for we are a mobile people, who dress, drink, and eat by means of a mobile economy. There is a limit to the amount the railroads can do to offset the disaster to our automobiles. Even now some of the Class I railroads are pressing into service outmoded wooden coaches as standard equipment on regular runs.

Already more than nine-tenths of the 40,000 automobile dealers of the United States have been forced out of the auto business. The National Retail Grocery Association estimates that one-third of the 380,000 grocers of the United States may be closed out before 1944. The mortality among filling stations is currently estimated at 100,000. By the middle of 1942 an estimated 40,000 roadside catering stands had shut up shop, and along with them at least 22,000 tourist camps, summer resorts, seasonal hotels and restaurants.[illegible]

Because of war and for want of rubber, the American automobile industry, as such, has ceased to exist. Early in 1942, after the War Production Board had "frozen" all newly manufactured autos, about 500,000 new cars and trucks were available in the United States—in all, a normal 60-day supply. The selling of new cars was prohibited during January and February, and total quotas of 40,000 new ones per month were authorized for March, April, and May, 1942. But only 17,000 were sold in the entire United States during March, and only 29,600 in April. Sales figures slumped even more drastically during June after the gravity of the national rubber shortage was known and as nation-wide gasoline rationing became a virtual certainty.

The impact of the crisis is being felt in a number of ways which are less obvious but equally unfortunate. More than any other agency, the automobile had transformed our recreation pattern from a blatant anarchy of medicine shows, circuses, slovenly beaches, carnivals, pink lemonade, and blue confetti to one of the most tangible of all American resources. A quarter of a century ago receipts of amusement establishments and excursion travel took first place in recreational spending. Because of the automobile, this industry has become one of staple merchandise and valuable services from which, directly or indirectly, the entire nation benefits.

In 1940 Everett B. Greaton of the Maine Development Commission, at Augusta, completed a statistical analysis of the $100,000,000-a-year vacation business of Maine. He deduced that the American recreational dollar was being spent approximately as follows:

	Cents
Hotels, camps, restaurants, etc.	16
Groceries	11
All other stores	10
Rooms, tourist camps, and roadside stands	7
Construction work	7
Garages and filling stations	9
Amusements and sports	6
Camps for boys and girls	5
Utilities and transportation	4
Insurance and taxes	3
Farm produce	3
Direct employment	2
Antiques and gifts	2
All other items	15

Recreation spending has come to mean spending for farm produce, drugstore merchandise, building and plumbing materials, hardware, department store goods, wages to caretakers and builders, shoes, clothing, furniture, garage and auto supplies, and the inevitable taxes. But today, as an institution so largely born of automobile travel, it has decreased at a rate without precedent in American history.

Simultaneously with its curtailment of recreation, the rubber shortage is causing drastic shifts in property values, depreciating the value of "summer places" in the country or far suburbs and accelerating the decentralization of American industries. The general dread of possible air raids will probably go far to offset the shrinkage in rural real estate values caused by lack of rubber and gasoline, at least along the eastern seaboard.

But with industry, the situation is dramatically different. Of the first $8,000,000,000 in government contracts for new war plants, the rural South and West have received far more than their normal share of industrial capacity as measured by 1940 output. The Atlantic states and New England are heavy losers. For example, Texas, with 3.4 per cent of the 1939 industrial capacity of the United States, has already received 10.4 per cent of the new war plants. The Basin South—Mississippi, Alabama, Tennessee, and Kentucky—which had 3.3 per cent of the 1939 industrial capacity of the United States, has thus far received 6.3 per cent of the new war plant output. The seven Prairie states, with 5.5 per cent of the country's normal industrial output, have already received 10 per cent of the still incomplete billions for war manufacturing plants. The Rocky Mountain states, with 1.1 per cent of normal industrial output, have received 4.6 per cent of the war plants.

This drastic relocation of industrial sites is not wholly the result of rubber famine: there are other noteworthy factors, such as planned strategy of defense, pressure politics, and public and private power-site developments. But the rubber shortage is none the less a contributing cause, one which from now on may become more decisive. In the past our dependence on rubber has done a great deal to make possible the westward shift in the national center of population. In time the rubber scarcity may tend to retard this movement, and to pull population eastward, or to factory centers.

This nation was built by the seeding and multiplication of rural communities. Beyond the corporate limits of its principal cities and towns, the United States is still a hodgepodge of some 100,000 rural or semirural communities. Paved highways, built and maintained principally with automobile and gasoline revenues, have so increased the speed of trade and traffic that indeterminable billions of dollars have been literally carried past the villages and into principal towns and cities. Despite this, the United States still has about a quarter of a million rural or semirural merchandising institutions still definable as crossroads stores, most of which are still solvent—a fact that is easier to state than to explain. For two decades or more, automotive ubiquity has threatened these enterprises with cobwebs, shutters, and abandonment; prospective customers have habitually traversed the 300 yards of Main Street at 40 miles per hour, or better.

Suddenly, and not at all mysteriously, the story is changing. The abrupt decrease in automobile travel is holding out new hope to the humble crossroads stores. Every month, every week, almost every day, their trade volumes are growing. Fewer cars hurtle past at breakneck speed. Local citizens are doing more of their buying at home, driving their cars fewer miles, making fewer sallies to the county seat and less frequent pilgrimages to the movie-studded factory town. Experts of the New England Council suggest that the trade volume of Grover's Corners rose markedly during 1942, and may easily double its 1941 volume during 1943. Should this estimate be valid for rural America as a whole, it would suggest that between 10 and 15 per cent of all the retail merchandising of this nation will be restored to local country stores. That is big business, and a noteworthy transition; perhaps it is one of the few changes that may be chalked up as benefits of the rubber shortage.

We do not know how long our rubber and gasoline famine may continue. We are almost certain that it cannot be materially diminished sooner than late 1944 or early 1945. Even then automobile tires may be exorbitantly expensive and of poor quality. Approximately 15,000,000 cars which are usable today will be worn out by 1945. Millions of new ones may then be in manufacture—better and cheaper cars than we have ever known before. But the prolific automobile production lines of 1941 no longer exist. However bountiful and ingenious the automotive future may be, time will certainly be needed for its resurrection.

Whether or not our 250,000 crossroads stores can hold any substantial part of the advantages being fortuitously dealt them is at present anybody's guess. Almost unquestionably, many thousands will. We have already spoken of the 48,000 United States communities which have no railroad facilities: at least one-third of all crossroads trading centers in the United States are among them. Still more are threatened with restrictions in local railway service. If common-carrier trucking dies by late 1943, as the American Trucking Association has so emphatically predicted, it is a reasonably safe bet that somewhere between 50,000 and 80,000 crossroads stores and about as many roadstands, shops, and eating places also will perish for want of transportation and deliveries. That would spell the largest and most abrupt mortality rate in the history of rural merchandising in the United States. It would also throw still greater advantages to those crossroads centers fortunate enough to be served by railroads.

All in all, the restriction and possible extinction of automotive transportation is sure to bring with it profound changes, both for better and for worse, in the economy and life of American small towns. The crack of the buggy whip and the clang of hammer on forge may yet remind us of the days of yore.

SINGAPORE AND JAPAN 9

AMONG the many interested readers of the British Supply Ministry's April Fool's Day communiqué of 1942 on the desperate plight of the empire's rubber supply was a certain James C. Francis James, originally of Cleeve Hill, Gloucestershire, then for nineteen years of the Malay Peninsula rubber lands, and now a detachment leader of the Winchcombe Home Guard. Jimmie James was in his late fifties. He would have liked to be with his two younger brothers in the Coldstream Guard; but the Army wouldn't take him, because Jimmie was not only too old but seriously impaired in health by his Malayan sieges of sprue and amoebic dysentery. Nevertheless, he is proving distinctly helpful to the war effort. During his nineteen hot and busy years in Malaya he became what is known as a commissary linguist. He learned to speak Javanese, Malay, and Tenggril, which is the talk of the south Indians whom British rubber plantation companies lured to Malaya by the tens of thousands. Jimmie also learned to speak Chinese, and since the war began he has proved almost invaluable as an interpreter for stranded, harassed territorials. Besides that, he knows as much about rubber growing as any man in England—or anywhere else, for that matter. Since his return a few years ago, he has achieved some distinction as a prophet of empire brotherhood and the new imperialism, as a contemporary definer of the white man's burden, and as a more just and discerning successor to the ideas of Rudyard Kipling. His story is in outline the whole shabby agricultural epic of Singapore rubber, and to tell it is to explain instantly what was wrong in Britain's most fabulously profitable colony.

I first met Jimmie James in Gloucestershire during 1929. I was lodging in Winchcombe Village, convalescing from a rather serious operation. Jimmie was languishing near by at his father's farm at Cleeve Hill, on sick leave from the Malacca Company estate down Singapore way. We met as completely impoverished invalids in one of the most beautiful of England's countrysides, and presently, at Jimmie's suggestion, we set forth upon a bus and bicycle tour of the Roman ruins in western England. There are a great many of these ruins, some of them of once-magnificent colonial estates of the early Christian era. You run across them here and there in the green English countrysides, much as you discover the far more recent but long-abandoned cellar holes of early New England. Sometimes you find the remnants of massive paved courts, and the straight-hewn pillars which were once part of the luxurious baths of the empire-building legions of the Caesars.

Mr. J. C. F. James had previously devoted a great deal of study to the ancient Roman homesteads of England, which he considered to be the best practical instances of enlightened imperialism in the history of man. Eighteen centuries ago England was quite literally the granary of Rome, probably the greatest sheep, cattle, and grain land in all the world, and by long odds the richest agricultural colony of the Roman Empire.

The colonial system in Roman England was distinctly military. For several centuries Rome maintained central army garrisons in England and in some instances, as at York, the same military organization remained intact for four hundred years. The Roman soldiers were paid largely in English lands, and they were retired from service with every incentive to benefit from those lands. On retirement, they usually married or took over Englishwomen, claimed their pay in hectares of land, became farmers, and spent the remainder of their lives in England.

There is good archaeological evidence that many of these Roman soldiers proved to be good farmers and valuable territorials. As Jimmie James used to point out, the young soldiers of Caesar's legions traveled to England with the comparatively certain knowledge that theirs was a career mission; that they would spend their lives in the great granary of the north; and that they would be paid principally in land, with which they personally would increase its wealth. Under those conditions the motivation for pillage and rapine was largely eliminated. No soldier, past or present, is inclined to ravish or needlessly injure what he knows is likely to be his own; and for the same reason Caesar's legionnaires apparently did not object to hard service in road building, dike building, or any other of the super work projects which characterized Roman long-term occupation. Actually, Roman soldiers built most of the roads of England and developed many of the great harbors; and they contributed their efforts willingly because they were confident of ultimately benefiting by their improvements.

Jimmie James dwelt upon these points over our rural cups of shandygaff and peary, and by way of contemporary contrast he talked of Britain's grotesquely botched conquests and exploitations of Malaya.

On such occasions he spoke with sincerity and emphasis. After his first busy decade in the distant rubber hells, Jimmie came to believe that, since Malaya and rubber would become his career, it was fitting that he should think along lines of beneficent imperialism, which was what Malaya needed but all too evidently lacked. When he compared his study and inferences about ancient Rome's imperialism in early England with his firsthand knowledge of modern British imperialism in the tin and rubber areas of Malaya, Jimmie frequently felt the need of a couple more drinks and sometimes for a few honest tears.

The latter were usually a forerunner of reminiscences. Since he was twelve or thereabouts Jimmie had been studying the Roman ruins of western England and pondering upon the courses of empire. At sixteen he went to work for a retired Indian Army colonel who stirred in him the ambition to enter the India Service. In 1914 the colonel died of what gossipy neighbors termed an alcoholic heart, and shortly thereafter Britain went to war against the Kaiser.

Being of fighting age, Jimmie promptly volunteered and went to France with an artillery regiment, which was promptly blown to pieces. Having acquired two wound stripes and a fervent contempt for young and inexperienced officers, Jimmie succeeded in obtaining transfer to a regiment of Australian Territorials, whom he liked very much. He remained with the Aussies until that regiment also was decimated with battle casualties, and then found himself detoured with sergeant's stripes to a stagnant depot brigade.

When the war ended, Jimmie learned that the then unprecedented crop of war-made millionaires had more or less taken over his home countryside and that there was no possibility of vacancies in the India Office. However, many London rubber companies were hiring men for Malayan service. In London, Jimmie made investigations at the office of Kyle, Palmer & Company, Ltd.; he was given a "descriptive pamphlet" which he absorbed with great thoroughness before he took the job.

The pamphlet showed pictures of giant Hevea trees, and dark-skinned, lank, half-naked coolies standing beside them, gazing most respectfully into the camera. Jimmie read of the principal rubber-tree diseases in Malaya—moldy rot, black stripe (which sometimes appears in the Hevea bark just above the tapping cut); brown bast, or bark cancer (resulting from too much and too deep tapping); the pink disease (a fast-spreading wet-weather fungus which encrusts the barks of many jungle trees); leaf mildew, which attacks the young leaves of rubber trees, and so on. He also studied the graphic clinical descriptions of root diseases of Hevea trees (the white, red, and brown root diseases, caused by soil fungi which attack tropical vegetation by root abrasion or by direct contact of healthy roots with diseased roots). He read, too, about wind-blown spores and dry-root rot which attack trees through wound surfaces; of ruinous termites which Malayans call white ants; of tropical caterpillars, bagworms, mealy bugs, and scale.

Jimmie took the diligent Britisher's interest in pathological descriptions; but the descriptive pamphlet did not reveal the highly significant truth that diseases of the people who work the rubber lands of Malaya are considerably more formidable than those of the trees.

The pamphlet then described Hevea trees in some detail, telling about male and female flowers; about normal fertilization by wind-blown pollen; and, to Jimmie's intense interest, about the exploding seed pods of Hevea: how the tightly wrapped brown seed pods containing three brown-black, oily seeds, if dropped upon the shaded jungle floor immediately below the tree, would die for want of sunshine and open air; and how, to offset this drawback, nature causes them to become filled with a sort of gas, from the inner pressure of which the pods explode at the right time, thus scattering the seed to distances of twenty yards or more, well beyond the range of the "shadow of death" cast by the parent trees.

Completely fascinated, Jimmie learned, too, about *lelang,* the flat, swampy land which must be avoided; how trivial food crops, such as tapioca and pineapple, are extremely hard on land, and the wasteful way in which Chinese had already worn out a considerable part of what might have been the profitable rubber lands of Singapore Island and Johore. He read emphatic statements that, regardless of the native's degeneracy, white men in Malaya should have mosquito-proof rooms and outside water closets. He noted humorless descriptions of the activities of the Chinese, and drank in the significance of paragraphs of advice to newly arrived British white employees.

Jimmie memorized several of the latter paragraphs, and even now, a quarter century later, he quotes them with considerable zest. One said: "A few flowering plants help the appearance of a Britisher's bungalow, but the border of empty beer bottles turned upside down sometimes to be seen is apt to cause a wrong impression. . . ."

Another divulged: "Evening clothes are seldom worn in Sumatra or Java, but a dinner jacket is sometimes useful. In British possessions, however, an evening suit is desirable. . . ."

Another: "A strong 12- or 16-bore gun is of use sometimes in the evening, but perhaps not so much so as it used to be before so many clearings were made. . . ."

After he had finished reading the pamphlet, Jimmie James went to a corner stationer's and asked to see a map of Malaya. He noted that Malaya is a gangling peninsula hung upon the extreme southeastern tip of Asia—in reality a prolongation of hot, marshy Siam and coast-greedy Burma. He noted Singapore, the island city which almost straddles the equator and bastions the narrow sea passage separating the Malay Peninsula from the huge, cucumber-shaped island of Sumatra. He noted, too, that the Malay States and Straits Settlements stretch southwest to northeast for several hundred miles and even on a stationer's map look like the hot countries they are.

Though a landlubber, Jimmie inferred the maritime importance of such a stronghold. Far off to the south and east is huge Australia. But straggling Java and ungainly Borneo are comparatively close. Quite evidently, Singapore guards the funnel-tip of the Malacca Strait to the rich south Orient: the great South China Sea, the V-shaped Gulf of Siam; south of the equator the Java Sea, and eastward the Seas of Flores, Banda, Arafura, Timor, and even the Coral Sea—all pouring their wealth into shipping lanes which crowd past Singapore en route to the huge Indian Ocean, the fat deep Bay of Bengal, the Arabian Sea and Persian Gulf, or still more impressively via the Gulf of Aden to the Red Sea, through Suez and the Mediterranean, past Gibraltar, through the Bay of Biscay, and then to England—in short, the lifeline of the British Empire.

Nevertheless, as he studied the stationer's map, Jimmie James became convinced that Singapore was primarily the stronghold of rubber, the clearing center of trade from all the Eastern tropics, and a naval base only incidentally. In time this conviction hatched into absolute certainty. He proceeded by ship to Singapore, traveled by rail into the fierce hot hills past Lumpur, and went to work as a timekeeper, and later overseer, for Lyton Produce, Ltd., Hevea rubber planters. Thereafter he learned about Malayan rubber in the only way to really know it—from the wet, hot loneliness of inland Malaya.

He learned first about land. There is very little owned or "freehold" land anywhere in Malaya or the Straits Settlements. Land must be acquired from the government subject to an annual rental, which in the early 1920's was $1 (Straits Dollar) the first year and $4 per year thereafter (though some of the older English rubber companies with the right connections in London were holding prize rubber lands for rentals of as little as 50 cents per acre, and this was still the case when Malaya fell). In Ceylon, native land titles were being issued, though these were notoriously unreliable—at best nothing more than "C.Q.P.'s" (Certificates of Quiet Possession). In Sumatra, shortly to become the highest-yielding Hevea center in the world, the planter or plantation company paid a duty of \$15 per acre (divided equally between the government and the local native sultan) and thereafter an annual rental of about 25 cents per acre, also divided between the Dutch government and the local sultan. In Java most usable land had been taken up many years earlier at rentals averaging about \$1.25 per acre yearly.

Ex-Sergeant James noted that the Dutch government, despite its faults, had consistently recognized certain native rights to lands of the Dutch East Indies, whereas the British government made no recognition whatever of Malayan rights in Malaya. In Sumatra, native peoples retained user's rights to fruit trees and to the indigenous rubber plant, *Ficus elastica;* and in order to realize those rights, they were entitled to walk right into Lord So-and-so's estate—unless he happened to have paid for the fruit trees or wild rubber, which was seldom the case. But no such folly persisted in Malaya. Under British law and licensing procedures, the natives had been told their place, which Jimmie quickly inferred corresponded rather generally to that of the termites.

He noticed other realistic details. For example, a great many of the plantation laborers were permanently sick, and correspondingly, throughout most of Malaya water supply remains a tragic problem. Most natives still drank and bathed in the open rivers or drew water from unpurified wells, and very little constructive work was being done by the British to better the situation.

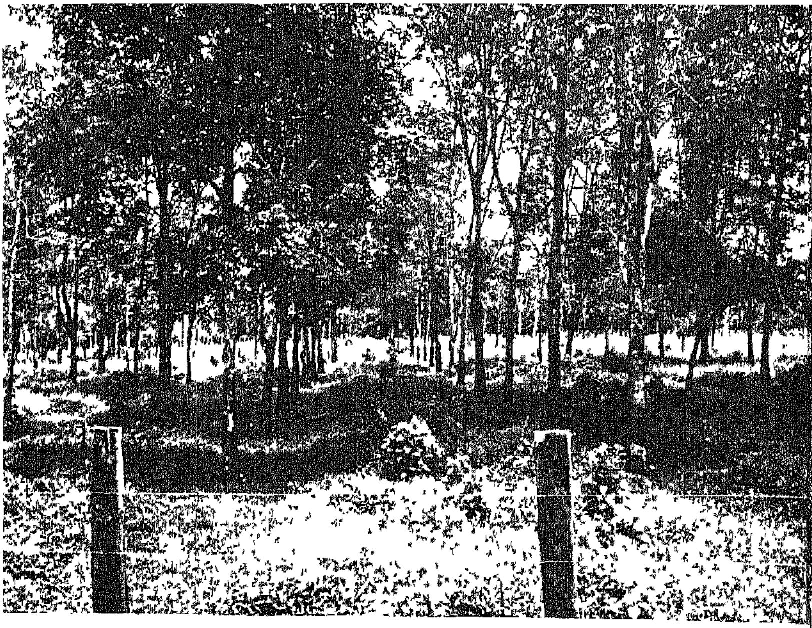
On returning to his bungalow at night Jimmie would usually sweat, drink beer, read the current *Company Bulletin* and draw up the day's "work sheet." Usually the *Bulletin* began with a pithy quotation, such as the following piece of clairvoyance, written in 1912 by Henry A. Ridley, director of the Botanic Gardens at Singapore:

"Synthetic rubber, a bugbear to many, is even less likely to interfere with the Hevea planting industry. It is quite possible to make real synthetic rubber in the chemical laboratory, but its cost would be so great that it could not compete successfully for many years with the real article at a price which would leave a big profit for

The Six-month-old Hevea Rubber Tree is Planted in its Permanent "Station"

Hevea Seed Planted in Nursery with Castor Plants as Sun Shelter.

Photograph by Iris Woolcock



Hevea Rubber Trees in Bearing on Goodyear Plantation near Cairo, Costa Rica These Trees were Originally Planted by the United Fruit Company in 1923

Photograph by Iris Woolcock

From the Hevea Flower Comes the Seed Cluster

Photograph by Iris Woolcock

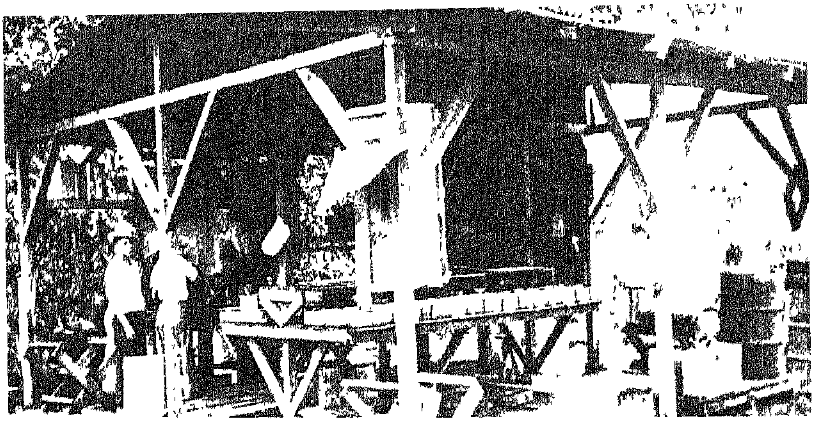
Walter N. Bangham, Distinguished Rubber Botanist of Sumatra, Java and Malaya who now Directs Central American Hevea Propagation (He Comes from Ohio).
Photograph by Iris Woolcock

Latex Collector Opens Skillfully the Wounds of the Hevea Tree and Takes Out Rubber.
Photograph by Iris Woolcock

The Budgraft Hevea. He takes the Live Bud and Locates an Incision Point.
Photograph by Iris Woolcock

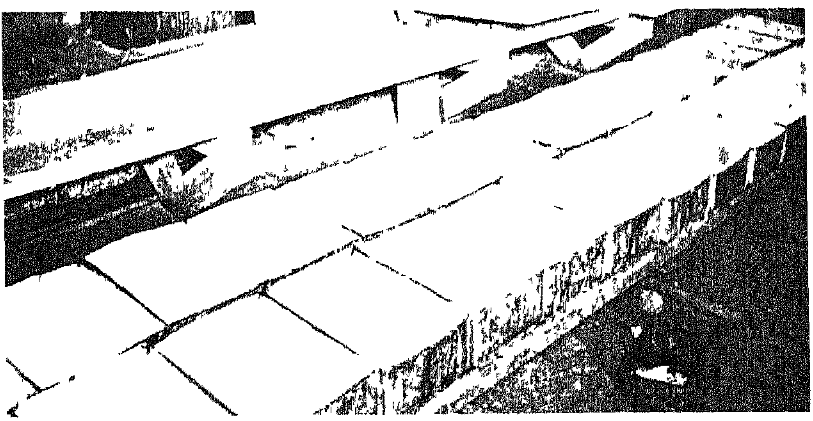
He Places the Bud Carefully into the "Slit" and Bandages It.
Photograph by Iris Woolcock

When the New Budgraft "Takes" He Clips Away the Top of the Seedling (Usually about One Month after the Graft is Made).
Photograph by Iris Woolcock



Farm Curing Shed Where Latex is Strained and "Set" in Curing Pans

Photograph by Iris Woolcock



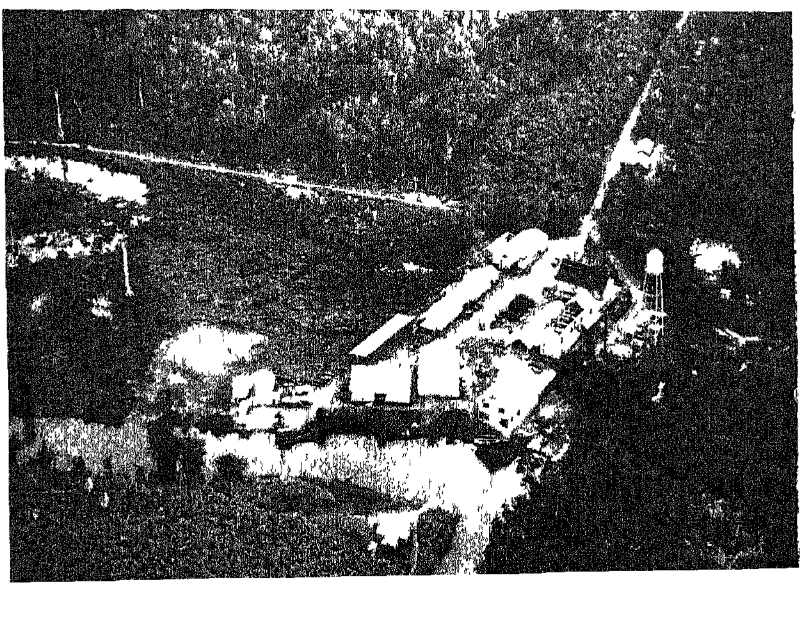
Strained Latex in Settling Pans.

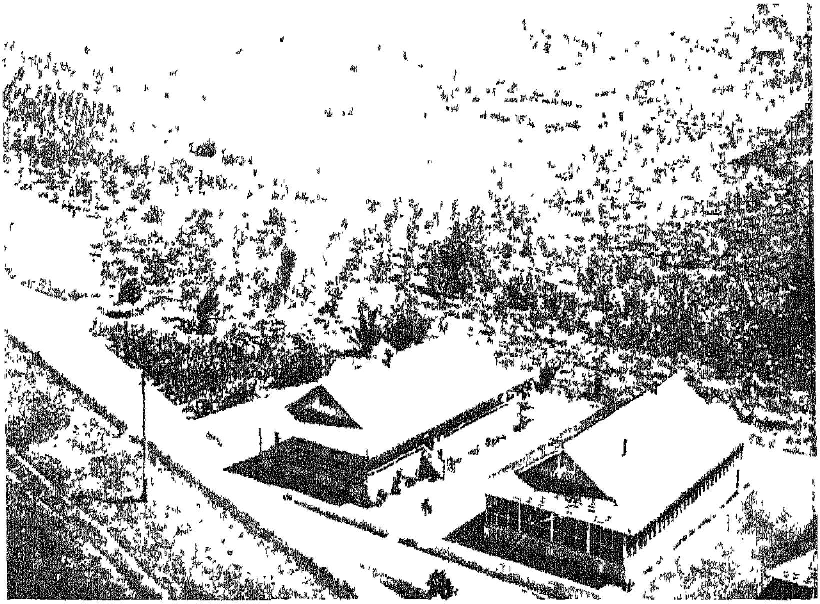
Photograph by Iris Woolcock

He Rolls the Towels Into Sheets, Hangs Up the Sheets and

Old-style Jungle Housing for Rubber Plantation Workers
Photograph by Iris Woolcock

View of the Firestone Plantation, Liberia, largest in Africa
Photograph by Iris Woolcock





An American Hevea Rubber Plantation Begins View of Fordlandia on the Tapajos River in Brazil
Photograph by Iris Woolcock

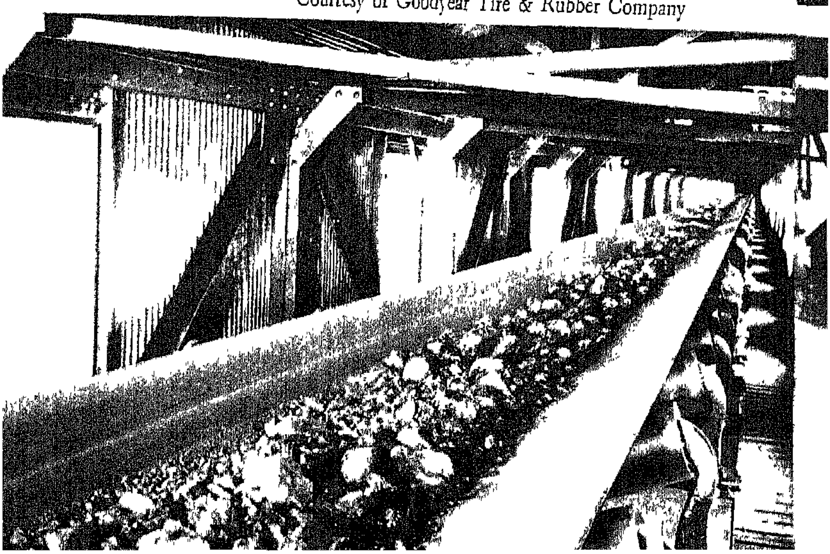
"Bush Rubber," a Field of Mexican Guayule Shrub.
Photograph by Iris Woolcock

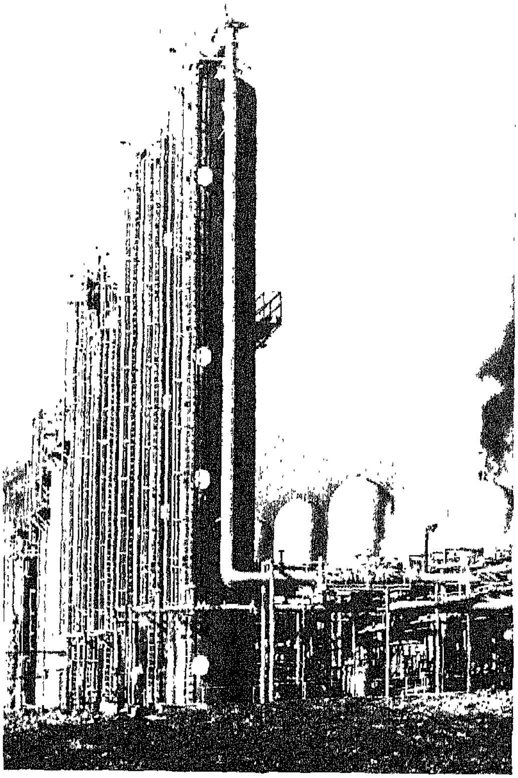
These Are Ten-year-old Cryptostegia Plants on the Yuma Mesa in Arizona.

Courtesy of United States Rubber Company

Rubber Conveyors Carry Millions of Tons of Materials

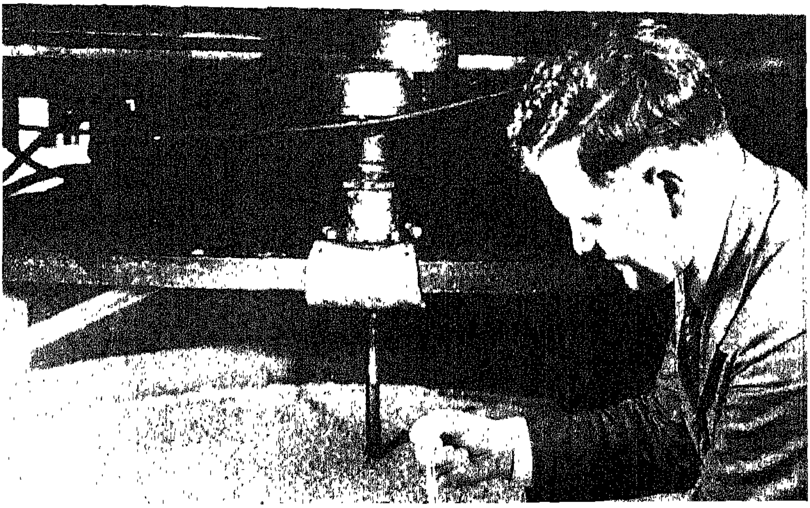
Courtesy of Goodyear Tire & Rubber Company

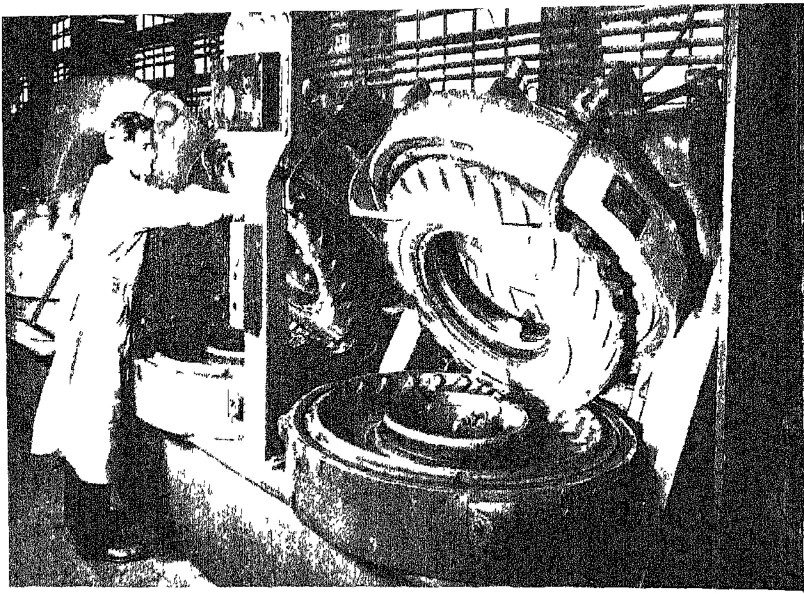




American Refineries Furnish the New Elastomers.
Courtesy of B. F. Goodrich Co.

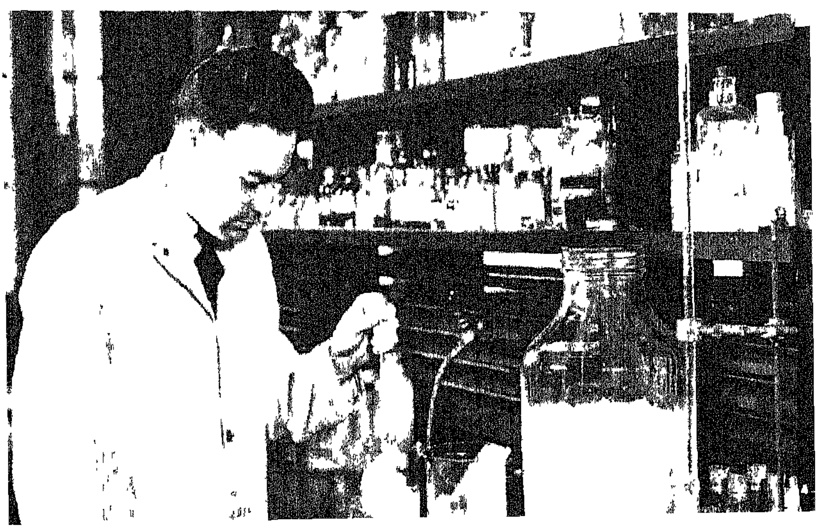
Dr. Waldo Semon, One of the Greatest of Rubber Chemists, Studies a Brew of Synthetic Rubber.
Courtesy of B. F. Goodrich Co.

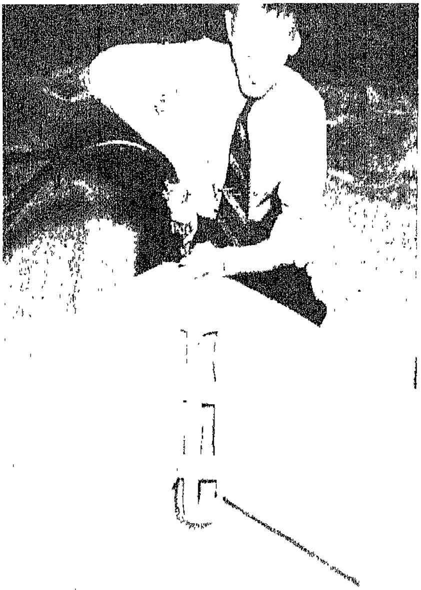




The Tire Mold is the Gravity Center of the Rubber Industry
Courtesy of B F Goodrich Co

Next to the Tire Mold is the Rubber Chemist
Courtesy of Goodyear Tire & Rubber Company

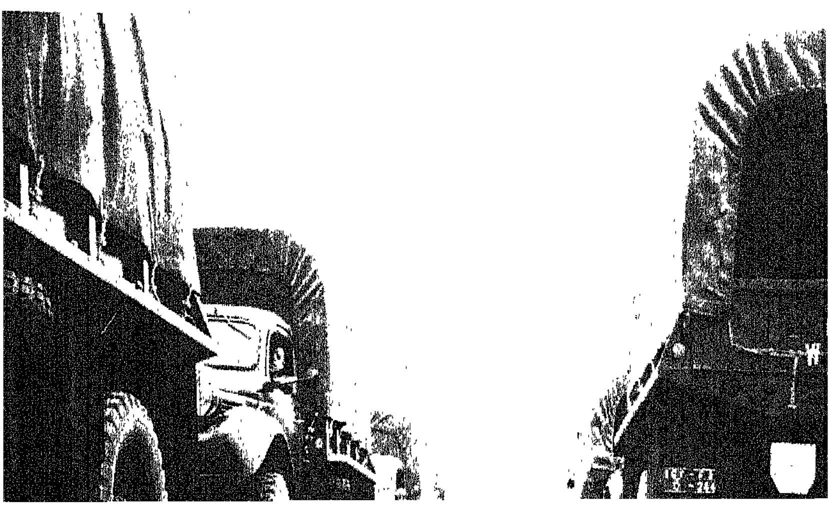


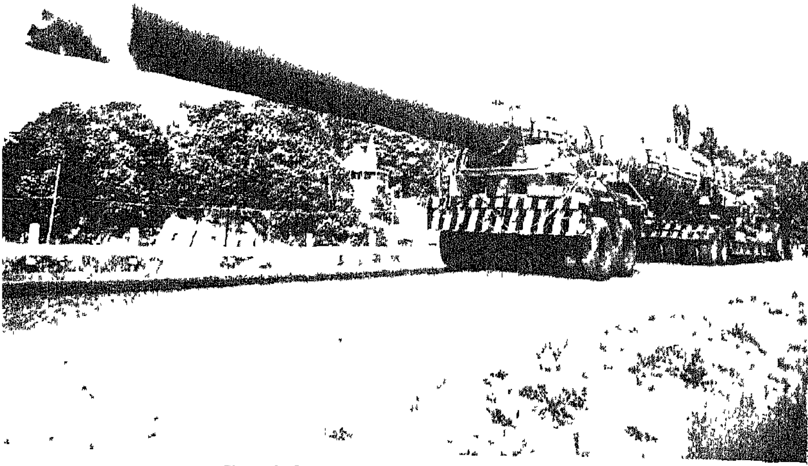


Factory Origin of *The Raft.*
Courtesy of Goodyear News Service.
Approved by U. S. Navy.

"Life Balls" For Our Military Aircraft—For Water Landings.
Courtesy of Goodyear News Service

Army Transports—1943.
Copyright Army Signal Corps



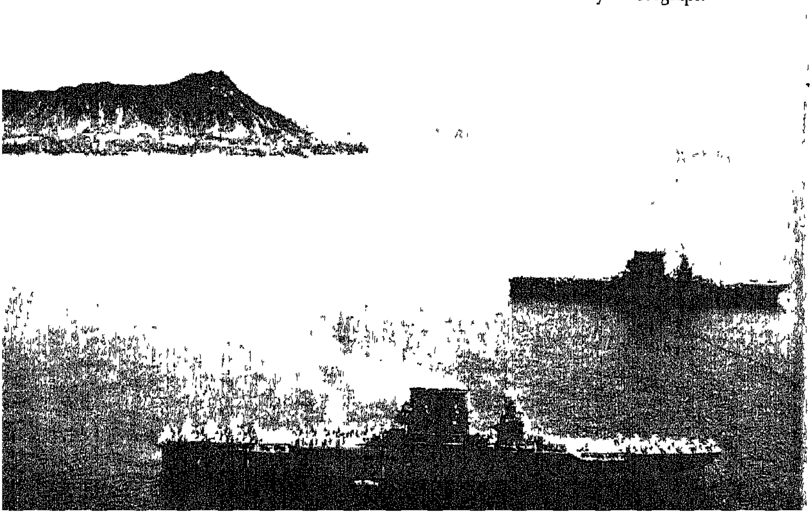


Big Caliber on Rubber Wheels.

Courtesy of Goodyear News Service

Rubber on the Fighting Seas—Aboard Two U. S. Navy Aircraft Carriers.

Official Navy Photograph



the planter. There is as yet no evidence that the synthetic product can displace the natural product from its most important uses. . . ."

Following the daily quotation, the *Bulletin* usually carried a few lines of seasoned practical advice to inexperienced rubber estate overseers: "It is a good thing to have the various rooms in the lines [barracks for laborers] separated from each other above the partitions by strong wire nettings. This prevents any coolie who has been shamming sickness from climbing over the partition and pilfering from his neighbor. . . ."

As for the work accounts, here was one reasonably typical until the fall of Singapore:

	Per Acre
Two men with 4 bullocks at 40 cents per coolie per day cultivate 5 acres per day	$0.16
Food for bullocks	.32
Depreciation on bullocks and cultivator	.10
	$0.58

Shortly after his arrival, Jimmie's "governor," whose bungalow lawn had long since been studded with inverted beer bottles, permitted him to make a brief study tour of the botanic gardens at Singapore. There Jimmie was permitted to visit the Number 2 rubber tree of Singapore's Gardens, a Hevea then thirty-four years old, which stood 84 feet tall and showed a trunk girth of 124 inches three feet from the ground. He also saw the Number 1 Hevea tree, which in only fifteen years had attained a height of 100 feet, with a girth of six feet. That sight was impressive to the point of inspiration. So, too, was James's discovery that a virile Hevea seed should germinate within forty-eight hours, reach a height of four or five feet within six months to a year, and thereafter gain three or four inches yearly in trunk circumference during at least thirty years of continuous growth.

During his brief seminar at Singapore, he absorbed several other salient truths about rubber: for example, the value of rainfall—a Hevea plantation with 100 inches of rainfall yearly is twice as productive as an identical plantation with only 80 inches; the fact that an acre is an area 220 yards long by 22 yards wide; and that planting Hevea trees ten feet apart in rows 20 feet apart provides 217 tappable trees per acre, whereas planting them at intervals of 22 by 11 feet gives only 180 trees.

Jimmie also received a Hevea tillage manual with practical instructions in English, Malay, Chinese, and Tamil—a language of southern India. He began to memorize the oily sounding Malay words such as *alwan susu,* which means latex channel, and *mongkuk chawa,* latex cup. He received instruction about proper conservation of precious Hevea seed, and he met in person the first rubber planter of Malaya, who was oddly enough the Chinese Tan Chang Yan, who had opened a private plantation estate on Malacca during 1895.

At Singapore Gardens he saw many other rubber-bearing plants besides Hevea, the Asiatic *Ficus elastica,* the Urceolina vines, African Landolphia, as well as Castilloa, Ceará, and Mangabeira trees, which have been known and used to various extents for rubber procurement during the past century. He viewed the biscuits of rubber, molded in shallow enameled-iron plates manufactured in England and bought by natives throughout the Eastern tropics. He learned that even in 1920 there were more than 2,000 British-owned rubber estates in Malaya, which were worked by about a million coolies lacking the right color or family connections.

He also found that only a comparatively small percentage of the rubber-harvesting, heavy-toiling coolies are native Malayans. Since 1900, Javanese, Tamils, and Chinese have been imported in ever-increasing numbers to clear and build up the world's foremost rubber-producing stronghold.

Earlier the story had been told in officially published tables:

Origin of Coolies

Year	*Tamil*	*Javanese*	*Malay*	*Chinese*	*Others*	*Total*
1906	29,358	4,070	1,494	3,433	914	39,269
1907	49,649	7,538	4,835	12,848	....	74,870
1908	51,409	7,473	4,416	15,068	....	78,366
1909	69,780	9,574	7,153	22,684	1,022	110,213
1910	98,988	17,760	14,258	45,663	2,361	179,030
1911	126,665	20,869	19,997	58,043	2,411	227,985

During those formative years of Malayan rubber the number of British estates climbed from 254 in 1906 to 964 in 1911. During the same period the acreages planted to Hevea rubber had increased from 99,000 to 542,000 and the value of rubber exported had jumped from about $13,000 to more than $50,780,000 per year. In 1915, when the age of the automobile and the pneumatic tire was clearly at hand, Amazon wild rubber was showing unmistakable signs of "drying up," and recovery of African rubber was also declining.

When James C. F. James arrived in Malaya in 1921, the acreages of Malayan rubber had almost quadrupled within a decade. The stately trees which had grown from the seed which the venturesome Henry Wickham had astutely removed from Brazil had indisputably become the Number 1 resource of Malaya. In 1900, four tons of rubber had been harvested and exported from the 7,000 acres of Hevea plantations then planted in the entire tropical East; in 1920, 305,106 long tons of crude rubber were harvested and exported from about 4,500,000 acres of Far Eastern rubber plantings! The following table, compiled by the International Rubber Control Committee in 1940, tells the story succinctly:

Year	*Plantation Acres Eastern Tropics (Acres)*	*Crude Rubber from Eastern Plantations (Long Tons)*	*Crude (Wild) Rubber from the Amazon (Long Tons)*	*All Other*
1905	125,000	174	32,624	23,255
1910	1,125,000	7,296	37,938	48,866
1915	2,500,000	116,370	34,610	19,846
1920	4,500,000	305,106	23,216	13,672
1925	6,000,000	488,825	25,298	14,362
1930	9,000,000	802,082	14,264	5,572
1935	9,250,000	855,038	11,275	6,100
1939	9,000,000	970,029	13,892	18,847
1940	....	1,390,469	17,661	21,933

The story of a changing horticulture of rubber was clearly indicated when Jimmie James began his career in Hevea estate imperialism. His layman's conviction that Singapore was more a rubber stronghold than a naval base was being proved. Plantation rubber had taken over, and wild rubber from the Amazon Basin and Africa were headed for oblivion. Malaya, an area only about the size of the state of New York, was alone producing almost three-fourths of the world's supply of rubber. In its rubber planting era, boom had followed boom. Competitive crops were blotted out. Native fruits, berries, and other jungle manna had been destroyed. Estates were swarming with imported Asiatic laborers. The lives of these laborers were wretchedly poor. Wages usual in rubber estates were averaging around 14 cents a day. Conditions of health and sanitation were vile. The death rate was tremendous—too high indeed for public disclosure.

In general the immigrant "coolies" were downtrodden Asiatics dumped into a remote and wretched milieu. Malaya never was a melting pot. A great many Asiatic workers bitterly hated their British overlords; and the motley hordes whom the estate men called "coolies" also hated one another, so much so that it was common practice to separate the barracks of Chinese, Indians, and Malays.

Jimmie James returned from Singapore to his "station" to continue learning about rubber the hard way, at first hand. During the hot and distracting twenties he saw from the closest possible range the inception of the Stevenson Rubber Control Act, and the establishment of the Malaya Rubber Institute, which was supported by a uniform crude rubber excise tax (2½ per cent ad valorem) and devoted to a reasonably competent experimental headquarters and a superb and costly propaganda machine.

In all his industrious, matter-of-fact life, Jimmie James had never conceived of such audacious propaganda, and even in his wildest dreams he had never imagined such pell-mell acquisition of wealth. During the early and middle 1920's crude rubber was gold. In 1925 the world price of rubber averaged 72 cents a pound and Malayan harvests of rubber were being counted in the hundreds of thousands of long tons. As the cartel gained power, rubber prices and volumes continued to soar. Profits on other tropical crops also were running high. In 1924 average net profits realized from selected Malayan coconut groves were around £5 19*s.*, or $33.85, per acre. That was good money, in anybody's language or country. But compared with rubber profits it was the merest chicken feed. In the principal rubber lands of Malaya net estate profits realized from Hevea trees six years of age or older were averaging well over $100 per acre per year, even with gross production costs calculated at 1*s.* 3*d.*, or around 30 cents, a pound.

It is James's studied conclusion that never in all the history of Malayan rubber estates has a well-located, well-operated rubber plantation honestly reported production costs of anywhere near 30 cents a pound. On his own plantation and a dozen others the actual production costs were around half that figure, even during the crazy twenties. In 1930, after the Stevenson control legislation had collapsed and world rubber prices had fallen to the epochal low of 3 cents a pound and had averaged only a fraction more than 10 cents for the whole year, Jimmie James observed that the estate for which he worked still lost no money.

But during all the 1920's money oozed from 600,000,000 Malaya rubber trees. Medium estates realized gross annual profits in excess of $200 per acre. One financier and student of Malayan rubber, William C. Maclaren, pronounced sagely: "It is evident that £200 to £250 per acre (approximately $972 to $1,215) for good rubber in bearing may not be too high a price to pay in the case of a well-kept, well-planted, and cultivated rubber estate."

With crude rubber prices above six shillings a pound, Malayan rubber estate wages were well under one shilling a day and the laborers' quarters were an international disgrace. The same W. C. Maclaren wrote with experienced understanding:

"Four or five coolies usually live in one room 10 by 12 feet so that it is a simple matter to count the number of rooms required for any labor force, bearing in mind that Tamils, Javanese and Chinese need separate lines or the latter will raise trouble.

"For good permanent double lines [barracks] of not less than 20 rooms the cost per coolie 5 to the room works out in Ceylon as about 2 pounds to 2 pounds 10 shillings per coolie. Sumatra costs would be about 3 pounds per head and in the Federated Malay

States and Straits Settlements 4 pounds per head. . . . The cheaper class of barracks put up in Java work out at 1 pound to 1 pound 15 shillings per head. . . ."

Jimmie James was disgusted to learn that in Malaya, rubber estate coolies were counted like cattle or hogs, in terms of the head, and that even on plantation accounts they were never described as people. And though he had seen many dismal slums and lived in overcrowded army barracks which were ruinous to the health and spirits of men, he had never seen any human habitation so desolate or so terrible as the coolie lines on Malayan rubber estates.

Despite the sweltering heat, the coolie barracks almost never had windows. Neither did they have stoves, running water, screens, or water closets. As a rule they were built hastily of wood, or wood and bamboo thatch, and placed upon pillars six or eight feet above the ground. Cooking had to be done over open fires and grates in these "underdecks," which usually lacked floors and were often vile and sour with filth. Ten by twelve feet was the standard size room for five laborers, or for an entire coolie family. Not even the heroic, poverty-ridden Chinese Army would tolerate such overcrowding. For five human beings to make an area of 120 square feet their permanent abode is not easily describable, or even imaginable.

Jimmie James clashed openly with his overseer when he urged that a new barrack line be provided with verandas. Though mosquitoes and a hundred other stinging insects swarmed over Malaya, wire screening was usually regarded as needless overhead. Hot nights followed hotter days in endless succession, merging into torrid months, seasons, and years. Coolies toiled, sweated, and subsisted on fares of rice, tapioca, and sometimes even bananas and other Lucullan dainties. Like ill-tended livestock, the coolies died of dysentery, crab yaws, hookworm, sleeping sickness, grotesque swellings of legs and breasts, enlarged spleens, protruding bellies which told of malnutrition, and unarrested malarias. With wearying repetition Jimmie James noted the symptoms of tropical and cosmopolitan diseases and of human degradation, of undisciplined capitalism, of the alignment of race against race, and other characteristics of the system which supported distant investors in fabulous wealth.

After his delayed sabbatical leave in Gloucestershire and his renewal of pilgrimages to the Roman ruins of West England, Jimmie returned to Singapore and became overseer of the rubber estate owned by the Chenang Produce, Ltd. The great depression came—to every place but Malaya: the estate which Jimmie James managed grew healthier and stronger. He doubled barrack space, and supplemented the lines with broad, screened porches. He provided stoves for cooking. He inaugurated a co-operative plan to help the coolies buy more and better food with the same money. He paid the maximum permissible wages of about 26 cents a day. He instituted a commissary, employed two well-qualified native physicians, and helped personally in attending the sick and the dying.

Even during the long, decadent years of the great depression the acreages of Far East Hevea continued to increase, and as profits tumbled, estate operations showed symptoms of improvement. But Jimmie James, like many others, knew that the improvements were not sufficient.

I met Jimmie James again in 1939, twice. First in Trinidad, later in Jamaica. Jimmie had come to Trinidad for "official consultation" with the staff of the superb Imperial College of Tropical Agriculture at St. Augustine, and to inspect certain abandoned Hevea properties in British Guiana and the West Indies. I had been in Trinidad studying an extremely malicious tropical fungus which was then imperiling the American banana industry. This fungus, *Cercospora musa zimm,* which causes the fiercely destructive sigatoka, or leaf-burn disease, of bananas is somewhat similar to the South American leaf blight, which had been one of the contributing causes of the early failure in Fordlandia.

From Trinidad I traveled with Jimmie to Jamaica where sigatoka, congested population, and complicated labor relations were bringing extremely hard times to that always charming island. We watched the quick rash of "lightning strikes," the pitiable abandonment of hillside banana patches, and the operation of severe empire restriction quotas on sugar and rum production. In spite of these difficulties, the crown colony government was fighting gamely, and it still is. The three great banana companies were working hard and well; Jamaica was proving herself a world pioneer in constructive resettlement. Except citrus culture, which is still rather bad, Jamaican agriculture shows many constructive improvements.

Jimmie James spoke of the impressive superiority of the crown colony of Jamaica, so long labeled a "losing venture of the empire," to the crown colony of Malaya, which has been so enormously profitable to the English purse. His admiration for Jamaica served to sharpen his disappointment in Malaya. At the Myrtle Bank Bar he commented prophetically on the courses of imperialism, good and bad. He said, "Jamaica will live. Malaya will fall. For north of Jamaica is the United States. And above Malaya is Japan."

I asked him whether Malaya would swim or sink against the Nipponese tide, when and if the latter came.

He said, "Sink"—and told the barman to double the next Scotch. . . .

The fall of the Malay Peninsula before the Mikado's fighting men is now history, written with the distinct implication that it was also the fall of the white man's easy domination of Oceania and Southeast Asia. It marked the end in Asia of British imperialism à la Victoria Regina and Rudyard Kipling.

In Malaya, 1942, British and Australian defenders, too few and perhaps several generations too late, fought with great gallantry. In general the crown colony functionaries were incompetent. Inland and coastal Malaya alike had been eaten hollow by fifth columnists and by poisonous, sullen native disloyalty to a proprietorship which had pompously and steadfastly refused ownership of land to bona fide native citizens, and which had instituted and maintained a lengthy regime of uneconomic favoritism to the "right parties," while permitting a badly maneuvered importation of Chinese, Indian, and Javanese laborers whose presence only added to the impoverishment and general helplessness of the Malay masses.

The Japs swept down the peninsula like a migration of monkeys, saturating the coast lines and sweeping inland through the rugged hill lands, the deep rough valleys, the tropical plateaus, and the river basins. British investors had profited hugely, at times incredibly, from this comparatively tiny tropical colony; yet British resistance showed unbelievable ignorance of tropical terrain and tactics. Though Singapore had proclaimed that it would never surrender, it did so quickly and unreservedly, because it was poorly supported by air and by sea, and outmaneuvered by land. Nothing spells out the tragedy of the entire affair more painfully than the huge coastal batteries of Singapore—pointing futilely in the wrong direction! Waterloo, we are told, was won on the playing fields of Eton. It is equally true that Malaya was lost on the rubber estates of investors who had never been closer to them than Southampton.

In the main, the estate managers did not fell the rubber trees when confronted with the Jap advance. In some instances there was not time enough; in a great many cases there was abundant time, as the invaders effectively proved. It was reliably reported that the defenders usually left the trees standing. They may have lacked the necessary felling tools or immediately available labor; but this possibility is not very convincing. Anybody who has ever spent time on tropical plantations knows that supplies of cutting tools are essential in controlling the always aggressive jungle.

The real reason was deeper and far more subtle: for a third of a century or more the catechism of the sanctity of rubber trees had been drummed into the consciousness of estate laborers. Perhaps their quandary on realizing that for once this sanctity had to be violated was at least comparable to that of the weary mules in our own South at the time of the inauguration of the Agricultural Adjustment Administration in 1933. New crops were already planted before the administrative machinery of the AAA was geared for action. Therefore it was deemed necessary to plow up specified acreages of cotton and other "controlled crops" as well as to slaughter many thousands of newly born pigs. Now, during all their bucolic lives cotton mules had been urged *not* to walk on cotton rows. They had been long accustomed to being cursed and belabored every time they stepped on a cotton plant. Abruptly, as a result of the bizarre brain storm in far-off, unpredictable Washington, these southern mules were commanded to straddle cotton rows and pull the plows which would destroy the most revered of Dixie crops. At first they firmly declined to mount the cotton rows. By move and gesture the mules said, "Hell, no, mister! You may be crazy, but I ain't. . . ." Similarly an un-Galluped poll of Malay estate coolies may have thought, "Cut down the rubber trees? That, we know, is unholy. We will leave them standing. . . ."

In any case trees were not felled by the defenders. But unmistakably and repeatedly the Japanese invaders did fell them. They drove their tanks and moved their men through the neat, grassy aisles of stately Hevea. When British and Australian light tank forces sought to counterattack, the invaders felled the trees rapidly and efficiently, thus shaping blockades which made the light tanks almost valueless. That is the testimony of official observers of the United States Army. British and Dutch high commands showed themselves poorly acquainted with essential consideration of the jungles, marshes, and humid weather, whereas the Japs demonstrated notable skill in tropical maneuvers. They knew the rubber lands with relentless thoroughness. They sought advantages and speedily grasped them.

I have served considerable time in tropical countries. I did not personally witness the fall of Malaya, but I have studied Malayan terrain, temperature, rainfall, and vegetation with thoroughness. Recently I talked with Malaya rubber workers who escaped the collapse of Singapore. In somewhat comparable jungles and plantation sites of this hemisphere I have watched Japanese "nationals" at work. When pitted against the jungle, the nontropical, nonagrarian Jap is remarkably competent. But I have also stalked Latin-American wild lands with norteamericanos from Fort Worth, Chicago, Des Moines, or Los Angeles who are just as competent, if not more so. As a hot country onlooker I believe that almost any tropical land is conquerable and can be policed by nontropicals who have the incentive and gumption to invade, organize, and hold.

In any case Japanese seizure of Far East rubber lands was not "miraculous." Its motivations may not be well enough understood by us. With no deference whatever toward the Nipponese, I suggest the following as provable incentives for Japan's pell-mell seizure of Malaya and, almost concurrently, of Sumatra and Java. That the Mikado's men desired to hold Britain's great bastion of Singapore is obvious. So was, and is, the Jap's anxiety to cut off principal rubber sources from his principal rubber-consuming enemies. But Japan also had very real economic and industrial incentives for seizing the world's foremost strongholds of rubber. Her investments in then foreign rubber-bearing properties had grown to noteworthy totals even before 1940, and she required extensive tonnages to feed her rubber industries, which were among the brighter prospects for a more or less legitimate Asiatic trade.

The development of Japan's rubber industry was belated. For the past three years it has been a tight-lipped military secret. But during 1936, a thoroughgoing report—which passed almost unnoticed here—was published at Tokyo by the Institute of Pacific Relations over the signatures of two well-known Nipponese economists, Dr. Teijito Uyeda, professor of economics at the Tokyo University of Commerce, and Teiju Odahashi, of the Institute's Council. For a semiofficial publication of the Japanese government (most of it is compiled from reports of the Ministry of Commerce and Industry) this report is remarkably forthright. It substantiates British-Dutch rubber cartel estimates that in 1935 Japan imported 56,000 kilograms of rubber—as compared with 497,000 for the United States; about 100,000 for Great Britain; 51,000 for France; 63,000 for Germany; 37,000 for the U.S.S.R.; 26,000 for Canada, and 22,000 for Italy. Thus during 1935 Japan was the fourth greatest importer of crude rubber and in terms of industrial tonnages a comparatively close competitor of Germany.

But the progress of the Japanese rubber industry had been extremely slow. In 1896 the Nitatsuchi Rubber Manufacturing Company opened shop at Tokyo; its chief products were novelties, principally red balls ornamented with red dragon symbols for sale to the Chinese. It soon failed. Then the Meiji and Nippon rubber companies were founded at Tokyo. Two more manufacturers appeared during the second year of the Russo-Japanese War. None succeeded. Their technical equipment and skilled workmanship were below par. In 1909 the Dunlop Company of London built and put into operation a Far Eastern tire factory at Kobe. Meantime, the Japanese government fumed ambiguously and placed protective tariffs ranging from 10 to 20 per cent upon all imports of rubber goods. Apparently that did not help the situation for Japan.

While British rubber plantation companies were taking over Malaya, and while British and American rubber factories were rising to giant stature, the Japanese rubber industry was still fumbling and unpromising. World War I gave the first effective lift to Japanese rubber manufacture. Between 1914 and 1919 Japan's imports of rubber increased tenfold, but the quality of her rubber goods and the efficiency of her manufacture remained relatively poor.

In most industrial countries World War I enormously stimulated rubber manufacture. In Japan that stimulation was short-lived. Dr. Teijito Uyeda politely describes the situation: "In the first postwar period, however, Japan's rubber industry, whose degree of technical skill was still no match for that of the American or European manufacturers, declined in activity. . . ."

About 80 per cent of Japan's early manufacture of rubber goods was centered in and about Tokyo and Yokohama. The earthquake of 1923 virtually destroyed it. A few of the factories were revived and removed to the Osaka-Kobe area; but thereafter, during the 1920's, Japanese rubber manufacture passed through gloomy days and touched bottom during the dreary depression of 1930 and 1931.

Then the military clique began its grim ascendancy, and so did the rubber industry. Again I quote Teijito Uyeda: "From 1932 on the industry was further spurred by the enormous increase in the Military Budget, for the quantity of rubber products used in modern military equipment is indeed great. Increased demand was reflected especially in the demands for ebonite, gas masks and waterproof fabrics. . . ."

By 1932 Japan was clearly on the road to war. War calls for rubber. Thousands of rubber factories began to spring up, most of them small. At first the Occidentals did not heed. Almost everywhere rubber manufacturing was "depressed," and the possibility of Japanese manufacture was carelessly underestimated. It is distinctly possible that Japan's conquest of the rubber strongholds of Malaya and the Dutch East Indies was planned as long ago as 1932 and 1933, while the Nipponese rubber industry was getting on its way to town, and to the great markets of Asia. One interesting item of evidence on this point is that early in 1942 the Federated Malay States were deluged with Japanese "conquest currency" (in Straits Settlements dollars). The multitudinous ten-dollar bills are stamped with an ornate engraving showing a grouping of tropical plants supposedly common to Malaya. Among these is a banana "tree," bent with a heavy stem of fruit. The currency pictures bananas of the Gros Miguel type which were being grown in considerable quantity in Malaya during 1932.

But the Gros Miguel, or Big Mike, had vanished from Malaya before 1941. The reason is pathological. Big Mike, which is a Canary Island and Jamaican type of banana, was introduced into Malaya by British planters early in this century. The variety is particularly vulnerable to sigatoka, and by 1940 all Gros Miguel bananas of the Far East were annihilated. Bananas of our own hemisphere had been seriously threatened by the same malady. Of the twenty-seven comparatively common species of musas, or banana plants, only three or four have outstanding resistance or virtual immunity to the fungus disease. In Malaya only the latter types have survived the past decade, and the Big Mikes, so accurately pictured in the Japanese currency designs, had completely vanished by 1935, or before. It would therefore seem likely that the meticulous Nipponese actually designed this Straits Settlements conquest currency before 1935, or possibly before 1933.

This is speculation. By 1936 the propaganda divisions of the Imperial Japanese government, including those of the comparatively respectable Ministry of Commerce and Industry, had become inordinately cautious about all news releases. But the 1935 statistics tic rubber industry remains enormously important to her stringent and tight-lipped economic system.

The majority of Japanese rubber mills are nonmetropolitan; they are small-scale local industries. Probably nine-tenths of them are located in small towns, villages, and at crossroads where labor supplies are normally cheap and abundant. Also, these midget rubber factories have consistently used a high percentage of child and woman labor, and this proportion has apparently grown during Japan's continuing years of war. In most instances there is no need to build labor dormitories, to recruit or contract for workers, or to pay wages above the abject rural minimum.

Prescribed holidays in most Japanese factories have never exceeded two a month. This number is now further reduced. The standard factory work hours are from seven in the morning to six at night, with a 30-minute lunch period and (during more leisurely times) 15-minute rest periods at nine in the morning and three in the afternoon. In the Japanese rubber industry, 1.8 yen, around 95 cents a day, is the usual maximum wage for male foremen. A yen a day is a base wage for adult men; .7 yen for adult women and older children. The usual payment for overtime is from 12 to 20 per cent of the regularly hourly wage. The liaison between rubber factories is more or less perpetual, with a given shop performing certain specified parts of the fabrication, with women or child labor doing most of the molding, sewing, and sheet work.

While the corporate rubber plantation companies of England, Holland, and their respective empires were exploiting the chronically low wages and the tragic living standards of the great Pacific tropics, Japan was busily digging in on the rubber industry front by making the most of plentiful domestic labor and of back-yard, small-profit proprietorship of factories. Broadly stated, the British and Netherlands general publics had little interest in the distant plantations companies which were gorging profits, while skillfully smoke-screened by their own well-paid propaganda departments. Malaya and Dutch East Indies rubber strongholds were grounded on and propped up by empire politics, but never for the public advantage or the military security of their respective empires. Neither the British nor the Dutch government at large was ever wholeheartedly in the rubber business, nor was any principal group of British or Netherlands citizens. In contrast to this European indifference, even a decade ago the rubber industry was definitely a public interest in Japan. Military orders sponsored and facilitated its expansion. Bureaus of the Mikado's government helped in every way to saturate large chunks of the Asiatic markets with Japan-made rubber goods. About three-quarters of a million citizens of Japan were directly employed in rubber manufacture, a great many of whom had no other means of employment. Besides these, ten or more times that number were profiting from the Nipponese manufacture of rubber wares; and the Imperial Army and Navy were profiting most plenteously of all.

The spectacular growth of Japan's rubber industry is also based upon cheap and abundant domestic labor, and until very recently upon the proposition that the actual cost of the crude rubber has never been a major part of the cost of finished products. Even so, as we of the United States are now learning, crude rubber supply remains the Number 1 essential to the life of a rubber industry.

Japan needed rubber for its military and naval establishments, for the continuation and expansion of Asiatic trade in the Japanese sphere. Japan needed rubber, and Japan took it—at the source. With rapacious boldness, our formidable Eastern enemy has seized for himself, by means of a long-studied scheme, domination of the Orient, which enterprising, self-loving, and self-pampering plutocracies had established and made great—not for their nation or empire, not for mankind at large, but most definitely for themselves and their relatives. The fall of Singapore and of the other Malayan and East Indies rubber capitals was therefore the outcome of a clash of imperialisms, neither of them enlightened, or just, or otherwise compatible with needs of the world's people at large.

10

CRISIS

GEOGRAPHICALLY, Singapore is somewhere between 9,000 and 12,000 miles away from us, depending on what part of the United States we live in; and even in these days of stratoliners this seems a long distance. But economically and strategically Singapore is as close to us as our very noses. For example, Charlie Miller's Garage, at Putney, Vermont, is locked because of the rubber shortage, the gasoline shortage, and the labor shortage, which are intimately and collectively related to a great nation's participation in a global war. Charlie sold gas, oil, tires, tubes, and parts. He also carried on a general automobile service and repair business and held a subagency for Studebaker automobiles and Fordson tractors.

When the government clamped down on automobile and tractor sales, Charlie stayed. But when the tire freeze-up came, with its inevitable shadow, gasoline rationing, Charlie and his mechanic turned in their overalls, locked the big door, and went to work for the navy. This is War, brother; the demise of the civilian tire was just one too many straws for Charlie Miller's Garage and thousands like it the country over.

For about forty years, Dennis Calver of Camden, Maine, has been keeping a country inn for summer vacationists. He was grossing about $12,000 yearly, a tiny fleck of the $100,000,000 a year which Maine usually earns from the 4,000,000 tourist automobiles which traverse its highways every summer. That $100,000,000 represents the principal industry of Maine. Even so, it's small change compared with the grand total of automobile-dependent recreation industries of all the United States, which in 1940 claimed about $5,000,000,000.

Old Dennis Calver saw the writing on the wall the day he read of the temporary close-out of rubber tires for civilian passenger cars. As his inn is more than twenty miles from a railroad, all his customers came by car. A 30 per cent drop in trade puts the inn in the red. Expecting a 70 per cent drop, Dennis closed his doors, bought a horse, and began planting a crop.

Kathleen and Samuel Widney had finally finished a house in the country which was going to give them clean air and quiet sleep after the bedlam of New York City, where both of them work—or rather that was what they planned in 1941. But their new house is nearly eight miles from the railroad station and their 1937 Dodge coupé rolls on slick, thin tires. They were going to trade it in on a new Dodge as soon as they could save a few dollars after the down payment on the house and land. But all new cars and tires were frozen, and eight miles twice a day is too far to walk or to taxi. Besides, there are the problems of fuel-oil supply and overcrowded trains. So the Widneys are still in their two-room New York apartment, which they don't like, and their pretty new house is empty.

Notice also the rubberless fortunes of the Rush family of Rogers, Arkansas. The Rushes are among the now skillfully exploited transient multitude sometimes called Arkies and Okies. The family includes Bill Rush and his wife Lulu; three sons, Bert, Charlie and Fred, all in their teens, and his daughter Joyce, who is twenty-one and divorced, with two young children.

The Rushes give their trade as Fruit Tramps. In the spring they usually pick Arkansas and Missouri strawberries, then pile in their 2-door Model A Ford sedan (1929 manufacture), buy another set of secondhand tires, and strike for the West. Sometimes they work the June wheat harvest in Kansas. Usually they push right on to the California valleys and, depending on times and opportunities, they help harvest lettuce, spinach, grapes, pears, prunes, apricots, peaches, and, God willing, apples from the Hood and Wenatchee valleys in the far Northwest.

Then they jig and rattle back to late fall and early winter cotton picking in Texas, Oklahoma, or southern Arkansas. For the rest of the winter they usually den up in a shack down in Abner Peel's cow pasture near Rogers, where the Rushes have relations.

Successful novelists and motion-picture people have been going to town with vignettes and librettos about the Rushes and their snag-toothed, travel-worn kind, not always bothering to recall that transient labor is still absolutely essential to the agricultural life of the United States, or that transience of labor—usually poorly paid labor—is as old as human enterprise, and has been, and may again be, the real groundwork of our national life.

At any rate, the Rushes are stalled. Their tires are worn out; the ration board is adamant, and anyway it is without appropriate instructions from Washington. Bill Rush and Bert, the oldest son, have jobs helping to build barracks down at Camp Robinson, Arkansas. Charlie joined the Army and has been sent to Australia. The rest of the family, as they put it, are just scratching along. No doubt all of them are wondering how the standing crops of strawberries, greens, peaches, prunes, apricots, and apples are faring. A great many other Americans are pondering the same thing as they wonder what we are going to do about a rubber supply.

These are but a few minor symptoms of the rubber shortage—a major crisis which has now settled upon virtually every square mile of the United States and upon most other nations of this hemisphere and of the anti-Axis world. Our rubber picture is dark, and as this book is written it is growing darker—perhaps in the manner of the maximum darkness which comes immediately before the dawn. The eagerly awaited report of the President's rubber fact-finding committee has stated that we shall be over 200,000 tons short of sufficient natural rubber for military uses alone by the end of 1943, and that this difference must be made up by synthetic rubber production. But this still allows none for civilian use. An appraisal of our current rubber quandary, as it has affected the immediate worlds of Charlie Miller, Dennis Calver, Bill Rush, Sam and Kathleen Widney, and 130,000,000 other Americans, calls for some notice of salient rubber arithmetic, which paradoxically is not very elastic.

During 1941, the United States consumed about 766,000 tons of crude rubber, as compared with 648,000 tons for 1940. Our 1941 consumption was the largest in history, and four-fifths of it, or slightly more, went for civilian uses. But 766,000 tons did not represent either the capacity of our rubber factories or the fulfillment of domestic demand for rubber goods. Actually, crude rubber supplies were under considerable restriction during the final five months of 1941.

I spent July of 1941 with the four big companies of that strange rubber capital, Akron, Ohio; here I was told by several of the most reliable rubber statisticians that United States demand for crude might easily reach 1,000,000 tons in 1941; that with continuation of what we then called the "defense" effort, the demand might well climb far above 1,000,000 tons during 1942 and 1943, that when peace comes again this nation's permanent requirements of crude rubber may still be above the million-ton mark because of the thousands of new and promising uses of rubber, and because all domestic rubber supplies will be pretty well exhausted when or before the war is over. These men were distinctly worried about the supply, even in 1941; but they had been concerned about it for the past third of a century, however frequently their plaintive prophecies were shelved, evaded, or openly pooh-poohed.

Yet, during 1941, many experienced students of rubber saw clearly the perils, and indeed the likelihood, of Japanese seizure of the Far Eastern Hevea lands. Rubber buyers usually know the ins and outs of Oceania reasonably well, and many rubber men were well aware of the alarming, if unappreciated, reports which were warming the Far East wires to Akron, as well as to Washington. Grave shipping shortages were already a reality. Shipping lanes and supply lines to the East were desperately imperiled. The so-called short hauls of rubber—7,000 to 9,000 miles instead of 11,000 to 15,000—were already being blocked by Axis conquest and were about as safe as a chain smoker in a gasoline refinery.

The scholarship of rubber is respectful of maps. During 1941, most of our rubber was coming from British Malaya, Sumatra, and Java, and 97 per cent was coming from the "area of the South China Sea"—lands which include Sarawak, Dutch and British Borneo, the Philippines, French Indo-China, Thailand, and Burma. Germany seemed to be winning the war during most of 1941. Axis conquests were queering the peacetime shipping routes of rubber, which are normally via the Strait of Malacca by Singapore, thence across the Indian Ocean and into the Red Sea, through Suez into the Mediterranean, past Gibraltar into the Atlantic, thence a straightaway to New York or other Atlantic ports. During 1941, Allied merchant shipping, already seriously depleted, was being forced to undertake the longer and far more costly transpacific run to San Francisco, or the far-south Atlantic run via Cape Horn. That alone spelled shortage of rubber due to a shortage of ships.

The scholars of rubber were also pondering our crude rubber reserves and stockpiles. News tickers were rattling with assurances that Washington was on the job, which in some measure was the truth. In 1939, Congress had given the Secretary of the Treasury about $70,000,000 for the purchase of "critical and strategic materials." Quite stupidly, rubber was not on the list, which did include tin, mica, chrome, tungsten, quinine, and other proper entries.

Even our Army and Navy, both with unexcelled reasons for knowing better, seemed officially certain that Dutch and British reserves of Far Eastern rubber were sufficient, eternal, and divinely protected. Though many well-accredited correspondents in Europe, Britain, and the United States were stating that the Dutch East Indies were virtually unguarded and that the empire defenses at Singapore, where big guns on fixed mounts aimed seaward, were by no means adequate, there was still no official expression of concern about our rubber supply until May, 1940.

On May 28th, while the Maginot Line was proving about as valuable as a truckload of sand in the Sahara, President Roosevelt made his historic pronouncement that the United States would be the "Arsenal of Democracy." On June 25, 1940, after France had fallen, our Congress authorized the Federal Loan Agency to build up domestic reserves of strategic materials, and three days later

President Roosevelt added rubber to the list. Thus the Rubber Reserve Company, directed by Jesse Jones of Texas, was born. Immediately Mr. Jones started bargaining with representatives of the International Rubber Regulation Committee, the previously mentioned British-Dutch cartel which Dutchmen had done most to institute. The best available records indicate that, however belatedly, Jesse Jones did a pretty good bargaining job. He was dealing with tough, devious traders. Total stores of Hevea rubber on hand in the Far East were described as about 150,000 tons. Despite the war, the fall of Holland, and the desperate peril of Britain, the cartel had been relentlessly squeezing down rubber production in order to maintain prices and profits. In fact, on June 30, 1940, the International Rubber Regulation Committee was allowing only 59 per cent of its proved Hevea rubber production to enter trade.

As Jesse Jones and his men continued to bargain, this quota climbed to 85 per cent. By the end of 1940 the Rubber Reserve Company reported purchase of 430,000 tons of rubber at a cost of $193,000,000—the prevailing world price. By 1941, the International Rubber Regulation Committee had approved Far Eastern Hevea production of 100 per cent capacity, and Jesse Jones and his colleagues had contracted for 1942 deliveries (never to be made) of 1,200,000 tons of Malayan and Dutch East Indies rubber.

That was "paper buying," and like a Congressional appropriation of $47,000,000,000, it implied rather glibly that the goods could be bought merely because the money had been raised or the credit fabricated. Albert L. Viles, president of the Rubber Manufacturers Association, reported the confidence of the International Rubber Regulation Committee that Jesse Jones's orders would all be filled. But previous history had proved that Mr. Viles does better at golf than at prophecy.

Oddly enough, United States merchants of rubber were actually exporting about 125,000 tons of salvage rubber to other nations during 1938, 1939, and 1940; and most ominously, at least 60,000 tons of this scrap rubber went to Japan to join company with the millions of tons of steel, petroleum, copper, and other war materials which United States exporters, some of them huge and rich corporations, sold to a long-recognized Pacific enemy at a time when it was already bloody and boastful in conquest.

For many years career rubber buyers in the Pacific tropics had been well aware of the great perils of the caldron of the Far East. Since 1935, the designs of Imperial Japan have been plain to most intelligent people. Of course rubber companies, rubber exporters and speculators, steel and petroleum exporters, and all their associates knew, at least in a general way, what was brewing in the Pacific. If you or I happen to be the proprietor of a gun shop, and a desperate gangster calls to buy a tommy gun, we can be practically certain that the mobster does not intend to use it as a mantel ornament. Pompous alibis offered by officers of international trading firms are traditionally dishonest, trite, and dismally stupid.

During 1939 and 1940, while Japanese bombers and ground forces rained death and ruin upon free China; while the Nazi war machine was crunching and slashing down Europe; while all literate citizens of the United States knew of these calamities; while United States stockpiles of rubber were rarely fulfilling manufacturing needs two weeks ahead of date, and while Japan enjoyed excellent rubber-purchasing agreements with most of the great Eastern rubber lands—all this time Japan was permitted to buy from United States sources tens of thousands of tons of manufacturable salvage rubber. Granted that Japanese manufacturing requirements call for a larger than average proportion of salvage rubber for use in making toys, mats, rubber fabrics, shoes, etc., it is nevertheless proverbial in any well-run rubber factory that excuses cease to excuse after the mold is set. That proverb is not peculiar to the rubber business. Charlie Miller, Bill Rush, Sam Widney, and all the rest of us have heard it elsewhere.

On September 12, 1940, the National Defense Advisory Commission recommended to President Roosevelt that, in view of the possible dangers of "remote concentrations of rubber supply," domestic capacity for producing synthetic rubber should be raised from 5,000 tons per year to 100,000 tons. Rubber industry executives, particularly John L. Collyer, president of the B. F. Goodrich Company, which has done most to promote the practical use of synthetic rubber in the United States, gave further voice to the recommendation. The National Defense Advisory Commission qualified its proposal by stating that the experimental plant for making synthetic rubber should be built by public subsidy only when and if America's normal supply became imperiled.

Actually the supply was already gravely imperiled. In Washington and Akron alike the doors of evasion were ajar. Quite understandably, rubber factory executives and workers did not choose to become tropical farmers or abject dependents of the Buna synthetics which the Standard Oil Development Company had horse-traded from the I. G. Farbenindustrie.

Our principal rubber manufacturers had not dodged the entire issue. Du Pont and Goodrich had already gone into small-scale production of substitute rubbers. The former had for several years been producing neoprene, a specialized rubber substitute (at 75 cents per pound as against about 20 cents, the world price of crude Hevea), and Goodrich had developed for experimental purposes its Ameripol tire made of "more than 50 per cent" synthetic rubber, and coming within 15 per cent of meeting the rigid government specifications for military tires; it had also been making Koroseal, another special-purpose synthetic. Both Goodyear and Firestone were developing and manufacturing other types of synthetic rubbers. The Goodyear Rubber Plantations Company, under John G. Blandon, veteran rubber buyer in Malaya and the Dutch East Indies, was planting miniature Hevea experiment farms in Panama and Costa Rica (with the active assistance of the United Fruit Company). Firestone was using about 8,000 tons yearly of "company rubber" grown in Liberia, Africa; and Henry Ford's trail-blazing Belterra and Fordlandia plantations were almost ready for initial harvest.

Thus the American rubber industry was not entirely asleep at the switch, but it was dozing. The same generality applied to Washington's interest in rubber. Congress had appropriated $500,000 to enable the Department of Agriculture to direct a preliminary three-year survey program to appraise the possibilities of growing rubber within the Western Hemisphere. Department men were already riding refractory mules along the back trails of Central America, and sipping highballs and nodding gravely as they watched Goodyear and United Fruit men doing most of the work.

During May, 1941, Jesse Jones presented to Congress his now famous ace-in-the-hole recommendation, which stated in effect that, although the South Pacific rubber supply appeared to be adequate and reasonably safe, the government ought to subsidize at least one synthetic rubber factory with a rated capacity of 10,000 tons per year. Mr. Jones and his Defense Plant Corporation authorized such a building program, and during July, 1941, announced "give-away loans" to raise the capacity to 40,000 tons. Firestone, Goodrich, Goodyear, and others joined in the gesture, and by the time of Pearl Harbor factories with theoretical capacities totaling about 100,000 tons of synthetic rubber yearly had been built or were abuilding, principally the latter.

On the day before Pearl Harbor, Charlie Miller, Sam Widney, Bill Rush, and most of the rest of us were busy, if not tranquil. The rubber industry (with individual exceptions) and rubber experts with the government seemed to be exuding a sort of cream-fattened kitten complacency. Great rubber plants were swinging deeper and deeper into war production, but factory warehouses were virtually empty. The Rubber Reserve Company, alias Jesse Jones, reported 430,000 tons of natural rubber "delivered or on the high seas"—barely a six months' supply; but plenty more was to come during 1942—at least 1,200,000 tons—more rubber than the whole world had ever used in one year!

Then Pearl Harbor jarred our complacency, stirred our honest wrath, and raised the curtain for Japan's grabbing the source of around 96 per cent of our now doubly essential rubber. Before Singapore and the Dutch East Indies fell, before Charlie Miller had to close out his garage, our government, by way of Jesse Jones and associates, had authorized a $400,000,000 grant for the production of 400,000 tons of synthetic rubber per year, and federal appropriations had been made for 700,000 tons of synthetic capacity.

The picture became blacker when Singapore surrendered. Our proved supply of rubber had been blasted. The Rubber Reserve Company reported an assured stockpile of 325,000 tons; slightly more than 100,000 tons en route by ship; about 170,000 tons in the possession of rubber companies; about 50,000 tons of reclaimed or salvage rubber at hand, a not-yet fully tallied but minor amount of Latin-American rubber available, and a possible 40,000 tons of synthetic rubber in prospect. All told, it was somewhere near a year's supply without restrictions; but the War Production Board promptly approved drastic restriction to hold 1942 rubber consumption to a maximum of 550,000 tons, a figure soon to be further reduced.

In Washington recently a sad young man, rubber co-ordinator for the Consumers Division of the WPB, removed his horn-rimmed spectacles, sighed loudly, and told me:

"All this wouldn't be so bad if only we didn't have allies. But we have allies, thank God! We have Russia, Britain, China, Australia, Africa, Holland, and about twenty other nations including half of Latin America to supply rubber to, and Japan has practically all the rubber. Our allies don't have any rubber. That means we can't possibly spare rubber to ordinary citizens—not in 1942, 1943—maybe not in 1944 or 1945.

"We have synthetic rubber plants building. We have junk men and filling stations who can collect somewhere around 300,000 to 500,000 tons of salvage rubber—at least for a while. We have in trade about 9,000,000 new tires that the government is buying up. But for ordinary civilian uses we will have to ban new tires and secondhand tires. For 1942, 1943, and probably 1944 we can't give one pound of raw rubber for making civilian automobile tires. We may have to immobilize half or two-thirds of all the private automobiles and trucks in the United States between now and 1945.

"That doesn't mean the government will commandeer just tires. It would be better to take the whole automobiles while we are about it and use 'em in defense transportation where they are needed.

"How much rubber is there going to be for John Q. Public? Brother, we'll be fool lucky if we have a quarter-million-ton stockpile by 1943. By 1944, the everyday citizen will be lucky if he gets enough rubber to buy the baby one nipple. . . . That is, if we win the war. . . . If we don't win the war, it would be better to freeze the baby, too. . . ."

The sad young man replaced his spectacles and murmured about a thirst for beer. He then handed me a selection of five mimeographed news releases which I deposited quietly in a heaped-up WPB waste basket in C Lobby of Temporary Building K.

Down the next hallway I noticed a wall motto which read:

"Tire Rationing Is Just What We Need
To Put This Country Back on Its Feet."

Such a sign displayed in a federal office building is itself a symptom of crisis. There are almost infinite arrays of symptoms, beginning with the customary newspaper "human-interest features," such as the one about Abner Peel of Rahway who learned how to mend ladies' girdles (also out of manufacture) with inner tube cold patches; or the story about Miss Gladys Lynn, Brooklyn business girl, who delivered 29 pounds of assorted rubber bands to her local filling station and explained that now and then she had been filching a rubber band from the supply room.

Other signs of crisis are more significant. At Rio de Janeiro on April Fool's Day, 1942, President Getulio Vargas of Brazil signed a decree proposing to end the long-standing monopoly of the Amazon rubber barons. The decree gives the Bank of Brazil control of the rubber trade of Brazil and ends, so we hope, the long, scandalous reign of the North Amazon rubber plutocracy.

On the same day Thomas P. Henry of Detroit, president of the American Automobile Association, reported that even before enactment of gasoline rationing, tire shortage had caused a 40 per cent drop in long trips by passenger automobiles in the United States and a 20 per cent drop in gasoline consumption by private passenger cars. The Petroleum Industry War Council promptly proposed that the oil industry, "with government financial assistance," produce a minimum of 300,000 tons of synthetic rubber a year in addition to the 700,000 tons already planned by government agencies.

On March 5, 1942, Leon Henderson, former Price Administrator and Director of the Division of Civilian Supply of the War Production Board, testifying before the Senate Committee Investigating National Defense Activities, made what this reporter considers the best and fairest public statement of the dilemma of rubber scarcity:

". . . We will not only have to do without tires but we will also be without a multitude of other rubber articles which have become essential parts of standards of life.

"I am not trying to scare anyone unnecessarily. I am simply attempting to develop public understanding and recognition of the hard, cold facts.

"I should like to give you first the crude rubber outlook for the next three years as we found it to be . . . when it became apparent that further shipments from the Far East could not be expected. . . .

"Table A indicates that at the current rate of use of rubber the United Nations would have had net stocks at the end of this year of only 278,000 tons, and faced a complete exhaustion of stockpiles by the end of March, 1943.

TABLE A

UNITED NATIONS CRUDE RUBBER OUTLOOK

	1942	*1943*	*1944*
Supply—New supplies during year:			
Crude Rubber Shipments	434,000	135,000	98,000
Synthetic Rubber	25,000	165,000	362,000
U.S. grown Guayule or bush rubber	......	1,000	5,000
	459,000	301,000	465,000
Demand—United States Military Forces	409,000	617,000	617,000
Lend-Lease, South American Export, U.S. Civilian	200,000	165,000	165,000
Rest of Non-Axis World	265,000	265,000	265,000
	874,000	1,047,000	1,047,000

	1942	1943	1944
	Deficit	Deficit	Deficit
Result—Supply Minus Demand	415,000	746,000	582,000
		Deficit	Deficit
Net Stocks End of Year for Next Year	278,000	468,000	1,050,000

"It was necessary therefore to consider what relief might be obtained from an increase in the actual delivery of synthetic in the amount of 300,000 tons in 1943 and 600,000 tons in 1944. Table B presents this picture. It indicates that as far as the crude rubber picture is concerned we would still have exhausted our stockpile by May of 1943.

TABLE B

United Nations Crude Rubber Outlook

	1942	1943	1944
Supply—New supplies during year:			
Crude Rubber Shipments	434,000	135,000	98,000
Synthetic Rubber	25,000	300,000	600,000
U.S. grown Guayule	......	1,000	5,000
	459,000	436,000	703,000
Demand—United States Military Forces	409,000	617,000	617,000
Lend-Lease, South American Export, U.S. Civilian	200,000	165,000	165,000
Rest of Non-Axis World	265,000	265,000	265,000
	874,000	1,047,000	1,047,000
	Deficit	Deficit	Deficit
Result—Supply Minus Demand	415,000	611,000	344,000
		Deficit	Deficit
Net Stocks End of Year for Next Year	278,000	333,000	677,000

"The Requirements Committee of the War Production Board, with this stark picture in mind, therefore was compelled to cut down the allocations to all classes of users in the United Nations picture by 25 per cent,, effective immediately. The effect of this drastic action is shown in Table C.

TABLE C

UNITED NATIONS CRUDE RUBBER OUTLOOK

	1942	*1943*	*1944*
Supply—New supplies during year:			
Crude Rubber Shipments	434,000	175,000	98,000
Synthetic Rubber	25,000	300,000	600,000
U.S. grown Guayule	......	1,000	5,000
	459,000	476,000	703,000
Demand—United States Military Forces	* 306,705	* 462,750	* 462,750
Lend-Lease, South American Export, U.S. Civilian	* 150,000	* 123,750	* 123,750
Rest of Non-Axis World	* 198,750	* 198,750	* 198,750
	* 655,455	* 785,250	* 785,250
	Deficit	Deficit	Deficit
Result—Supply Minus Demand	196,500	349,250	82,250
Total Stocks at Beginning of Year	693,000	496,500	147,250
Net Stocks End of Year for Next Year	496,500	147,250	65,000

* Showing effect of a 25% reduction in demand which will be met.

"Let me point out again that in none of these three tables does the allocation for United States civilian purposes provide any rubber for any of the 30 million passenger cars which are now in operation here. I think the Committee will agree with me that the action taken to freeze all existing stocks of tires was well justified, and that instead of the situation improving it has become increasingly grave.

"Frankly, I believe it will almost require a miracle to secure the amount of synthetic rubber—300,000 tons in 1943 and 600,000 tons in 1944—shown in that table. If the miracle doesn't occur, if the synthetic rubber plants aren't completed on schedule, our situation will be immeasurably worse. . . .

"Ordinarily we require about 40,000,000 passenger car tires for replacement each year, plus camelback for recapping about 5,000,000 others. We will be able to meet, through recapping, only about one-seventh of the combined passenger-car tire replacement and recapping demand. This means that only those passenger-car users on the Class A or Class B eligibility lists will be able to secure recapped tires. As a practical matter it means that we will be doing well if we are able to keep running some of the cars of defense workers, the largest group in the Class B list. In addition, there will be a few new passenger-car tires sold from inventory to Class A users. . . . Thus you can see there is little hope that the ordinary passenger-car operator can get either a new or recapped tire in 1942, 1943 or 1944.

"This means that when the tires on the average passenger car begin to go bad that car will have to be taken out of operation. We hope at best, as we see it now, to maintain in operation over the next three years a total of 7,500,000 passenger cars, including those belonging to a large number of defense workers.

"But this can be done only if speeds are kept below 40 miles an hour, if tires are given the best of care, if they are inspected frequently to insure recapping when the proper time arrives, and if all unnecessary driving is eliminated. . . . We know that in 1943 and 1944 recapping of passenger-car tires alone will not be sufficient.

"If we don't use extreme care in driving speeds, tire inspection and tire maintenance, if we don't campaign vigorously for scrap rubber, and if we don't control the use of reclaim rigidly, we may be faced with the necessity in 1943 and 1944 of severe gasoline rationing to preserve tires or, as some have suggested, confiscation of tires on private cars.

"In closing, I want to warn the public against holding out any hope of getting substantial amounts of rubber in the near future from Brazil or from the guayule plant. Brazil never has produced more than a small fraction of our needs since the use of automobiles became wide-spread in this country. We can expect a little expansion of production there, but the problems of labor, transportation, and initial processing at the source will be extremely difficult to overcome. Likewise, several years would be required to develop the cultivation of guayule on a volume basis. We cannot expect substantial relief from either of these sources soon."

As the rubber crisis grows more acute, American attention is directed more and more to the subject of scrap rubber which was the subject of a presidential proclamation and a 25-day nation-wide collection campaign of only mediocre success. President Roosevelt has remarked to his press conferences that "No two experts seem to have the same idea about how much scrap rubber there really is in the United States."

The point was well taken. Authoritative estimates of scrap rubber at hand recovered within the United States have ranged from 5,000,000 to 10,000,000 tons. The actual collection during the first half of 1942, including approximately 320,000 tons collected at some 250,000 filling stations during the great scrap rubber drive from June 15th to July 9th, was under 500,000 tons.

Salvage rubber is far from being the same as crude rubber. It can be replasticized to make a successful blend with crude rubber, but it cannot be completely regenerated. Since about 1900, reclaimed rubber has been among the staple supplies of the American rubber industry. It is not ordinarily used to any great extent in first-grade tires. In times of peace, however, reclaimed rubber is extremely important in dozens of other commodities, such as heels, carriage tires, toys, garden hose, matting, and so on.

In the past, American factories have consumed a general average of about 150,000 tons yearly of reclaimed rubber at prices averaging between a fourth and a third those of crude rubber. The recovery of scrap rubber has varied greatly with existing world prices of crude rubber. In 1929, while the price of crude rubber was high, the tonnage of scrap rubber reached 219,000. It fell with the price of rubber, but in 1940 it again rose to 209,601 tons.

By 1942 rubber reclaiming capacity in the United States had reached an estimated 350,000 tons per year; but up to the middle of that year, no such capacity had ever been put to use. According to John L. Collyer, during the first quarter of 1942 scrap rubber was being collected at a rate equal to less than half of this capacity, or barely 12,000 tons per month. This ridiculous record was occasioned by poor organization of the reclaiming industry, poor cooperation by scrap dealers, and perhaps most of all by a stupidly low ceiling price, suggested by the cohorts of Mr. Jesse Jones, of $18 per ton for scrap rubber.

Even before Pearl Harbor the price of $18 a ton for scrap rubber was inexcusably low. In the World War I, scrap rubber brought $280 per ton. At prevalent 1941 wage scales and crude rubber prices, $50 a ton would have been a minimum price for effectively collecting scrap rubber from garages, attics, cellars, and trash piles. Even Mr. Jesse Jones has now learned that it is not easily collected; it tends to accumulate in small quantities and in remote and inaccessible places. By weight it is rarely ever more than one-third recoverable rubber, which rarely has more than half its original resiliency left after salvaging. Even so, scrap rubber is a precious strategic resource at this time, and thus far it has been managed badly.

Before Pearl Harbor reclaimed rubber had been used principally in the carcass of the tire, the treads and side-wall reinforcements being made of fresh crude rubber combined with large percentages of carbon black. At present, even the most exacting military specifications for tires allow a reclaim content of 15 per cent. Of course, tires can be made entirely of reclaimed rubber; but the mileage obtainable from such tires would be extremely low, certainly not much more than 5,000 miles, even at very low driving speeds. A new reclaiming process recently announced shows promise of bettering this performance figure. Many tire experts contend that the most reclaimed rubber which can be used effectively in any tire is about 85 per cent. Supported by 15 per cent of new crude rubber, such a tire might run about 7,500 miles at 30 miles an hour. Ordinarily, as already suggested, the more rational uses for salvaged rubber is in heels, footwear, electrical insulation, and the like; but the fact remains that automobile tires are the principal source of salvaged rubber.

United States Rubber Company experts estimate that the average weight of cast-off tires salvaged during recent years has been 28.7 pounds when new and about 25 pounds when salvaged, or a wear loss of only about 12 per cent. They believe that during the five years between 1937 and 1941 about 40 per cent of all rubber discarded in the United States was reclaimed. That left about 1,700,000 long tons still unsalvaged. In the past, scrap rubber which was not collected and reclaimed during the year in which it was discarded was listed as lost. The situation is different now. But dealers in scrap rubber are inclined to believe that comparatively little rubber discarded prior to 1937 can now be recovered. Therefore the United States Rubber Company estimates that about 500,000 tons of the discard rubber is actually recoverable. This implies that only 10 per cent of the discard rubber of 1937 and 1938, 25 per cent of that of 1939, and 50 per cent of that of 1940 and 1941 can possibly be recovered. Actual collections have closely substantiated this conclusion. The same authorities predict that recovery of scrap rubber abandoned during 1941 will prove disappointingly small, since millions of tires that would ordinarily be junked are now being driven to their last mile; in fact, the abandonment of old tires and other worn rubber during 1942 has been the lowest in history.

The reclaimed rubber situation remains confused. From this confusion several virtual certainties emerge. Reclaimed rubber is by no means the equivalent of crude rubber, which is about five times as strong in terms of pounds per square inch of load. Therefore it cannot conceivably solve our dilemma. Production in quantities of a half million or more tons can postpone confiscation of privately owned tires and cars for months; but it cannot assure civilian tires before 1945, and probably not then; nor can it assure an imperative minimum of rubber for war uses.

The rubber crisis continues to develop like malaria, or any one of a dozen other enormously complicated diseases which spring from a comparatively simple cause. Like a virulent epidemic, it spreads rapidly from community to community and from nation to nation. However dramatic and grim, its pathology is unprecedented. Its motion is witheringly destructive. But its treatment and eventual cure must necessarily be constructive.

To date, the constructive symptoms include the most exhaustive and energetic searching for rubber substitutes which the world has ever known. Recently, while I was interviewing patent experts with the United States Bureau of Standards, this truth was impressed upon me. One of these experts, who insists that he be mentioned only as Dr. X, held in one hand a Rube Goldberg masterpiece of a "spring bounce, tire-less auto-wheel," which an inmate of a Missouri insane asylum had mailed directly to President Roosevelt, and in the other hand a printed transcript of one of the most highly regarded new patents for a synthetic elastomer.

The spring-bounce wheel was merely another pathetic but noble fantasy. The new patent (U.S. No. 2,281,613, granted to Heinz Wollthan and Wilhelm Backer of Cologne-Mülheim, Germany, and assigned to Jasco, Inc., a Louisiana corporation) is interesting and significant because it is typical of the new desperate-need era of industrial chemistry that is upon us. It was described as follows in the New York *Times* of May 17, 1942:

"Starting with butadiene, a by-product of the petroleum industry, an emulsion is made containing this reagent, together with a compound called mercaptan. Also present in the solution may be styrene or acrylic acid nitrate. To make the synthetic rubber . . . heat the emulsion.

"Polymerization, a process in which the molecules of butadiene join with each other, or with the styrene and acrylic acid nitrate, to form the complex molecules, takes place, with the formation of rubber-like products. It is the presence of the mercaptan, which must contain at least six carbon atoms, that prevents retardation of polymerization, a slowing down of rubber formation that is said to occur in other processes. . . ."

Many other therapeutics for rubber shortage are appearing, among them synthetic rubber made from domestic crops. Dr. Henry A. Knight, the distinguished chief of the Bureau of Soil Chemistry of the Department of Agriculture, told me that usable rubber can be made at a cost of 40 cents a pound from alcohol distilled from corn at the then current market price of about 82 cents per bushel.

The strategy of making substitute rubber from domestic crops is one of utilizing surplus crops or crop wastes for making cheap alcohol; this can be done only by perfecting refining methods which recover the maximum amount of alcohol and by planning the most economical concentration of plant materials. In this war era we have comparatively few surplus crops. Our needs for smokeless powder and other explosives have created such an unprecedented demand for alcohols that even whisky production is being curtailed! Also sharp demand for most food crops has hoisted farm prices to a level where, most unusually, there is comparatively little cheap plant material suitable for making alcohol. These are unfortunate times in which to prove great domestic crops a profitable source of substitute rubber. But rather quietly the strength of proof grows.

Thus the case of substitute rubber made from important farm crops grown in the United States, as against that of substitute rubber made from petroleum and petroleum products, is another warm and befogged issue of our rubber crisis—another still unclarified factor in the yet unanswered question, "When will we have enough rubber?"

To date we do not have any widely usable production of substitute elastomers made from alcohol. As this book is written, about 2,000 tons of substitute rubber are being made from petroleum bases each month. This amount is growing. Current estimates of the War Production Board are for some 420,000 tons to be produced by the end of 1943. We are still faced with the production differences between test tubes and factory vats; between heating points of one square inch and a hundred square feet; between the handicrafts of the skilled experimentalist and those of the hour-conscious machine tender. In other words, the often great difference between laboratory and factory results has yet to be overcome. We still do not know how good petroleum rubber can be made in terms of tire use. No man is yet certain exactly how much, if any, natural rubber it will ultimately be necessary to blend with synthetic rubber for tires.

Other authorities, who include an actual majority of proved and respected producers of rubber, again remind us of the case of Hevea trees in the American tropics. We must have rubber. The really basic question is whether we are going to take our supply from rubber-bearing plants—particularly Hevea, the original and preponderant source—or from laboratories; from nature or from petroleum, coal, limestone, alcohol, or other products donated by nature, but requiring elaborate and costly processing. American inventive genius? American ingenuity? Let's grant they exist. But for the sake of honesty, let's also admit that they have a part to play in making the growing of rubber-bearing plants a great and beneficial agriculture for the Western Hemisphere.

Almost all rubber has come from plants which are indigenous to this hemisphere. The Hevea tree is still our principal source of rubber: it is not easy for any machinery, factory, or laboratory to compete with it: because Hevea is a strong, sound tree which through the centuries has dotted and to some extent mastered the overvegetated jungle; because Hevea is a distinctly tropical plant which is continually growing and creating rubber. In some instances good laboratories and efficient factories can offer competition to the badly worn soils of the Temperate Zone; to the rapidly thinning lands of the United States, where average growing seasons range from 120 to 160 days a year. In the vast realm of synthetics, it is frequently possible for an ingenious man to compete with a half-dormant nature, to produce at economic parity with a dissipated and semi-impoverished topsoil.

But much of the deep, fine soil of the American tropics remains the most productive land in the world. The Hevea tree grows and produces not just from April to October, but every day of the year—no lunch hours, no Sundays, no holidays. Indeed, the process of growth and latex formation go on even at night! The productive power of tropical earth, rain, sunlight, and seasons can never be measured by Temperate Zone yardsticks. Man's efforts to compete with fabulously rich tropical earth, with eternal tropical growth, in the production of an essential material is usually a futile enterprise—even when the basic materials which we would use for making substitute rubbers are free and plentiful.

Our natural supply of petroleum is uncertain; many of us may live to see its final exhaustion within the United States. Farm crops are and probably will ever be more than sufficient to feed the people of the United States properly; but the comparative cost of growing these crops is high, and it will remain high.

Basic petroleum materials used for synthesizing rubber are worth about $20 per ton on prevailing markets, before they enter factory vats. That is a cent a pound—not cheap for a crude raw material which requires complex and exacting manufacture involving skilled labor, superb technical supervision, costly machinery and rare metals, costly buildings, heavy taxes, and rapid capital depreciation. Fast-changing technologies endanger the security of investment in synthetic rubber factories. The inevitable overheads are unusually heavy.

But in the eternal lush tropics sunlight supplies heat and power free and unmetered. God and time and erosion provided the rich earth and the virile herbaceous life. Transportation is difficult and comparatively costly. But in comparison with the always huge distribution costs of goods in the United States, the costs and problems of tropical transportation are not too formidable. In most of the American tropics which are best suited to growing Hevea or closely related rubber-bearing crops, land is still cheap—a tiny fraction of the value of comparable lands within the United States—and millions of square miles of tenantable lands still await settlement. Even in the rich tropics of Central America (much of which is ideally suited to rubber production) only about one-tenth the available land is in cultivation. In the huge Amazon Basin this fraction falls to less than 1 per cent.

Immensely rich valley lands in Honduras, Nicaragua, Costa Rica, and Panama, lands known to be suited to Hevea rubber, are being bought today at prices ranging from 50 cents to $4 per acre. The same values, or less, apply to many regions of South America, to which Hevea trees are indigenous.

A factory site in Camden or South Bend, Cincinnati or San Diego is likely to cost as much as 100,000 acres of productive, sheltered rubber lands in a tropical valley of Latin America, and the factory's taxes will probably be between ten and five hundred times as great. Speaking generally, the open lands of Latin America are not yet shackled with taxes, as are the valuable lands and resources of the United States.

Here on paper let us forget, for the moment, the costly factories and high overheads of synthetic production, and notice another alternative. Almost anywhere in the United States one acre of land which produces 50 bushels of corn per year is likely to be worth between $100 and $300—the price of from 25 to 1,000 acres which one might take at random from the fertile frontiers of the American tropics, a million square miles of which are the original rubber lands of the world. Yearly taxes levied upon an acre of United States land which can yield 50 bushels of corn are likely to equal the entire cost of an acre of potential Hevea rubber land.

Conceivably, but not actually in current practice, about 500 gallons of industrial alcohol could be distilled from the 50 bushels of corn raised on a good Iowa acre. Conceivably too, with drastic improvement of methods for making substitute rubbers from alcohol, as many as 200 pounds of rubberlike material could be made from the 500 gallons of alcohol at costs currently estimated at 40 cents per pound. This is theoretical, of course. But let's be tolerant of theories and respectful of the distinguished organic chemists who believe that rubber substitutes can be made from the great crops which annually rise from our fields.

One acre of selected, high-yield Hevea planting, after ten to twelve years, can be expected to produce between 1,200 and 1,600 pounds of ready-to-use natural rubber. The initial value of that acre of land is probably $5 or less, with taxes of a few cents. Such an acre can be expected to continue bearing at the same rate for at least 20 years; it may continue bearing profitably for 50 years more. In general, if the land is well chosen, planted to selected bud-grafted Hevea trees, and given effective care, the rubber-producing life of the Hevea tree is at least 33 years, with annual maintenance costs no greater than those of the acre of corn land.

First costs of planting rubber trees are considerably higher than annual costs of planting corn. Seed farms or co-operative nurseries must be developed for propagating and budding the young Hevea trees. These must be transplanted to fields. Occasionally, though not usually, the new trees must be sprayed for leaf blight, lace bugs, or other natural enemies. But no routine cultivation comparable to that required by corn is necessary, a saving likely to be at least partly offset by the comparatively greater cost of carrying the rubber to market.

There is no general rule for the average cost of planting an acre of rubber. Certain British rubber plantation companies, politically molded in London, have spent $300 or more per acre for establishing Malayan rubber estates. But compared with that of most other tropical crops, the bona fide planting and horticulture of rubber trees is simple and inexpensive. Big trees must be felled to make room for the Hevea seedlings; but once well started, the Hevea tree effectively holds its own against the competitive jungle growth.

Today in Central America, notably in Honduras, good Hevea rubber plantations are being prepared and planted at costs as low as $40 per acre. In Sumatra about $100 per acre was the average overhead for bringing high-yielding Hevea plantations to bearing. In these instances labor was cheap, but land rents and other overhead items were higher than those now current in many lands of the American tropics. In any case, when compared with a really difficult tropical horticulture, such as that of bananas, Hevea is cheap and easy, the overhead being considerably lower on small, independently owned farms than on large, corporate-owned plantations.

This is what the planter, or farmer, of the American tropics is likely to say while he ponders future sources of rubber. This worthy hombre probably respects the industrial ingenuity of the norteamericano. Even so, he may gently point out such pertinent items as these:

1. Unquestionably synthetic rubber is superior to natural rubber for particular uses, such as resistance to heat, oil, and sun; but it is a conspicuous fact that a supply of natural rubber is complementary to and not necessarily competitive with a supply of synthetic rubber.

2. Regardless of specialized superiority of certain types of syn-

thetic to natural rubber, most practical authorities agree that the latter, particularly Hevea, is definitely superior to synthetic rubber for the manufacture of tires and tubes, which represent about three-fourths of our entire consumption of rubber.

3. The Hevea tree is one of the few important crops which can store its harvest without cost. If rubber prices are too low to justify harvest, the rubber can be left in the trees. If they are too wretchedly low to justify the tenure of farms, Hevea groves can be left to return to bush or jungle. Almost invariably the rubber trees survive. When prices rise, and rubber demand awakes, the dormant latex is always there.

4. Regardless of market prices, a hard-working man in a good Hevea grove can take out enough latex in one day to make about 30 pounds of dry sheet rubber. If rubber is worth 22 cents a pound on the plantation, as it was during 1941, his gross income is therefore around $6.60 a day. Mr. Jesse Jones and his colleagues have recently estimated that synthetic rubber can eventually be made from petroleum in 700,000-ton quantities for about 25 cents a pound, with a possible variation of 5 cents a pound, "one way or the other." At such a price the hard-working tropical (of whom there are millions in this hemisphere) who harvests 30 pounds of rubber daily, can establish a gross earning of $7.50 daily, even in direct competition with synthetic rubber. If prices fall to 10 cents a pound for crude rubber, he still has an earning potential of $3 per man-day. Even at 5 cents he can still exist, for a gross income of $1.50 daily is above that of hundreds of thousands of farmers in the United States. Even in 1933, when for a brief period world prices of rubber fell to 3 cents per pound, the better-run Hevea plantations of the Pacific East lost little or no money. In Sumatra a probable half million acres of Hevea planting were temporarily abandoned. When rubber prices improved, these lands, principally in small farms, were profitably returned to harvest.

5. The men who spend their lives at successfully growing rubber in the tropics point out still another significant bit of rubber arithmetic. According to Mr. Jesse Jones's records of donation of taxpayers' money to the subsidy of American petroleum companies,

the equipment necessary for producing one ton of synthetic rubber a year costs about $700 to $1,000.

That sum of money, if capably and honestly spent in establishing well-located Hevea plantings, should provide between ten and forty acres of high-yielding rubber trees. A low average harvest from such planting would be between 6 and 24 tons of dependable crude rubber a year, or between 6 and 24 times the investment return procurable from subsidized rubber-from-petroleum enterprises. The latter may not be solvent at all. But Hevea rubber is a good crop, profitably proved on four continents and scores of islands—a crop which can most assuredly be grown well and abundantly in this hemisphere.

6. Charlie Miller, Sam Widney, Bill Rush, and the rest of us who ask, "When will we have enough rubber?" and receive the answer, "Certainly no sooner than 1945 and very probably not then," might consider one other truth behind the prevailing rubber crisis, a fact already mentioned, but worthy of a brief repetition: Hevea horticulture is not necessarily the *old* way of producing rubber, and the production of elastomers is not necessarily the *new* way. By 1910 synthetic rubbers were patented in London, Berlin, and Paris. The development and effective utilization of Hevea horticulture is barely begun. It was not effectively proved until about 1937. Furthermore, practical research in rubber-bearing plants besides the Hevea tree is still in its infancy. Maximum Hevea rubber yields as of Pearl Harbor may very well be considered low average yields of Central and South American groves a quarter century from now. This statement is based upon actual botanic and horticultural experience. Strategically speaking, rubber is almost unquestionably the most important crop in the world today. As a crop, it is also one of the least developed. The current crisis of rubber is enormously important to the development of successful synthetic or substitute rubber. It is equally important to Western Hemisphere establishment of rubber agriculture. Either development will require time—at a breath-taking juncture when time is the most precious of all commodities.

WAR

AND

RUBBER

11

BY now everyone realizes in a general way the military importance of rubber; but few people really appreciate the vast tonnage required not only for airplanes, gun mounts, and battleships, but for less spectacular but equally important items, such as raincoats, boots, gas masks, hose, and other miscellaneous equipment. The tabulation[1] below brings these facts home better than any that has come to the author's attention:

Heavy bomber = 1,825 pounds. (One tire uses over 100 pounds. Self-sealing tank uses 1,429 pounds.)
Medium bomber = 804 pounds. (Self-sealing tank uses 528 pounds.)
Pursuit plane = 255 pounds. (One tire uses 17½ pounds. Self-sealing tank—177 pounds.)
Scout car = 306 pounds.
Light tank = 489 pounds. (Tracks alone use 317 pounds.)
Gas mask = 1.11 pounds.
Gun carriage for 37 mm. gun = 61.1 pounds.
Gun carriage for 57 mm. gun = 82.1 pounds.
Two and one-half ton Army truck = 446 pounds.
Motorcycle = 10.7 pounds.
Pair of ski boots = .31 pounds.
Pair of hip boots = 2.62 pounds.
Ten-ton pontoon bridge uses 3,644 pounds.
Aircraft tires range from 17 to 100 pounds each.
165,000 pounds of rubber go into making a 40,000-ton battleship; 100 pounds go into the tire of a big bomber.

Probably the most astonishing item on this list is the amount of rubber required in the self-sealing gas tank of a heavy bomber—two-thirds of a ton! These tanks are huge affairs, made of many layers of rubber-impregnated fabric and capable of holding several hundred gallons of fuel. When we talk about huge fleets of Flying Fortresses to bomb Germany, we should bear in mind the demands that this would make on our slender rubber reserves!

Rubber is as indispensable to our armed forces as powder and bullets; in modern war it means the saving of lives and perhaps the winning of battles. The vital surfaces and subassemblies of fighter planes are made of rubber. Army trucks, transport cars, bicycles, and motorcycles roll on tires having heavy, deep-cut treads. A 16-inch rifle, the largest gun used by American forces, moves overland upon a battery of 38 reinforced rubber tires. Howitzers, machine guns, 37-millimeter cannon, and other light field weapons also require tires. Antiaircraft guns are mounted on rubber. American motorcycle troopers charge into battle upon new tires, pistol holsters flapping ominously, goggles and rubberized headgear drawn tight, and automatic rifles spurting red.

It is to the eminent credit of American rubber manufacturers that our armed forces move on the best tires in the world. Significantly, they are also making tens of thousands of nonrubber war essentials, such as wings, subassemblies, and essential parts for Brewster, Vought-Sikorsky, Consolidated, Martin, Grumman, Curtiss, and other renowned makes of fighting planes.

Our parachute troops are protected against hard landings by foam-rubber pads. Airplane fuel tanks are bulletproofed with linings of gum rubber. Rubber-built airships, or blimps, help to patrol our shores against submarines; barrage balloons, tethered with cruel steel cables which cut invading enemy planes to shreds, help to safeguard cities and war storage centers. Rubber life vests are standard equipment for American airmen whose planes may be forced down at sea. So are tens of thousands of inflatable pneumatic boats, or life rafts, used alike by flyers, ship men and marines. Also there are flotation bags—huge, pneumatic balls, covered with rubber-coated fabrics; when these are deflated they fit into the wings of fighting planes and bombers; if the plane must make a landing on water, they can be quickly blown up to serve as buoying agents to keep the plane afloat.

In rubber factories one may see the manufacture of powder bagging which holds propellent charges for big guns, or watch the fast-whirring manufacture of thousands of lengths of fire hose. The unending transparency of Pliofilm and other rubber films comes from myriad rollers; this provides wrapping for materials requiring airproof, moistureproof, and germproof containers. Gas masks are another important use of rubber in modern warfare, and they are being produced by the million. Gigantic rubber hose is used to fuel battleships. Rubber transmission belting, by the thousands of tons, speeds the machinery of war production. Pneumatic hose facilitates mining, road making, and a hundred types of military construction. Rubber conveyer belts, sometimes weighing hundreds of tons each, carry huge volumes of ore, earth, coal, iron, and metals out of mines, across canyons, from boatside or railroad cars to factories, furnaces, refineries, and other war plants; they are also necessary in constructing dams, subways, and tunnels. In a "lightning" war, wherein speed and versatility are of the essence, rubber is extraordinarily well equipped by nature to play an integral and essential part.

Current progress in rubber manufacture is probably the most rapid and varied ever attained by an American industry. Of necessity headline rubber news is war news. Of the 65,000 rubber articles now under patent or pending patent, nearly 25,000 are helping build our new Army, Navy, and Air Corps. Our present war effort has become the greatest stimulus to the development of rubber since 1839, when Charles Goodyear "invented" vulcanization.

With steel and petroleum, rubber is now one of the prime military materials. Field guns, tanks, armored cars, and transports; planes, field kitchens, hospitals, horses, and mobile plane-repair shops are rolling to war on rubber tires or tracks. Our military vehicles require an average of 300 rubber parts or fixtures apiece; a heavy bomber uses about 400, and a 35,000-ton battleship more than 20,000. Last winter we were able to fly bombers to England because of rubber de-icers on their wings. In fact, we are learning that for many uses rubber lasts longer, moves faster, is more resistant to high speed, and is generally more "maneuverable" under battle conditions than is steel.

Our new Army profits accordingly. Tanks are taking to rubber, the standard 28-ton light tank, or M-3, using about 1,600 pounds of it. Sponge-rubber pads protect the crew from injury caused by being thrown about inside the tank. As long as rubber supply was sufficient, new-style tanks were equipped with rubber tracks—lugs of hard rubber vulcanized upon steel cores which turn on bogie wheels or rollers, also made of solid rubber vulcanized upon steel rims. Thus rubber works against rubber, instead of steel against steel, to increase speed; to reduce strain, vibration, and dead weight; and to muffle noise to a point where our new tanks can receive orders by radio in the thick of battle. These advantages are now being sacrificed because there isn't enough rubber, and the treads are being made of steel, which reduces speed by 10 per cent.

Another remarkable achievement is the all-rubber mount for antiaircraft guns, particularly the 40-millimeter. Each mount has about 1,500 parts. Mechanical earth drills now used by the Army (they can dig a 20-inch hole six feet deep in three minutes) also travel on rubber tires.

Since our Army began to move on rubber, notable progress has been made in tire building. Most spectacular is the development of the self-sealing, bulletproof tire, equipped with gum-type elastomers which close bullet or shell punctures. In tests, clip after clip of high-powered 50-caliber bullets are fired at close range into a self-sealing tire. Then the tire is transferred to a military vehicle and, in order to qualify, must run for an hour or more with pressure losses no greater than ten pounds. The self-sealing fuel tank, now standard in our fighting aircraft, is another application of the same principle.

Military aircraft must be prepared to make rough, fast landings, and the resulting grind upon tires, particularly in the case of bombers, is tremendous. Today the world's biggest airplane tire—a

36.00-40 casing—is being manufactured by Firestone for the new Douglas B-19 bomber. Though adapted to the standard tricycle landing gear, each tire is built as if it were to carry half the bomber's total weight of 82 tons. Standing eight feet high, the tire weighs 961 pounds and has a tread which carries five inches of solid rubber. To build one such tire requires 600 pounds of crude rubber, 148 miles of cotton cord, 3 miles of steel piano wire for beading, and 300 pounds of compounds! A new Firestone heater unit designed to "cure," or vulcanize, tires from eight to ten feet in diameter weighs 300,000 pounds and stands as high as a 2½-story building when the lid is opened!

Uses of rubber in aviation are increasing almost as rapidly as our output of bombers. One is the recent development of tires which conduct static electricity into the ground, and thus eliminate a serious fire hazard. The rubber industry has taken over production of barrage balloons, one tested form of protection against aerial bombardment. This construction is extremely complicated, since it involves perfecting and rigid inspection of suitable rubberized fabrics, inflation equipment, stabilizers, and seam closure with specially developed rubber adhesives. Control, or "weather-surfacing," wings of military aircraft is another important new job for rubber. So is insulation of delicate aviation instruments.

Rapid development of rubberized or rubberlike tenting materials points to a time when air bases, like circuses, can be "pitched" overnight. These weatherproofed tents and shelters are already enormously important to our land forces. The oxygen mask for high-altitude flying; heat-retaining boots and zipper suits for military flyers; flame-, gas-, and grease-resistant coverings for both men and vital engine parts are a few more instances of the importance of rubber in air supremacy.

Use of rubber for combat weapons, and for transport of troops, munitions, and supplies to fighting fronts constitutes but one chapter of the war-and-peace epic of rubber. As can be seen from the foregoing account, the wartime uses of the elastic magic embrace all the vast field of peacetime uses, and extend far beyond them.

For example, here on my desk is a War Production Board order (Title 32, Chapter IX, Subchapter B, Part 940, Amendment No. 7 to Supplementary Order No. M-15-b) *To Restrict the Use and Sale of Rubber,* a document made effective on April 1, 1942.

Comparatively speaking, it was not a drastic order; in fact, it was but a mild suggestion of what was to follow. The order enumerates 23 groups of principal rubber products in List A (Admitted War Essentials) and states the monthly percentage of each item allowed to be manufactured, compared with the total production of each item during the same month of 1941. In List B, it records 27 additional groups whose manufacture is not specified as valid during the month of April, 1942; List C contains seven groups of products allowed in manufacture on a specified percentage basis; and List D includes rubber goods the manufacture of which is temporarily prohibited. The order is vivid reading matter only because it records, with all the impartiality of fine type, those rubber products which are considered immediately apropos of war needs.

One notices first the "100 per cent items"—those whose manufacture quotas were confirmed without reduction of output. These include:

concentrator belts
industrial belt linings
  and clutch facings
polishing belts
screen diaphragms
acid hose
cement-gun hose
chemical hose
grease-gun hose
hydraulic control hose
railroad hose (all types)
rotary oil-drill hose
sandblast hose
air-drill hose
dredging sleeves
industrial vacuum hose
oil suction and discharge hose
pneumatic hose
spray hose
paint-spray hose
steam hose
suction hose
welding hose
gasoline and oil-tank water hose
  (not including curb pump
  hose)
mine safety battery parts
mine safety lamp parts
respirators
hose masks
gas masks

goggles and inhalators (for mineworkers)
airplane de-icer parts
gaskets and washers
gas-main bags
linesman's protective devices
locomotive driving units
mine ventilating tubing
pipe coupling rings
pipe lining discs
shoe diaphragms
molded seals for dam and lock gates
autopsy and mortuary gloves
electrician's gloves
blood pressure bags
brain surgery caps
dental separating strip and mouth parts
medical and dental finger-cots
inhalation bags and face pieces
invalid rings
operating cushions
parts for medical, surgical, dental, veterinary and mortuary instruments
prostatic bags
rubber bands and cushions for artificial limbs
rubber dentures
tourniquets
umbilical belts
urinals
vaccine caps
X-ray sheets
gloves
aprons

Manufacture of items cut to one-half of previous outputs, are:

hospital sheeting
ice bags
metatarsal cushions or pads
truss-pad covers
self-adhering gauze bandages
pneumatic truss pads
breast pumps
water bottles and combination syringes
medical droppers
veterinary sleeves
automobile hydraulic brake hose
air brake and vacuum brake parts
clutch facings
brake linings and brake blocks
shock absorber bushings
steering post alignment bushings
windshield wiper blades
suspension and torque arm bushings
center bearing mountings
spring bumpers
remote control gearshift bushings
cements and tie gums (for bonding rubber to metal only)
sealed beam gaskets
hydraulic clutch and throttle controls

Increased production was permitted in the manufacture of abrasive instruments (160 per cent) and milk and milking machine equipment (140 per cent). Manufacture of fire and mill hose was cut to 30 per cent; that of engraver's rubber to 50 per cent; of automotive fan belts (for trucks, busses, tractors and farm implements only) to 20 per cent of the previous year's output.

Manufacture of flush valve balls, flush-toilet washers, and water-meter parts was whacked down to 70 per cent. Limitation to 85 per cent of the former production included hard-rubber pipe and fittings, rubber buckets, pails, dippers, funnels, bottles, beakers, baskets, racks (for handling corrosive materials and explosives), also rubber pumps and parts, and rubber-insulated receptacles for handling explosives. Eighty per cent quotas fell to sweeper belts, pulley lagging, last-puller belts, cleats and bucket pads, fingerprint rubber, rubber offset and newspaper blankets, surgical tape, medicated foot pads and plasters.

With our rubber-dependent world at war, almost all civilian uses of rubber are ranked as military or strategic uses under emergency quotas; even feeding nipples, pessaries and prophylactics, surgeon's gloves, rubber footwear (for severe industrial use), compounds for insulating wire and cable, cable-splicing compounds, conveyer and elevator belting, rubber-lined acid tanks, drums, pipes, and fittings (hard and soft); rubber-covered rolls and roll coverings; press die pads, loom pickers, pneumatic, solid and cushion tires and tubes; camelback, capping stock, filler strip, striping stock, lug stock and base stock for retreading and capping tires; vulcanizing materials, container-sealing compounds and sealer gaskets; commercial driving equipment and meteorological balloons.

These are merely a few excerpts from current rubber-use orders; a complete list would fill this entire book. There are thousands of specific military uses for rubber which at this time cannot be reported. In this connection another fact is noteworthy. Military operations consume or destroy tires, tubes, and many other items made of rubber at a rate unknown even in the most extravagant civilian use. An ordinary four-ply tire for a pleasure car contains about ten pounds of crude rubber. The wearing life of such a tire averages around 26,000 miles, varying somewhat with roads, speed, driver's skill, and other considerations. Six-ply tires are standard for military vehicles and their average wearing life is probably under 9,000 miles, even in the United States. There are several reasons for this. Army tires must carry heavy loads at high speed over terrains likely to be rough. In combat, the operating life of tires and vehicles is amazingly short—frequently 1,000 miles or even less. Accurate averages can hardly be predicted, since in terms of rubber, as well as strategy, most depends upon whether we fight our war, or principal parts thereof, in Russia, Germany, the British Isles, Australia, Africa, the Near East, or Asia. But it is generally true that the life of the average military tire used in the United States is one-third to one-half that of the average civilian tire. However, on entering battle in Russia, Australia, Africa, the Near East, or Asia, the running life of a military tire may very well be one-tenth or even one-twentieth that of a civilian tire driven only from White Plains to a Radio City parking lot. Rough ground, heavy loads, high speed, and too many bullets or shell fragments are ruination to tires.

Surveys made recently by the War Production Board indicate that even several months after Pearl Harbor our Army was treating its tire supplies rather carelessly. One such survey, presented early in 1942, showed that about half of all tires examined by the diligent fact-finders of WPB were underinflated; that 37 per cent were incorrectly mounted; that tires still capable of many thousands of miles of wear were thrown away at 10,000 miles; and that as many as one-third of the tires junked were suitable for reissue. The surveys showed incompetent storing and servicing facilities for tires and tubes, as well as insufficient training of drivers, and lack of uniform routine for testing tires and tubes!

Most American owners and drivers of automobiles are traditionally and fantastically abusive of tires, but waste of rubber and tires by government workers has recently been scandalous. However, in the armed services this is being corrected rapidly. The

Navy, including the Coast Guard and Marine Corps, has inaugurated a skillful and well-directed effort in rubber conservation. The Army, at present our largest consumer of rubber goods, has issued and put into force orders which make its personnel, particularly company, regimental, and division commanders, officially and individually responsible for good care of all tires and tubes used by their commands.

However expert the care given to military tires and tubes, their service life is far shorter than under normal conditions. Military consumption of rubber per ton-mile of transportation, whether in action or in training, inevitably exceeds that of even the most careless civilian use. For this and other good reasons first consideration must be given to provide as large a "factor of safety" as possible for the imperative needs of our armed forces, and those of our allies—*in other words, not only enough rubber for predictable demands, but enough to take care of emergency needs as well.* In the frantic scramble for the available rubber supply, ordinary civilian requirements simply cannot be met.

Yet the fact remains that two-thirds of our entire supply of rubber is still in the tires and tubes on the 27,000,000 passenger cars—principally pleasure cars—in use or storage in the United States. This reservoir of rubber is estimated at 1,200,000 tons (almost twice our total 1942 stockpile of rubber) giving bounce and durability to an estimated 173,000,000 tires owned by the people of the United States. As this book is written it seems virtually certain that some part of this huge reserve must be bought, confiscated, or otherwise appropriated for military use before the end of 1943. Whether or not this turns out to be the case, it is hardly deniable that one of the most intelligent summaries of the situation was supplied by John L. Collyer, president of the B. F. Goodrich Company. It is a pamphlet quite pertinently entitled, *Will America Have to Jack Up Its 29,000,000 Automobiles?*

Mr. Collyer writes plainly and clearly:

"Without rubber we would be economically paralyzed in peace time . . . helplessly crippled in war. Tires for planes, tanks, trucks, trailers, trains, ships and mechanized equipment of every type need rubber vitally.

"Without rubber we could offer only 1860 defense against 1942 attacks. . . ."

Analyzing our rubber position in a confidential report to United States government officials on May 1, 1941, the B. F. Goodrich Company emphasized four possible threats to the source of supply. The report said in part:

"Here are the dangers that may threaten our rubber supplies: 1. Capture of territory by unfriendly powers. 2. Shortage of ships to transport rubber. 3. Shutting off shipping routes by unfriendly powers. 4. Destruction of the rubber trees.

"Since that time, with the possible exception of destruction of the trees, all these things have happened. War has cut America's rubber lifeline.

"Our May 1, 1941, report canvassed the possibilities of obtaining rubber from South America, from Africa, from the guayule shrub. It emphasized that all sources but one were unprepared or inadequate and would take long years to develop into large-scale production. The *one* source of large tonnage of new rubber was shown to be synthetic rubber. To obtain the necessary synthetic capacity, to carry on the necessary research, to get the manufacturing 'know-how' will take time.

"Our limited crude rubber supplies must bridge the gap. We must make the greatest savings that American ingenuity can obtain by using reclaimed rubber, chemicals and substitutes for rubber wherever possible. . . .

"Eventually products made of rubber must be replaced or vital services will break down. Workers must have transportation to and from distant war production jobs. A way must be found to keep America's automobiles and trucks—key factors in United States war or peace economy—on the road. We must keep *them* rolling, too.

"Only one course is open. We need a much more intensive program of rubber conservation. This can be accomplished by the whole-hearted co-operation of the government, industry, the Army and Navy and private owners of automotive equipment.

"The rationing of civilian tires was a prompt and necessary move, but there are other possibilities where total savings may be impressive. Here are a few suggestions:

1. Carry further the conservation efforts being made by the Army and Navy.

   First: In the *purchase* of rubber products, make sure quality specifications do not exceed actual service requirements. Equipment that may be used only 5,000 miles does not need tires (using far more rubber) that will go 25,000 miles.

   Second: In the *use* of rubber products, more attention to the care and repair of rubber used by our armed forces can substantially cut down replacement needs.

   Third: In handling the *reserve* supply situation, centralized control of reserves will avoid wasting today's vitally needed rubber in idle inventories. A factory does not permit every department to carry replacement parts for its own motors.
2. Consider adoption of proposed national orders for additional rubber conservation:

   A national speed limit for the period of the emergency. Limitation of the use of autos to necessary trips only. Strict limitations on purchase of used and repaired tires.
3. Make reclaimed rubber play an even greater part in eking out our reserves. We need a national rubber roundup to assure more efficient collection of scrap rubber. [This took place in July, 1942.]

   We need an expansion of reclaiming facilities. We should use a part of the expanded capacity to build a national stockpile of reclaimed rubber.
4. Greater conservation in rubber factories. Waste in the manufacture of rubber products must be cut to an absolute minimum.

"Only if all these measures can be taken aggressively now will rubber and reclaimed rubber be available to keep necessary civilian cars and trucks in operation until synthetic rubber begins to come from our new plants. America's rubber situation is grave: it calls for sacrifices by everybody. . . .

"How long you can keep your *own* car rolling is more important to our country's war effort than you may realize. . . . Here is what you can do—in fact what you *must* do if you want to help your country by keeping your car serviceable and ready to perform the many vital services you will need it for in the future:

1. Keep correct air pressures in your tires at all times. Check the inflation once a week. Overinflation causes rapid wear because the tread contact with the road is reduced. Underinflation causes uneven wear on the shoulders of the tires. A tire underinflated 20 per cent will deliver 15 per cent less mileage. Both underinflation and overinflation make a tire far more likely to be injured by bruises. When your tires are being inflated, check them for obvious external injuries and remove tacks, glass, stones, etc., that might be imbedded in the tread.
2. Shift your tires from wheel to wheel every 5,000 miles to insure uniform wear on all tires, including the spare. (Wise use of spares tires can add about 20 per cent to the use of all civilian automobiles.) Tire wear on the different wheels is not uniform. By switching the tires around you distribute the uneven wear equally.
3. Whenever you change a tire, check the air pressure after a few miles of service. When a tube is mounted in a tire a certain amount of 'trapped air' is left between the tube and the inside of the tire, which gives a false air-pressure reading. This air will leak out over a period of time, and as a result, if the tire is not re-checked, it may become badly underinflated.
4. Don't take corners at high speeds. It wears out tires faster than anything else. If you speed around a curve the force of your speed tends to make the tires slide sideways. This actually grinds rubber off the tread.

5. Never slam on your brakes except to prevent an accident. When you come to a skidding stop rubber is worn off the tires. After a too-quick stop, the black streaks of rubber left on the pavement are quite obvious: they represent from three to five hundred miles of tire wear. Put on your brakes gradually and keep the rubber on your treads.
6. Have your wheel alignment—front and rear—checked regularly. A tire on a wheel that is only one-half inch out of line is actually *dragged sideways* 87 feet in every mile! This grinds off rubber. Many car owners lose from 20 to 50 per cent of their tire mileage by having wheels improperly aligned. Have yours checked by an expert.
7. Drive slowly. Speed causes heat and increased abrasion, and thus wears out tires quickly. The slower you drive the more mileage you will get. For example, if you used to drive 60 miles per hour and you cut your speed down to 30 miles an hour now, you can get at least three times as much tire mileage.
8. Start gently. Don't spin your wheels and thereby wear off rubber. Spinning your wheels causes destructive abrasion of the tire against the road. This is often the reason why 'stop-and-go' driving in the city causes low mileage. The driver who is always first away when the green light is on may be the first one to have to jack up his car.
9. Don't bump into curbs. No tire will stand such abuse. If a tire is crushed between the curb and the steel rim of the wheel, it may be severely injured. Play safe when parking; stay a few inches away from the curb so that you will neither bump against it nor scrape it.
10. If your car begins to steer queerly, slow down. This is very often a sign that something is wrong with a tire. If you are getting a flat tire and stop soon enough, your tire may be saved by a minor repair; otherwise it may be ruined.

"Use your car as little as possible; its mileage is a valuable asset to you and your country. So don't waste it. You know best when you have to use your car, and you can save the rubber on it by either staying at home, walking, or using other available transportation. . . ."

The report adds some appropriate suggestions about how to make ordinary household rubber goods last longer at home:

"The three worst enemies of rubber are oil, heat and sunlight. If you keep your rubber products, whether they are overshoes, kitchen mats, water bottles or bathing caps, away from these three destructive agencies as much as possible they will inevitably give longer service.

"Whenever oil or grease, fats, gasoline, benzine and the like are spilled on a rubber product, wash it off at once.

"When rubber products are not in use, keep them in a cool, dark place.

"Don't pull or tug too hard on such articles as overshoes, boots, galoshes and gloves. Keep them dry but don't put them on hot radiators or in the sun.

"Your hot-water bottle will give longer service if you do not use water hotter than 140 degrees F. After using, drain it thoroughly, inflate it slightly by blowing in it, replace the stopper and store in a cool, dark place.

"Your garden hose will last longer if it is coiled and stored after use. Do not hang it over a nail or peg, as a permanent kink will result, which will mean a burst next time you use the hose. . . ."

Mr. Collyer's booklet is an excellent manual for the care and conservation of rubber; it brings home to the reader the fact that civilian and military rubber needs are often identical and that all articles made partly or entirely of rubber and all the tens of thousands of uses for rubber are now linked inevitably to war needs. There are simply no definite boundaries between military and civil needs for rubber and its conservation: almost every civilian requirement has become a military necessity.

With all deference to the possibilities for production of synthetic rubbers, our current rubber consumption must still be considered in terms of the natural product. Our supplies of natural rubber in sight include about 8,000 tons of guayule rubber, principally in Mexico; about the same quantity of plantation-grown Hevea from Liberia and other West African areas; an estimated 50,000 tons of wild Hevea rubber from Brazil. The latter, if it is to be obtained at all, must be tapped from growth of 4 trees per acre—an average yearly recovery of 500 pounds per man—over at least 200,000 miles of jungle trails which have yet to be opened. Every ton, every pound of new rubber which can be procured from American nations, Liberia, or any other non-Axis area is enormously important to our war effort. One ton of new rubber can "sweeten up" as many as ten tons of salvage rubber; it can supplement in essential manufacture several tons of heretofore untried synthetic rubber.

Even so, we do not, and will not immediately, have enough rubber to equip our fighting forces and those of our allies properly. Tragically, fighting men of the United Nations must suffer the consequences. Again let's look at the records. As of July 1, 1942, the total stockpile of available crude rubber in the United States was about 765,000 tons. Approved requirement of the armed forces of the United States, even with maximum enforcement of all conservation methods, is at least 400,000 tons. In addition, our factories and our government are vitally obligated to supply rubber material to the armed forces of most of the United Nations. Also we are obliged to supply certain essential shipments of rubber goods to at least a dozen American republics which lack domestic supplies of rubber, or industrial means for causing those supplies to materialize. If all military and naval needs of the United Nations could be supplied without stint, war uses of rubber might easily total a million tons a year, or more.

Reclaimed rubber is at present our greatest emergency source until synthetic production takes up the slack. For most military uses reclaimed rubber is an inferior product, but infinitely better than no rubber at all. Blended with crude rubber it becomes invaluable. Reclaimed rubber alone cannot make a good tire or serve to win the war, but the combination of reclaimed, synthetic, and crude rubbers can be used for building serviceable truck or auto tires, or for retreading them. The latter requires only about five pounds of rubber mixture, as against some fifteen pounds for complete manufacture of one tire for a light army vehicle. If the side wall and carcass are in good condition, the retreading process may add as much as 80 per cent to the working life of a tire.

In 1941, only about one-fifth United States consumption of rubber was for military uses. This fraction is now greatly increased. Until 1942, the civilian public was receiving and enjoying the lion's share. Turn about is fair play any time—particularly now. Rubber from reserve stockpiles, from junkyards and salvage dumps, hoped-for synthetic rubber from cooking vats and factory rollers—each is like one leg of a three-legged stool to bear the staggering burden of momentary needs. "Civilian rubber" is now "military rubber," essential to our victory and survival.

LOOKING FORWARD

12

DURING October, 1941, a long-established and respected New York rubber importer received what he considered a bizarre request. A principal Dutch plantation company operating extensive Hevea rubber properties in Sumatra called upon him to recommend an American source of foodstuffs for feeding rubber plantation laborers of the Dutch East Indies.

The importer, who has never represented himself as a food expert, knew that the Far East rice supply had been gravely disrupted by Japan's prolonged rape of China and by poor growing seasons current in various Pacific lands during 1940 and 1941. He knew, too, that the fishing industries of the Far East had suffered seriously from the war. Accordingly, he went marketing in New York and Chicago. After long searching and elaborate examination of commodity prices, he decided that canned dog food is the most nourishing cheap food which can be economically exported from the United States to the East Indies. So he bought several hundred cases of prepared canned dog food, shipped it via San Francisco to Java, and awaited the inevitable "work report." On receipt of this delectable dietary staple, the Dutch rubber planting company favored the rubber importer with the curt report that the dog food was entirely too good for the coolie labor of Java and Sumatra rubber estates! The report reiterated the common knowledge that many commercial brands of canned dog foods are well fortified from a nutritional standpoint: their vitamin contents are adequate and the mineral and calorie-producing ingredients are well balanced. The wholesale price of the dog food, f.o.b. Chicago as of October 1, 1941, averaged no more than five cents a pound. But the extremely wealthy Dutch rubber growers complained that this price, even if considered as f.o.b. Batavia, was "exorbitant"; that abrupt transition from staple or traditional coolie fare of the Dutch East Indies to good medium American dog foods must of necessity be considered both radical and extravagant; and that its issuance would put "grand notions" into the minds of indispensable laborers, and beget "extravagant desires." It was therefore concluded to be inadvisable and unsuited to the requirements of their principal rubber estates.

Less than eight months later Secretary of State Cordell Hull delivered a radio address from Washington which I consider one of the most enlightened pronouncements in American history. Here is a brief quotation from that address:

". . . This latest assault on human freedom is, in a profound sense, a searching test for nations and for individuals. . . .

"We have always believed—and we believe today—that all peoples, without distinction of race, color or religion, who are prepared for and willing to accept the responsibilities of liberty, are entitled to its enjoyment. We have always sought—and we seek today—to encourage and aid all who aspire to freedom to establish their right to it by preparing themselves to assume its obligations.

"It is plain that some international agency must be created which can—by force, if necessary—keep the peace among nations in the future. Then with peace among nations reasonably assured, with political stability established, with economic shackles removed, a vast fund of resources will be released in each nation to meet the needs of progress, to make possible for all of its citizens an advancement toward higher living standards, to invigorate the constructive forces of initiative and to enterprise.

"No nation will find this easy. Neither victory nor any form of postwar settlement will create a millennium. Rather, we shall be offered an opportunity."

The seven and three-quarters months which separated receipt of the antidog food verdict and this utterance of the great Tennessean

Secretary of State are among the most memorable in history. During this brief time World War II achieved global dimensions. Japan attacked Pearl Harbor, causing within eighty minutes the largest single Army casualty list in the military history of our nation and more Navy casualties than had been suffered in all the previous 167 years of United States history. The principal Axis powers had declared war against the United States and ten other American nations. The invasion forces of Japan had swept rapidly and efficiently to easy conquest of all the principal rubber-producing lands of the Far East. British arms forfeited Malaya; even more abjectly, the land and naval forces of the Dutch East Indies, despite the gallantry of the latter, collapsed in the face of Japanese assault. The small, graceful brown men of Indo-Polynesia, for whom dog food had been adjudged too good a fare, found protection by the Netherlands military to be a mirage of luxury. After careful study of a Niagara of news reports, I believe that the real battle for the East Indies was lost less because of the efficiency of Japanese arms and tactics than because of the state of mind revealed by such tenets as suggested by the verdict of a plantation company which was "morally convinced" that dog food is too good a fare for plantation workers.

It is not intended to denounce bitterly Holland's century-old exploitation of the prolific East Indies. It is common knowledge the Netherlands "union" with the East Indies was in several respects more honorable and just than Britain's with Malaya, Borneo, Ceylon, and neighboring rubber lands; also that official Dutch colonial policy was no less just than the imperialistic efforts of at least two principal United States rubber companies which have long operated properties in Sumatra, and immeasurably better than Belgium's rubber-greedy crucifixion of the African Congo. It was a better imperialism than Germany had ever attained in Africa. In general, it was morally superior to any major imperialistic venture of France. There were good points about the Netherlands exploitation of Sumatran and Javan rubber—but not enough of them.

The story of rubber has been, and is, sociological as well as industrial and scientific. Rubber is a basic world commodity whose production, manufacture, and distribution require a measure of social justice which has never yet been achieved by any principal nation. It is also a key crop of many equatorial lands, a resource which by its very nature and horticulture acts as a foundation for other resources. Quite conceivably the continuing enslavement of rubber lands could of itself be sufficient to invalidate a victory by the United Nations. After that victory is won at inevitably high costs in life, property and other resources, rubber production might again be the means of shaping the ruinous march of retrogression of mankind; once more might become the effective tool of shrewd, selfish men, nations and political cliques who, in shortsighted greed, could wreck and nullify the forthcoming peace.

To avoid further abstractions I here list some relevant statistics of the Dutch East Indies, as presented by Arthur S. Keller, a distinguished economist of the Pacific East who is author of that pertinent statement, "It is the Indies which makes Holland a world power."

The population of the Dutch East Indies in 1941 was about 70,000,000; some 240,000, or about ⅓ of 1 per cent of this population, were of European blood (principally Dutch) and about 2 per cent (roughly 1,400,000) were Chinese. Yet in terms of annual net income (as of 1937) the ⅓ of 1 per cent Dutch and other Europeans were officially assessed for 286,770,646 guilders in income; the 2 per cent of Chinese were assessed 97,564,162 guilders; and the more than 97 per cent natives were assessed for only 36,544,990 guilders—which means an average annual income countable in pennies.

Dr. Rupert Emerson of Harvard comments: "The broad conclusions which follow from examination of these income tax figures are borne out by such other random pieces of evidence as that, at the beginning of 1941, the relatively tiny European community possessed nearly 60 per cent of all the private automobiles in Java and Madura while the natives, who form over 97 per cent of the population, owned less than 15 per cent. Similarly the Europeans were in possession of nearly 50 per cent of all the radio sets in the island." [1]

Mr. Keller's summary of estimated annual Dutch returns from the East Indies for 1940 is as follows:

Source	*Probable Dutch Share (Per Cent)*	*Dutch Returns in Florins (about 49 Cents U.S.) Including Interest Dividends, and Undivided Profits*
"Direct Gains"		
Sugar investment	95	24,000,000
Rubber and other agriculture	60	48,000,000
Agricultural loan banks	100	16,440,000
Tin	90	540,000
Oil	40	30,000,000
Shipping	100	6,000,000
Railroads	95	9,000,000
Private industry	50	1,500,000
Miscellaneous, including insurance	100	15,000,000
		150,480,000
Profit on exports		6,000,000
Profit on sale of arms, supplies and equipment to Netherlands Indian Government		1,800,000
Interest payment by Netherlands Indian Government to Government of Netherlands		7,000,000
Interest payment by Netherlands Indies to Dutch private citizens		28,000,000
		42,800,000
"Indirect Gains"		
Salaries of White Dutch in Netherlands India pension		50,000,000
Pensions		40,000,000
Wages paid in Holland on Dutch exports to Netherlands Indies and re-exports from Netherlands Indies to other countries		30,000,000
		120,000,000
Total take and leechage per annum		313,280,000

("Netherlands India as a Paying Proposition," *Far Eastern Survey,* Arthur S. Keller, January 17, 1940; see also, *The Netherlands Indies and the United States,* World Peace Foundation, Boston, 1942.)

This table has much to do with the world story of rubber and the inevitable sociological obligations involved in rubber production. It shows the extent of the Dutch control of the magnificent Dutch East Indies which on December 7, 1941, were producing about one-half the world's total supply of rubber. Incidentally it casts all too clear a light on why canned dog food was considered too Lucullan a fare for the Javanese and Sumatran rubber workers.

In writing this book I have deliberately avoided the more or less classic horror stories of rubber. I have not recited the scalp-creasing atrocities attributed to the henchmen of Leopold II of Belgium in the rubber-bearing Congo, or by British and German agents in earlier and even more gory procurement of African rubber; nor have I mentioned the deplorably vicious drug monopolies or concessions which have been carried on with British or Dutch official sanction in some of the rubber production areas of the Pacific tropics. It is now common knowledge that Japanese invaders of Eastern rubber-growing strongholds are openly exploiting the ready-made villainies of Anglo-European traffic in drugs and narcotics, and that the black night of the Eastern rubber lands seems destined to turn even blacker. It is likely indeed that Japan may succeed in fleecing the rich East Indies more completely than Holland did.

The story of rubber has been a story of greed and glory—principally the former. As the largest consumers of rubber, the people of the United States negligently and unintentionally permitted the continuation of its bitterness. Since about 1820, when the first occasional and unregistered dribbles of crude rubber, loaded as ship's ballast, began to reach North American ports from Brazilian and Caribbean outposts, until December 7, 1941, when the United States, the consumer of more than three-fourths of all crude rubber then in export, was ruthlessly attacked and plunged into the greatest of all wars, the United States government had devoted no consistent study or plan of action to essential rubber sources.

Carelessly and docilely we permitted two great international rubber cartels to incubate and spread: the effect of the first of these (the Stevenson Plan) was to "shake down" the American consumer of rubber; that of the second (the International Rubber Regulation Agreement) which allowed participation of a few United States rubber buyers, was to withhold principal world rubber production from the Western Hemisphere and keep it in monopolistic hands. With equal carelessness and docility we have allowed four great rubber companies to dominate the strength of United States buying power in the world rubber market. For almost a third of a century rubber has been our greatest deficit commodity and during many of these years our largest imported raw material. Skillfully and in many respects admirably the United States rubber industry has gained world leadership in the manufacture and sale of rubber goods. But that impressive position has been built upon the quicksands of untrustworthy supply. It has never been correlated with a competent merchant shipping program. For more than a decade it has remained oblivious of the accredited reports of perils to rubber supply which have long been current and increasing in the Pacific East—perils conspicuously defined by the war policies and open pronouncements of Japan and Japanese foreign trade. For many years these perils were common knowledge to the rubber industry of the United States and repeatedly the situation was officially and accurately reported to the government.

It has already been pointed out that Latin America is the home of the principal rubber-bearing tree. Before the presidency of Franklin D. Roosevelt the tacitly established policy of the government had been to retard the economic development of Latin America—or at least not to advance it—for the convenience of petty commercial minorities of the United States. Happily, this has been radically changed in recent years; I believe that neither the economic nor the ethical tenets of the Good Neighbor policy are open to challenge. As regards rubber and certain other indispensable commodities, such as coffee and vegetable oils, the functional application of the Good Neighbor policy has been unfortunately delayed. The blame cannot be fairly attached to any individual in our present government. Of depression-born necessity, the Roosevelt

Administration has been an enormously busy one. Its agencies and efforts have been hugely dispersed. It is a matter of record, however, that through the State Department the administration has repeatedly recognized and stated the urgent need for more liberal and just regulation by the Dutch of the East Indies and their invaluable storehouses of rubber, tin, and other great resources upon which industrial America has so long depended. In Latin-American affairs it has unquestionably displayed the most commendable and constructive official attitude ever accorded Pan-America by any federal administration, in inspiring contrast to the thumb-twirling indecision and the legalistic commercial piracies countenanced and even encouraged by the Hoover and the Coolidge-Harding administrations, and by a long and dismal parade of their political predecessors.

Despite noble intentions and much good work, the Roosevelt Administration has not given adequate consideration to the imperative need for rubber supply from natural and synthetic sources. It did not entirely evade the challenge. For example, even before the outbreak of this global war, Congress had made an appropriation of $500,000 for the investigation and encouragement of rubber crops within this hemisphere. To anyone acquainted with the practical operation of a tropical agriculture this sum is absurdly small. British and Dutch investment companies had spent billions of dollars in building up the rubber plantations of the Pacific tropics. One American tropical farm organization, the United Fruit Company, has repeatedly appropriated from $8,000,000 to $20,000,000 per year—not to introduce a new tropical crop, but merely to expand production of a crop or crops already under way. In the orderly establishment of comparatively minor tropical crops, such as bananas, sugar cane, and cacao, the United Fruit Company has invested at least six hundred times as much money as our Congress provided for the location and survey of plantation rubber, which has long been the largest single entry in the profit column of tropical imports. In the process of administering this tiny appropriation, the Department of Agriculture assigned to a handful of employees of the Bureau of Plant Industry the gigantic task specified by the Congressional enactment.

I was at work in Central and South America when the Department of Agriculture's Hevea rubber horticulturists arrived. In Costa Rica and Honduras I had the pleasure of working with members of the group. I noted that the United Fruit Company gave them free use of soil surveys and of various lands, experimental planting sites, and other physical properties; also that several of the Latin-American governments co-operated cordially and well. The Goodyear Rubber Plantations Company, which in 1935 had started the first Western Hemisphere Hevea rubber nursery at Gatun, Panama, and in 1936 had established near Cairo, Costa Rica, a Hevea plantation on lands, in buildings, and with original rubber plantings contributed gratis by the United Fruit Company, also aided the Department of Agriculture men in every possible way.

While struggling gamely with red tape, they managed to establish at least ten good rubber experiment stations in as many key areas of the American tropics; observed the practical work of the Goodyear Company, the United Fruit Company, and other experienced tropical planters; and reported the possibilities for profitable production of Hevea rubber in the Latin-American countries between Mexico and Bolivia. I respect the findings and the accomplishments of this group, especially their recommendation that a dependable Western Hemisphere rubber supply will best be established when and if most of it is grown independently by citizen farmers of Latin America. But the fact remains that $500,000 is barely enough money to establish one medium-sized, or 1,000-acre, banana plantation; and in view of the goals for which it was appropriated, this amount was a rather sickly joke.

Thus far, virtually every planting of Hevea rubber which grows in this hemisphere must be listed as experimental. To date, the inter-American total of such plantings is probably about 25,000 acres, or perhaps one-fortieth of the acreage necessary to supply natural rubber from American sources to meet an estimated 60 per cent of present and future rubber needs of the United States. The penny-whistle dimensions of American investments in rubber plantings, like those of the actual and current procurement of synthetic rubber, are hard indeed to excuse.

In any case, in terms of natural rubber, corporations, individuals, or employees of the United States are certainly not pocketing a lion's share of the wealth produced by the soil of the American tropics. We have not schemingly made peons of most or all of our tropical neighbors, nor deprived them of free men's rights to own and to use their lands. We are not obliged to use our increasing needs for rubber and other tropical products as implements with which to impoverish native millions of these peoples. We are not yet obliged to use armed violence or power politics to regain lost tropical empires against the will and the welefare of their inhabitants.

On the whole, the current efforts and experiments by United States business to establish efficient Hevea plantations within the American tropics are honorable. From their beginning (with the Fordlandia experiment opened in 1928) these efforts have shown what, for want of a better phrase, we may call "superior intentions." Henry Ford has paid and is paying his Brazilian labor well —a daily wage average of about twenty times that paid in Sumatra. He has built good hospitals. He has appropriated work and money to establish health standards which, according to the late League of Nations medical statistics, are unrivaled both now and in the past by any rubber-producing area of the Pacific tropics.

Neither Ford's nor any other United States venture in rubber-growing enterprise has yet advocated the use of dog food as a suitable fare for the native workers. Impartial appraisal of a tropical plantation is rarely easy; but I believe that no contemporary rubber plantation is more significant scientifically and socially than Henry Ford's Belterra on the Tapajós in Brazil. Speaking from firsthand acquaintance, I also believe that the Goodyear rubber plantations in Central America are praiseworthy. Their actual and current production of rubber is not yet impressive; but they are already helping to supply the seedstock and techniques for a new American horticulture of rubber. The principal Goodyear Hevea plantation (of about 2,500 acres) in the Caribbean lowlands of Costa Rica continues to feature advanced techniques in bud-grafting high-yield rubber and studied endeavors to produce low-cost rubber regularly. The advantages of these efforts are self-evident.

But perhaps the most promising of all American efforts to re-establish Hevea as a staple crop of this hemisphere is the unprecedented move of the United Fruit Company, which during July, 1942, launched what it terms a "new agricultural charter" for Middle America. This program proposes to sponsor the practical planting of Hevea rubber, *abacá,* or Manila hemp, essential oils (such as citronella and lemongrass), the valuable rotenone insecticides (which include Derris and other so-called fish-poison plants native to the American tropics), cork, teakwood, and other great tropical crops now largely lost to us by Japan's seizure of the Eastern tropics. At present the United Fruit Company is establishing in Honduras a 1,000-acre nursery of Hevea rubber trees. This acreage is approximately one hundred times the size of the original British planting of Amazon Hevea in Ceylon, Hongkong and Singapore—plantings which ultimately supplied almost all the seeding stock for some nine and a quarter million acres of British and Dutch colonial rubber now held by the Japanese.

The United Fruit Company's rubber nursery now materializing in Honduras is being planted with the seed or budded with the plant material taken from exceptionally high-producing and rugged Hevea clones. If skillfully managed, within a decade it should supply the planting stock for tens of thousands, even hundreds of thousands, of acres of high-yielding Hevea for the American tropics, which would eventually be capable of yielding from 1,200 to 1,800 pounds of crude rubber per acre annually. For the planting stock is as good as any in the world today, and the soils and climates of much of Middle America are more favorable to Hevea than those of most of the Eastern tropics.

In Panama and Costa Rica the United Fruit Company has already planted about 20,000 acres of abacá, a bananalike tropical crop which yields Manila hemp, the standard fiber for making ship's rope. This is the first ever to be grown in this hemisphere.

Before the Pearl Harbor tragedy this fiber was imported principally from the Philippines and Java. Urgent war needs for the harvest from at least 125,000 more acres of the crop must now be met.

It is the studied plan and specific promise of the United Fruit Company that as soon as these crops have been established in the American tropics, their further cultivation and propagation, and in some instances extensive acreages of suitable lands, will be given outright and without cost to independent citizen farmers of Middle America.

Some years in tropical agriculture have convinced me that the best way to introduce any crop is to attend skillfully to its initial propagation; and then plant it openly so that citizen farmers can see the new resource in growth and preferably at profitable harvest. The profit instinct of our southern neighbors, as regards Hevea rubber or any other promising tropical crop, is strong. The value of word-of-mouth advertising and testimony of personal experience is equally great.

Any student of agriculture knows that great crops are rarely introduced singly or independently of other crops. In most parts of the world agrarian history has proved that countries take over crops and crops take over countries by process of infiltration and co-ordination. In general this has been the history of all agriculture, but it is especially true of tropical agriculture. Hevea rubber is an instance. When rubber trees were first brought to the East Indies, Malaya, and other parts of the Far East, they were planted experimentally as supplementary, or incidental, crops. Such classic harvests of tropical countries as coffee and cacao trees frequently require shade for protection against sun and storms. In frequent instances the sturdy and fast-growing Hevea tree was first used in the Pacific tropics as a "shade crop" for coffee, indigo, spices, and other comparatively fragile crops. When the shade crop became the most profitable, the rubber planting rush began. It is well to remember that in the equatorial lands of the Far East the economy of rubber trees was first co-ordinated with that of other crops. It is thus a comparatively safe prophecy that a similar co-ordination will be worked out for Hevea rubber which can, and unquestionably will, be grown as a crop in the Western Hemisphere.

Other characteristics of the Hevea tree are noteworthy. One of many needed commodities which can be grown effectively in the American tropics, it is among the few tropical crops which are well adapted to peasant agriculture or to small, independent farms. This fact is proved in the important minority of free holdings or peasant patches of Sumatra, where it also has been demonstrated that details of Hevea propagation, such as cross-pollination and bud-grafting to produce high-yield and disease-resistant strains, can be administered in or from central nurseries, which in turn can be operated and supervised as public services or as growers' co-operatives.

As already noted, when once in bearing, Hevea is an exceptionally simple crop to grow and requires an absolute minimum of equipment. In most cases an ordinary farm family can attend it and prepare the harvest for cash sale. Hevea is also well suited to diversified farming programs. The groves can be used as pasture lands for cattle or other livestock. They can be supplemented with various small-acreage family crops which reduce or eliminate the overhead during the necessary waiting time. At the present time particularly, the growing of Hevea can readily be co-ordinated with that of other tropical stand-bys and newcomers, such as hemp, cordage, coffee, essential oils, castor, and rotenone plants, and various other tropical crops which are permanently required by the United States and elsewhere in the Western Hemisphere.

In the tropics and out, the perils of one-crop agriculture have been frequently proved: well-planned broadsides of crops and cultivation schemes are infinitely safer than any one-crop concentration, however dependable. This generalization has an enormously important bearing on the future production of rubber in the Western Hemisphere. Unlike bananas and coffee, which are now practicable only as large plantation crops, rubber can be grown as a small-farm stand-by, both because it is outstandingly hardy and because it flourishes on land no longer capable of producing bananas—the traditional "gold" of the equatorial belt. Of course, like most other crops, the Hevea tree has natural enemies. In this hemisphere the most serious of these is the South American leaf blight, a wind-blown round-spore fungus which implants itself upon the leaf surfaces. But this can be controlled by spraying, and better still by the scientific development of disease-resistant strains by means of selective breeding. At worst the natural enemies of rubber trees are less formidable and more controllable than those of banana, coconut, or any one of a dozen other tropical plants.

As a student of Pan-American agriculture, I am convinced that the future of that sturdy aborigine of the American tropics, the Hevea rubber tree, is particularly bright, especially on tropical farms. I consider the current efforts to develop Hevea nurseries and superior planting stock, in conjunction with energetic experiments in co-ordinating rubber cultivation with that of other important crops, to be outstandingly good and hopeful news. There is no real doubt that rubber trees can be cultivated cheaply and well in the American tropics. I believe they will be. I believe, too, that the forthcoming Western Hemisphere rubber lands can be and will be lands of free men and private ownership; that the growing of rubber can and will merge into a new and better order of hemisphere agriculture and trade—an order free of the anarchies of international cartels and other devices begotten from the exorbitant profit of a self-chosen and usually absent few at the price of the economic and political subjugation of multitudes of tropical peoples.

After several years of firsthand work and observation of agriculture in Central and South America, I am equally confident that, with local and minor exceptions, there is plenty of labor available with which to produce commanding volumes of rubber or any other tropical crops which the American tropics may elect to produce. I have utmost respect for the competence and adaptability of farmers and farm workers of this region who, when healthy and contented, rank high among the farm workers of the world today.

A former Texas cowboy who is now overseer of a banana plantation in the Chiriquí area of Panama was speaking of the plantation companies of Malaya and the Dutch East Indies and their recent Nipponese successors. He said, "We can beat those sons of bitches at their own game. We can whup 'em easier by improvin' the game. . . ."

The agriculture of bananas has proved that claim. The banana is an Old World crop, probably indigenous to the hot, wet valleys of India. By way of the Arabs, Chinese, Indians, and other traders in roots, the banana crop has gained widespread importance throughout the Pacific tropics, in Africa, and various tropical islands many centuries before missionary priests first carried it to the West Indies and Central America. Before 1890 the banana industry of this area was of no great importance; but since 1910 it has consistently dominated the world export markets for bananas. Since 1920, average commercial banana yields per acre in the American tropics have climbed from around 150 bunches per acre to 300 or even 400 bunches. Net tonnages per acre have increased at least threefold, and the quality of the fruit is much improved. One after another French, German, British, and Italian banana companies have collapsed before American competition. In peacetime, Russia, Germany, most of Europe and the British Isles, like most of the United States, depend on the American tropics for their banana supplies.

Yet Central American banana growers have no magic wands. As a rule they do not exploit coolie labor. Statistics reveal that average banana farm wages paid in Central America during the 1930's were about 20 per cent higher than average farm wages paid in the United States during the same decade. Largely during the past five years the banana has become the most highly merchandised of major crops. This has further raised banana wages and changed tens of thousands of reputedly "simple" machete swingers to expert operators of sprays, tractors, and other agricultural equipment. Our southern neighbors have effected these transitions with almost incredible ease.

A banana sprayman earns in a day what a Malayan rubber tapper earns in a month. Generally the former is at least proportionately healthier and more valuable. His social and professional merits will continue to increase with his wages. He is a living proof that coolie wages are the worst of all agrarian bargains, and that good wages can and should be the best bargains. He contradicts all the smug eyewash about the decisive need of cheap tropical labor; he is an easy-motioned denial of some of the most treasured credos of world capitals and Foreign Policy Associations. He is a highly significant American of today and tomorrow. His ancient combination of rich earth, plentiful rainfall, ardent sun, and capable work can win as easily or more easily with rubber than it has won with bananas. Our need for rubber is the greater, and its urgency can yet change great frontiers of jungle into richly producing fields. Time is needed—ten years at least. Health administration is needed. (At long last the United States government is appropriating money to wage the crucial battle for health in the American tropics.) Justice and tolerance on the part of the educators, journalists, and other molders of opinion in the United States also are necessary; and they are now forthcoming. Within fifteen years, at most, the American tropics can produce a great part—perhaps 40 to 60 per cent—of all the rubber that we need, along with many other necessary tropical commodities; and there is excellent prospect that they will.

The ever-social story of rubber and its uses has now reached what seems to be a record high of utter confusion. While groping for an entirely unprecedented production of synthetic rubber (hopefully set at between 700,000 and 1,000,000 tons a year) the United States continues to support most of our war effort and to fill the crucial needs of our allies from stockpiles or from salvage of scrap rubber. Long a victim of politics, the issue of rubber supply is as deep in politics as ever. Science, war, and economy be damned, many congressmen have demanded the production of rubber from those sources of most benefit to their constituencies. Petroleum men proclaim the merits of petroleum-derived rubber. Distillers shout the advantages of alcohol rubber. Farm blocs orate on rubber from domestic crops, which are or may be in surplus. Twenty-five large industrial concerns, including the Atlantic Refining Company, Cities Service Oil Company, Gulf Oil Company, Humble Oil Refining Company, Phillips Petroleum Company, Pure Oil Company, Richfield Oil Corporation, Shell Union Oil Corporation, Sinclair Refining Company, Socony-Vacuum Oil Company, the Standard Oil Companies of Indiana, New Jersey, and Louisiana, the Texas Company; the big four rubber companies, Goodyear, Goodrich, Firestone, and United States; Carbide and Carbon Chemical Company, Dow Chemical Company, E. I. du Pont de Nemours and Company, Hycar Chemical Company, Koppers Company, and Monsanto Chemical Company—have thus far been the recipients of most of the public money handed over by the United States Treasury via Jesse Jones to subsidize synthetic rubber production in the United States.

Reporting in the New York *Times* of July 24, 1942, John MacCormac summarized well: "Thus far none of the individuals and agencies which have had a hand in the rubber situation has been able to establish facts to the satisfaction of the public. The rubber trade has challenged the position of the government, and government agencies which have been concerned with the situation have contradicted one another, often in the same day. . . ."

Eight months after the United States entered the global war, and four months after Japan's seizure of the last important Pacific rubber stronghold, millions of American citizens continue to ask whether there really is a serious rubber shortage (a query answerable only by "Yes"). Our people continue to ask how much rubber there may be for civilian consumption and when it will be available. (Thus far that question has no better answer than "Almost certainly there will be no substantial amount of rubber for civilian use before 1945.")

Many other widespread and legitimate questions about rubber wait unanswered. We are not fully decided as to whether synthetic rubber can best be made from alcohol or from petroleum. The amount of scrap rubber still obtainable in the United States waits a reliable estimate. Thus far the actual collection and delivery of scrap rubber has been disappointing. The conviction that country-wide gasoline rationing is necessary to conserve the existing stock of civilian tires continues to gain momentum—practically if not politically. For the sake of tire saving, and for the first time in our history, automobile use must somehow be controlled.

Meanwhile our need of rubber and the importance of rubber in war continue to increase. But exact determination of war needs for rubber is at this time impossible. It obviously depends upon the course and length of the war. At minimum it seems likely that the armed services of the United Nations will require at least 1,000,000 tons of rubber per year for the duration of the war. Within a year, the United States is almost sure to encounter a deficit even for supplying the needs of its own fighting forces; and it certainly has not enough rubber to meet a fraction of the needs of its world-scattered and rubberless allies.

Not all the United States supply of crude rubber, unofficially estimated as 750,000 tons as of August 1, 1942, is being devoted to military needs. The 1942 collection of scrap rubber, which after sorting and initial refining probably will not exceed 300,000 tons, is being divided between war needs, essential war industry, and (tentatively) retreading tires used by civilians who are entitled to tires under the rationing plan of the Office of Price Administration.

It is certain that 1943 will see the crucial stage of our already acute rubber shortage. Importations of wild rubber from Latin America are being estimated at from 75,000 to 125,000 tons for the coming year. Such estimates are still speculation. It is certain that synthetic rubber will be the decisive factor of the fast-crowding rubber crisis—however confused and slow its production may prove to be.

At all events life-or-death needs and relentless shortage are writing new and increasingly dramatic chapters in the unendable book of rubber. The status of rubber as an essential material and its place as a human denominator grows to ever greater importance. On the elastic magic of the Amazons and the American tropics depends much of our future and that of all the Western World. Rubber and rubber production are already marked as essential factors of the postwar world. Speaking both literally and figuratively, future ties between nations and peoples will almost certainly be bands of rubber—both natural and synthetic.

NOTES

CHAPTER 3. CHARLES GOODYEAR

1. From *Gum Elastic,* the Autobiography of Charles Goodyear (2 vols.). New Haven, Conn. (Vol. I, 1853; Vol. II, 1855).
2. *Ibid.*

CHAPTER 7. SYNTHETIC RUBBERS, OR ELASTOMERS

1. *India Rubber World.*
2. New York *Times,* July 23, 1942.
3. *The Lamp,* Standard Oil Company of New Jersey, Vol. 23, No. 3, October, 1941, pp. 14-18.
4. *Ibid.,* October, 1941.

CHAPTER 8. OUR RUBBER-DEPENDENT WORLD

1. Published by *Rubber Age.*
2. New York *Times,* April 2, 1942.
3. American Automobile Association, Detroit.

CHAPTER 11. WAR AND RUBBER

1. *Goodyear News,* July 20, 1942.

CHAPTER 12. LOOKING FORWARD

1. *The Netherlands East Indies and the United States,* pp. 28-29. Boston: World Peace Foundation, 1942.

DIGEST OF
BARUCH COMMITTEE REPORT

Mr. President:

Herewith is presented a digest and full report of the committee you appointed on August 6th, with instructions that the survey "include not only facts with respect to existing supplies and estimates as to future needs, but also the question of the best method to be followed for obtaining an adequate supply of rubber for our military and essential civilian requirements. . . . to recommend such action as will best produce the synthetic rubber necessary for our total war effort, including essential civilian use, with the minimum interference with the production of other weapons of war."

We find the existing situation to be so dangerous that unless corrective measures are taken immediately this country will face both a military and a civilian collapse. The naked facts present a warning that dare not be ignored. We present herewith the significant figures:

CRUDE RUBBER POSITION OF THE UNITED STATES
(July 1, 1942, to January 1, 1944)

On hand July 1, 1942 (stockpile)	578,000 Tons
Estimated imports July 1, 1942, to January 1, 1944	53,000 Tons
Total crude rubber	631,000 Tons
Estimated military and other essential demands July 1, 1942, to January 1, 1944, with *no* allowance for tires for passenger automobiles	842,000 Tons
Deficit that must be met by production of synthetic rubber before January 1, 1944	211,000 Tons

Unless adequate new supplies (natural or artificial) can be obtained in time, the total military and export requirements alone will exhaust our crude stocks before the end of next summer.

Tires on civilian cars are wearing down at a rate eight times greater than they are being replaced. If this rate continues, by far the larger number of cars will be off the road next year and in 1944 there will be an all but complete collapse of the 27,000,000 passenger cars in America.

We are faced with certainties as to demands; with grave insecurity as to supply. Therefore, this committee conceives its first duty to be the maintenance of a rubber reserve that will keep our armed forces fighting and our essential civilian wheels turning. This can best be done by "bulling through" a gigantic synthetic program and by safeguarding jealously every ounce of rubber in the country.

At the same time we find that rubber for necessitous civilian use has been insufficiently allocated. More must be allowed for tire replacement and recapping. That is part of the conservation program we submit. More rubber use to those who need it; less to those who don't!

Let there be no doubt that only actual needs, not fancied wants, can, or should, be satisfied. To dissipate our stocks of rubber is to destroy one of our chief weapons of war. We have the choice!

Discomfort or defeat. There is no middle course.

Therefore, we recommend:

That no speed above 35 miles an hour be permitted for passenger cars and trucks. (In this way the life of tires will be prolonged by nearly 40 per cent.)

That the annual average mileage per car now estimated as 6,700 miles a year be held down to 5,000 miles, a reduction of 25 per cent. (This does not mean that each has a right to 5,000 miles; it applies to necessary driving.)

That more rubber than is now given to the public be released fully to maintain, by recapping or new tires, necessary civilian driving.

That a new rationing system of gasoline be devised, based on this 5,000 miles a year to save tires.

That the restrictions as to gasoline and mileage be national in their application.

That compulsory periodic tire inspection be instituted.

That a voluntary tire conservation program be put into effect until gasoline rationing can be established.

Gas rationing is the only way of saving rubber. Every way of avoiding this method was explored, but it was found to be inescapable. This must be kept in mind: the limitation in the use of gasoline is not due to shortage of that commodity—it is wholly a measure of rubber saving. That is why the restriction is to be nation-wide. Any localized measure would be unfair and futile.

This note of optimism is permissible: if the synthetic program herein outlined will fulfill reasonable expectancy, it may be possible to lessen this curtailment before the end of 1943. But until then, any relaxation is a service to the enemy.

In answering the questions of how much rubber do we have and where are we going to get more, the country is dependent, finally, upon the production of synthetic rubber which, it is hoped, will reach its full swing in 1944.

Why not earlier? Why so late? The answers to these queries lie in the past. These errors, growing out of procrastinations, indecisions, conflict of authority, clashes of personalities, lack of understanding, delays, and early non-use of known alcohol processes, are not to be recounted by us, nor shall we go into the failure to build a greater stockpile of crude rubber. We are concerned with the past record only in so far as it has seemed to us to cast light on problems of future administration.

To prevent a recurrence of these mistakes, this committee asks an immediate reorganization in present method and the creation of a Rubber Administrator. This official will have authority over the policies governing the priceless stock of rubber now on our automobiles, the drivers of which are trustees of our national safety. He will direct the course of the technical and industrial development—wholly new to America—of the synthetic rubber production.

If our hopes are realized, the production of Buna-S and neoprene (the two synthetic materials on which we now rely most to replace crude rubber) will total 425,000 tons by the end of 1943. But, on the other hand, the figure might easily fall to less than half that amount if delays occur—delays of as little as 120 days. "Bugs" may be found in plant construction or in the operation of any one of the three processes used in the manufacture of Buna-S. With 425,000 tons we should have a margin of safety, a slight one, to be sure, perhaps 100,000 tons above necessary inventories for ourselves and our allies —for the front. With only 200,000 tons of Buna-S produced, our supplies would be exhausted. The successful operation of our mechanized army would be jeopardized.

We cannot afford to take a chance. It is better to be safe than to be sorry. We dare not depend upon unbuilt plants; upon increasing the reclamation of scrap; upon bringing the tire-manufacturing capacity up to equal a theoretical synthetic production; upon other unproven factors.

The members of this committee have full faith in the ability of American industry to lick all these problems, but there is grave uncertainty as to time. Whatever our hopes, or even our reasonable estimates, until the synthetic rubber plants are operating at capacity, and beyond, we cannot take unnecessary risks. We cannot base military offensives on rubber we do not have. All our lives and freedoms are at stake in this war.

Until synthetic comes fully to hand, we recommend that sufficient reclaimed rubber, a small amount of crude, and an increased supply of Thiokol, or other substitutes, be made available for the tire replacement and recapping program, which we urge shall go into effect at once.

Perhaps this should be said: few believed that 90 per cent of our normal supply of crude rubber would be cut off when Pearl Harbor was attacked December 7th. And only a few evaluated the situation correctly after that date!

There are almost as many estimates of future supplies—the rubber we do not have—as there are persons and agencies concerned in this problem. It is important to bear in mind that these are only estimates—based upon great intangibles.

How much rubber we shall get from South America, for example, depends on the shifting of nearly half a million natives into the Amazon Valley—it would be one of the great population movements of history—and on how many of them succumb to sickness and disease. It depends, too, on how successful we are in combating the menace of Hitler's undersea raiders.

No one can estimate with certainty the amount of scrap rubber in the United States. About 400,000 tons of scrap rubber were collected in the drive inaugurated by the President last June. This gathered scrap will yield about 300,000 tons of reclaimed rubber. It is true that nowhere near all the scrap in the country has been collected. However, there already is on hand more than enough scrap to keep the entire reclaiming industry operating at capacity for many months. The committee is recommending measures to step up reclaiming operations to the fullest capacity and also a 20 per cent expansion of existing reclaiming facilities. Until that is done, the accumulation of huge scrap piles is an unnecessary fire and sabotage hazard which gives the committee much concern.

Roughly, a year will be required to increase reclaiming capacity appreciably. Too, reclaimed rubber is inferior to natural rubber, and its use as a substitute for crude is limited. So, again, we find that in the final analysis we are basically dependent upon synthetic rubber.

Failure of the responsible officials to request the aid of Russia in setting up our synthetic system is a neglect for which we have not had a satisfactory explanation. The Soviet Republics have been first or second in the production of synthetic rubber, and we are asking that their "know how" be obtained. The Soviet has expressed a willingness always to be co-operative. Russia has lost, through the German advance, between 50,000 and 60,000 tons of its rubber-making capacity.

Among other points to which the committee directs attention are:

Faulty flow of critical materials may block or delay plant construction.

No new synthetic processes are to be substituted for those approved.

That the present program must be expanded to 1,100,000 tons of all synthetics.

That the road rubber (rubber actually in tires now used on passenger cars and trucks) totals 1,000,000 tons.

In rubber, the United States must be listed as a have-not nation.

Once we are secure in our position, we shall be freed from a source of worry that affects the high military and other governmental figures. We shall gain that position through sacrifices. There is no royal road to victory.

Herewith, we submit the digest of our findings and recommendations and, as a separate document, the full report.

Respectfully submitted,

Giving Civilians More Rubber

All the many witnesses who appeared before the committee urged the need for conserving the rubber now on automobiles. There was disagreement only on methods. The committee, however, has been concerned not only with reducing the use of rubber but with seeing that enough rubber is provided to maintain a minimum of necessary civilian driving. The committee does not believe in the doctrine of sacrifice for sacrifice's sake nor that workers should be expected to live in tents and farmers trudge miles to market unless our situation is so desperate that there is no alternative.

Our analysis of supply on hand and expected shows that at best only enough rubber can be made available for civilian use to maintain average mileage of vehicles at 5,000 miles a year. At present the annual average is estimated to be about 6,700 miles which would mean that a further reduction of roughly 25 per cent in mileage is necessary. The 6,700 mile figure, in itself, is a reduction from the prewar national average of about 9,000 miles a year. In good measure this voluntary conservation on the part of motorists is a reflection of the fear that when present tires are worn down no new tires will be available. Should this apprehension be relieved by an enlarged tire replacement program, without any other restriction, the committee fears that voluntary conservation would largely disappear and the average mileage would shoot up. It would then take 250,000 tons of crude rubber a year to supply all cars with all the rubber they need. If additional rubber is to be made available to civilians, there must be a sure control over rubber mileage. After analyzing every possible method, the committee finds the quickest, surest, and most convenient check is through the nation-wide rationing of the use of gasoline.

Therefore, *the committee recommends this five point program of rubber rationing:*

1. A reduction of the average mileage to a total not to exceed 5,000 miles per year by nation-wide rationing of gasoline.
2. Enlargement of the present tire-replacement program to provide sufficient recaps and new tires for the maintenance of this minimum of essential driving and to prolong to the utmost the useful life of tires now on the road.

3. Prompt and strict enforcement of a nation-wide speed limit not exceeding a maximum of 35 miles per hour for all passenger cars and trucks. Voluntary reduction to 30 miles will give substantially further mileage.
4. Compulsory periodic tire inspection.
5. An interim program of voluntary tire conservation until the rationing and inspection programs can be put into operation.

Rationing Must be Nation-wide

It must be kept in mind that we are not restricting the use of gasoline as such; we are rationing gasoline as the only effective measure to hold down tire use. To make the restriction other than nation-wide would be unfair and futile.

As part of this program, *the committee recommends that sufficient reclaimed rubber, a small amount of crude, and an increased supply of Thiokol or other substitutes be made available immediately for making new tires and retreads for civilian use.* Thiokol is a rubberlike material which can be used to make retreads with an average life of about 5,000 miles. At present the production of 24,000 tons a year is planned. The committee recommends the expansion to 60,000 tons a year. With prompt action, this capacity can be provided by early 1943, and more than 50,000 tons produced next year. Thiokol retreads are serviceable only when driven at speeds under 40 miles an hour, which makes a rigid speed limit all the more imperative.

Conservation Essential

It must be clear that this program is not intended to give every citizen the right to drive 5,000 miles. This figure is an average which obviously means that the mileage allowed less essential drivers must be cut considerably below that amount to permit greater mileage for more essential drivers. The proper distribution of mileage to various drivers is a matter to be worked out by the responsible governmental agencies.

It should also be stated that, in the committee's judgment, even this indicated curtailment of driving will be insufficient to meet the situation unless there is an intensification of such conservation measures as car pooling and sharing of rides, and the purchase by the government of extra tires and spares from persons who do not need them for resale to war workers, farmers, and others who do need them.

Protecting Necessary Driving

The committee has given careful consideration to the objections against the use of nation-wide gasoline rationing to conserve rubber. It realizes that real hardships will be caused many persons, and that some industries, communities, and business pursuits will be particularly hard hit. However, the disadvantages are outweighed by the necessities for a sure, effective method for seeing that essential driving is maintained.

We Are a Have-Not Nation

Each time a motorist turns a wheel in unnecessary driving, he *must realize that it is a turn of the wheel against our soldiers and* in favor of Hitler.

The rubber rationing program proposed here should be considered as providing only a minimum of conservation and not as eliminating the need or value of the voluntary conservation measures now being practiced by many motorists.

The committee is confident that the American people, once acquainted with the uncertainties of our rubber supply, will gladly accept whatever conservation measures are necessary. If our supply situation is eased—and the expansion of the synthetic program that the committee is recommending holds out that hope—these conservation measures can later be relaxed somewhat. But until the soundness of the synthetic program has been fully demonstrated, and sufficient capacity is in actual production to meet all our military requirements, it is not safe to borrow, from the rubber we have, for any but the most essential of civilian needs.

When it comes to rubber, we are a have-not nation. If we are to err, it must be on the side of sterner curtailment and conservation to anticipate the worst dangers that the war may bring.

Program Unduly Delayed

While the committee has not sought to recount the mistakes of the past, it is concerned with the question of whether the present administrative organization is such as to insure the effective carrying through of the program. It is not.

The committee finds a number of different government agencies with overlapping and confusing authority over the synthetic rubber program. The conflict between the Rubber Reserve Company, a subsidiary of the Reconstruction Finance Corporation, and the Office of Petroleum Co-ordinator has delayed and complicated the bringing in of new facilities for the production of butadiene from oil. To make Buna-S rubber, the synthetic around which the government's program has been built primarily, three separate kinds of plants must be erected, for producing styrene, for producing butadiene, and for combining the two—"polymerization" is the technical term. At present the butadiene part of the program is lagging behind the styrene and polymerization capacity. Thus, any delay in getting the greatest possible butadiene production directly reduces the amount of synthetic rubber that will be produced.

The production of synthetic rubber represents an investment exceeding $600,000,000 and is one of the most complicated technical projects ever undertaken in this country. Yet, in none of the government agencies has there been a clearly recognized group of independent experts to make the technical decisions. Reliance has been placed on one part-time technical adviser, aided by committees drawn from industry. This technical adviser has testified that on more than one occasion he requested the appointment of an adequate technical staff, in vain. The committee has found many evidences of procedures bordering on the chaotic in which nontechnical men have made decisions without consulting with subordinates nominally in the positions of responsibility.

There have been many adjustments and readjustments in the synthetic rubber program. Some of these were inevitable. Some appear to be the result of bad administration.

Russian Help Not Asked

One example of inexplicable administration that we can mention is the failure to obtain detailed technical information concerning the experience of Soviet Russia in making synthetic rubber. Russia has been manufacturing synthetic rubber successfully for more than ten years. Had the offer of the Soviet government made in

February to exchange full information been accepted, it is conceivable that plants for producing synthetic rubber by the Russian processes might well be on the way to completion. To date we have no detailed information as to the Russian experience, nor analyses of Russian tires. We feel this information should still be obtained.

Restrictive Secrecy

One of the more critical technical battles that must be won is in the compounding of synthetic rubber. Synthetic rubber requires more time and effort to fabricate into tires—about one-third less in efficiency is reported. While tires for light passenger cars can be made entirely out of Buna-S rubber, thus far in the manufacture of combat and heavy duty tires, which represent about 70 per cent of the Army's requirements, a good percentage of crude natural rubber must still be used. As long as crude rubber must be mixed with Buna-S, we do not dare cut too deeply into our stocks of crude rubber—a minimum carry-over into 1944 of 100,000 tons is vital.

However, the dissemination of technical information on the compounding of Buna-S to all rubber companies has become an accomplished fact only in the last few days. On July 3rd of this year an agreement was entered into between the Rubber Reserve Company and four large rubber companies, by which Rubber Reserve alone was permitted to give out information on compounding to other companies. It took six weeks of repeated effort for the Rubber Branch of the War Production Board, desiring to launch a program of education throughout the industry, to get this vital information released by the Rubber Reserve.

New Administration

We recommend a complete reorganization and consolidation of the governmental agencies concerned with the rubber program. These changes should include:

(a) A directive by the President ordering the Rubber Reserve Company and all other government agencies to act in all matters relative to the rubber program as directed by the chairman of the War Production Board.

(b) The appointment by the chairman of the War Production

Board of a Rubber Administrator, delegating to him full and complete authority in all matters related to rubber, including research, development, construction, and operation of plants. The chairman of the WPB should divest himself of all direct concern with these matters.

(c) Establishment of an adequate technical staff, properly staffed under the immediate supervision of the Rubber Administrator, funds to be provided for these purposes.

Centralize Oil Operations

That the Petroleum Co-ordinator be directed by Presidential Order to act on specific directives from the Rubber Administrator to explore all methods for the production of butadiene from petroleum and natural gas products and to recommend new proposals to the Rubber Administrator for consideration and action. However, to make certain there are no construction delays because of conflicting authority, the construction of all plants and equipment concerned with the production and purification of butadiene from oil shall be under the direction of the Rubber Administrator. The Petroleum Co-ordinator shall supervise the operation of these plants, after construction, but he shall not change the presently authorized program (or plans for operation) except as approved by the Rubber Administrator.

In delegating this added responsibility to the Petroleum Co-ordinator, the committee has sought to secure complete co-ordination of the butadiene-from-oil program with other petroleum and natural gas requirements, especially for aviation gasoline and for toluene for explosives.

As the situation develops it may be desirable that the funds required for the rubber program be put directly at the disposal of the chairman of the War Production Board for the purposes of the Rubber Administrator instead of, as at present, indirectly through the Federal Loan Agency.

The most important feature of these administrative changes is the type of man who is appointed as administrator. He should be a man of unusual capacity, a thoroughly competent operating and manufacturing executive, preferably with experience in the rubber industry. No plan of organization can bolster up a weak man sufficiently to meet the difficult problems he must face.

No Changes in Processes Now

The committee has investigated, with the aid of its experts, the status of the present government program for the production of synthetic rubber and believes that every one of the processes is technically sound and ultimately will work. The committee has also investigated many other processes not now in the government schedule. In its opinion a number of these processes have promise, but it does not believe that any one of them gives sufficient certainty of producing more rubber quickly enough to warrant substituting it for processes already in the program.

In war one cannot wait upon perfection. Any weapon on the battlefield is better than the best weapon on a blueprint. *The committee recommends that the present program be pushed forward with the greatest possible speed, without further change, except that if new projects are adopted they be made additions to the present program.*

Delays Not Unlikely

The committee has examined the present status of the government's schedules and estimates that if the present construction program can be met on the dates specified and technical difficulties in reaching full production are overcome, there will be produced during 1943:

400,000 tons of Buna-S;

30,000 tons of neoprene (in part from private sources);

62,000 tons of Butyl rubber; and

24,000 tons of Thiokol (from private sources).

Only Buna-S and neoprene can be used for the combat and heavy duty tires. Between them, these two synthetics and a portion of the Butyl rubber could offset the likely deficit of crude rubber which the country faces during the critical year of 1943. Under present priorities and allocations, however, there is grave danger that the construction of the synthetic program may be delayed by as much as four months. If this occurs, the production of Buna-S in 1943 will fall below 200,000 tons, and our supplies of rubber will be inadequate for military needs.

Critical Materials

Much has been said of shortages in critical materials. There are two kinds of shortages: the first, where there is not enough to go around for all essential purposes; the second type of shortage is where enough of the material exists, but it is not available when and where it is urgently required. There are a few materials short in the first sense; but many have been short in the second sense of failing to be where needed when needed.

In large part, this has been due to permitting materials to be used for purposes not essential to the conduct of the war; to the lack of vigorous policy of conservation inventory control and finding of substitutes; and most of all, to the changing, complicated, and ineffective methods that have been used to distribute materials and to control priorities. Shortages have been accentuated by superimposing upon the heavy military demands and the delayed conversion of civilian industry to war purposes, a vast war construction program approximating $17,000,000,000. This program will be near completion by the end of this year—about 75 per cent is to be finished in January—and all of it about July 1, 1943. Thus, large amounts of construction materials will be released.

After this, the question of critical materials will be eased, provided vigorous measures are taken to increase supplies, to find substitutes, to press research work, to complete conversion, to effect the utmost in conservation, inventory control, standardization, and simplification, and above all, to perfect a simple workable system of priorities for the distribution of materials. Too often an attitude of complacency has been assumed, and there has been a failure to take those vigorous measures necessary to increase supplies working closely with the industries concerned. There has been some disposition to accept the "impossible" instead of trying to overcome it.

The military men must decide what things come first in war production; but it is the duty of this committee to point out that unless the flow of materials for the construction of these synthetic rubber plants is insured, there will be no rubber in the fourth quarter of 1943 with which to equip a modern mechanized army.

Expand for Safety

The year 1943 is so critical for the rubber situation that the production of 100,000 or 200,000 tons of Buna-S may be the determining factor in the success of our military program. To add a greater margin of safety to the program the *committee recommends these additions:*

A. An increase in the production of butadiene by 100,000 tons, to be obtained from a refinery conversion program, more commonly known as "quick butadiene." This process utilizes refinery equipment made idle by the lessened demand for gasoline and which can be brought into production in six months. Since butadiene output is lagging behind styrene and polymerization capacity, if this additional butadiene can be made available quickly enough, an additional 40,000 to 50,000 tons of synthetic rubber could be produced in the critical year of 1943. This extra butadiene, too, would furnish insurance against possible difficulties with other plants and be a stand-by capacity as a reserve for the future. To be of greatest value this butadiene should be brought into production by next spring. Delay on the part of the government can turn this quick butadiene into slow butadiene.

The committee is concerned by the efforts on the part of many persons to substitute this so-called quick butadiene process for the regular butadiene plants scheduled in the government's program. The first thought that occurs to the committee is "Why now? Why not months ago? Why the sudden activity?" and above all, "Why substitute at this late date?" The committee recommends the quick butadiene program as an addition to, not a substitution for, the present program.

A Second Process from Grain

B. In addition to the increase provided for through the refinery conversion program, the *committee recommends another increase of 30,000 tons of Buna-S.* This should come from a plant to be erected during the latter part of 1943 to come into operation early in 1944.

There are two advantages in delaying construction until this time. There is good reason to believe that with the completion of the present huge war construction program, the present tightness of critical materials will be less acute and facilities for fabricating and for chemical equipment will be more readily available. Second, within the next three months it will be possible to judge better as to the relative merits of two processes for making butadiene from grain, which are not now in the government program—the so-called Polish process from alcohol and the butylene glycol process from grain.

Plants in Grain Areas

The plants for the production of this additional 30,000 tons of Buna-S by a grain using process should be located near the grain area. Such units should preferably be operated under the control of a local group.

More Alcohol

The estimates of alcohol supplies and needs given us by different agencies vary considerably. If no additional alcohol is provided for the expanded rubber program we have recommended, there is a possibility that at some time in the future the production of smokeless powder and other munitions may soar and alcohol be diverted from the making of rubber. *We recommend that facilities for the production of 100,000,000 gallons of alcohol be erected on sites near the grain-producing areas and accessible to water transportation.* This would make it possible for molasses to be brought to the plants by barges after the war in the event that the manufacture of alcohol from grain proves uneconomical.

In recommending this addition to our alcohol facilities, the committee wants to make clear that it is providing only enough additional alcohol to meet the increased demands of the expanded synthetic rubber program. The committee is not saying that that is all the extra alcohol that may be needed for all war purposes. By the use of newly developed apparatus, these alcohol plants can be constructed with but little expenditure of critical materials.

No Food Shortage

The Secretary of Agriculture has assured the committee that no concern need be felt that an expansion of the alcohol and butadiene from grain will interfere with our food supply. After all food requirements that can be anticipated now are met, there still will be upwards of 1,250,000,000 bushels of wheat left on this continent.

Relaxing Restrictions

If by the end of 1943 the actual production of synthetic rubber measures up to schedule and if synthetic rubber can be used readily, or if military or export need for rubber prove less than now anticipated, it should be possible to relax the restrictions somewhat on civilian driving. Before that can be done, however, there must be an assurance that at least 150,000 tons of Buna-S rubber a year will be available, in excess of military needs, for civilian purposes.

Under the rubber rationing program recommended by the committee, civilians will continue cutting into their capital—the rubber on their tires—although at a much lesser rate than now. By 1944 a further expansion of tire replacement for civilians to repay this "borrowed rubber" will be necessary. One of the impelling reasons for the committee's recommendation that the synthetic rubber program be expanded is because we desire to see this rubber turned out that will keep America on wheels.

More Neoprene

As a margin of safety on the military side, *we recommend the construction of 20,000 tons a year of additional neoprene capacity.* Neoprene is the one synthetic rubber which has been shown to be the full equivalent in quality of natural rubber for combat and heavy duty tires, either by itself or in combination with Buna-S. The relative high cost of neoprene in terms of critical materials and electric power needs are offset by the fact that it is an insurance against the possibility that our imports of natural rubber, already reduced, may be cut off or that the production of Buna-S in 1943 be delayed, forcing us to cut too deeply into our crude stockpile.

The New Program

The War Production Board has fixed the total annual output of Buna-S rubber at 705,000 tons for the United States. *The committee* *recommends that this ceiling be raised by 140,000 tons to 845,000 tons.* Additional styrene and polymerization capacity should be built, as necessary, to take care of the increased production of butadiene. This expansion should be directed to produce the maximum possible amount of Buna-S before January 1, 1944.

In addition to Buna-S, the expanded program recommended by the committee calls for 69,000 tons of neoprene, 60,000 tons of Thiokol, 132,000 tons of Butyl, with other synthetics like Flexon being added to the program if they can be brought in during 1943 after being adequately tested.

Standardizing Polymerization

At present four of the large rubber companies have designed their own polymerization facilities, each differing somewhat from the others. Each type of facility represents the best efforts of a group of keen technical men. Last May, Rubber Reserve decided to standardize all the polymerization plants to be constructed chiefly to save critical materials. In essence, this means standardizing the operation.

The design now ready is a compromise of the ideas of four separate technical groups. It may or may not incorporate the best ideas of each; on this point there are grave reasons for doubt. At all events, no one has ever operated such a standardized plant. The committee does not wish to criticize the decision, but does recognize the need for the immediate construction of one such standard plant so that experience with its operation can be obtained at the earliest moment. *We recommend the swift construction of such a plant.*

More Protection

Sampling inspections were made of a number of crude and scrap rubber stockpiles and of the methods being used for their protection. While the situation in general is satisfactory, a number of spots were found where protection from fire is definitely inadequate. The committee suggests the advisability of more adequate protection. These stockpiles constitute some of the most critical possessions of the nation.

Plant Capacities

A very important consideration in connection with the synthetic rubber program has to do with the capacity of the country to manufacture rubber goods out of the natural and synthetic rubbers which will be available. It would be obviously foolish to carry through a program of plant construction for the manufacture of synthetic rubbers only to discover too late that the fabricating facilities were insufficient to handle the rubber.

The committee has made a survey of these facilities and finds that, as matters now stand, there will not be sufficient factory capacity to deal with the quantities of synthetic rubber that will be produced in 1944. One important limiting factor is that, at present, it takes about a third more time to fabricate synthetic than natural rubber. While this would indicate that the capacity of the industry should be increased, the technical developments in the art of processing are proceeding very rapidly and the time required to manufacture synthetic goods certainly will be reduced. It follows that output will be increased. The committee has been informed that the decision on whether to expand capacity can safely be deferred to April, 1943, and therefore recommends that the Rubber Administrator review the problem early next year.

The committee's findings and recommendations on plant capacity are given in greater detail in the full body of the report, which in addition contains other detailed recommendations and findings.

Free Competition

In concluding this summary of findings and recommendations, the committee wishes to point out that never before has this country embarked on an undertaking comparable to the development of the synthetic rubber program. It is not only an ambitious technical project that must be rushed to completion at breakneck speed, but in large measure it is a new political and economic undertaking. It seems to us of vital importance that this program be managed in a spirit of the fullest competition and interchange of information among all groups. On the one hand, there should be the most complete interchange of information and, on the other, as much competition in research, development, and operation as possible. Such, after all, are the conditions in the field of laboratory science where during the last hundred years such tremendous strides have been made—co-operation and competition going hand in hand.

Nor is the committee unaware that the production of synthetic rubber is potentially a large new postwar industry and that different groups will be contesting for a share in this postwar industry. This struggle should not be allowed to obscure the basic facts of our situation as regards the war and rubber. No matter what processes were provided in the program, there would be the same uncertainties as to the future, the same huge requirements, the same threat to our essential civilian economy, and the same necessity for conserving the rubber we have until our new rubber comes in.

The committee recognizes that there still is room for reasonable scientific disagreement over many of the processes for making rubber that are being developed. It is quite possible, even likely, that before much of the synthetic rubber now planned is produced, better processes will have proven themselves. In any new industry the processes of today are outmoded by the processes of tomorrow and tomorrow's by those of the next day. However, our need for rubber quickly is too great to wait upon perfection and if this committee were to advise the newly appointed Rubber Administrator it would say, "Bull the present program through."

For Victory—Unity!

In drawing up these recommendations the committee has sought to find a basis upon which the entire nation can go forward together, uniting our energies against the enemy instead of dissipating them in domestic wrangling. It appreciates that it is asking the public to make sacrifices because of mistakes that have been made and for which the people are not to blame. But wrong things done in the past cannot be cited as a defense for making mistakes in the future. The war demands that we do these things. Victory can be won in no other way.

The Committee:
James B. Conant
Karl T. Compton
Bernard M. Baruch,
Chairman

September 10, 1942

BARUCH COMMITTEE REPORT

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and

SUMMARY OF RECOMMENDATIONS

1. Statement of the Problem
2. Procedure of the Committee
3. Analysis of Supply and Demand for Rubber

   Without synthetic rubber, our stocks of new rubber would be exhausted during 1943. If synthetic rubber production now planned comes through on schedule, we can get through, but without adequate reserves against contingencies. The allotment of a small amount of reclaim and synthetic material will provide a tire replacement and recapping program, but only with drastic restrictions on civilian driving.
4. Rubber Requirements of the Armed Services

   The armed forces have already severely reduced their rubber requirements and instituted conservation measures. They state that further substantial reduction would seriously impair fighting efficiency.
5. Tires for Passenger Automobiles

   In order to maintain civilian driving to a degree necessary for public morale, avoidance of unnecessary hardship and efficient functioning of our economy, *the committee recommends* a program of civilian automobile tire conservation based on supervised recapping and replacement of tires to maintain cars in operating condition, safeguarded and combined with universal enforcement of a 35-mile per hour speed limit, tire inspections and reduction in mileage to a national average of not over 5,000 miles per car. It further recommends nation-wide gasoline rationing as the quickest and most workable method for conserving rubber through control of mileage. It also recommends an expansion of the Thiokol program for recapping by 36,000 tons.
6. The Synthetic Program

   To safeguard the military situation in the critical year 1943 against possible delays in synthetic rubber production, or failure to secure expected crude rubber imports, or further expansion of requirements dictated by enemy actions or new strategy; also to provide the additional rubber needed to maintain the civilian automobile use outlined: *the committee recommends* (1) that there be no further substitutions in the plans now laid down; (2) the immediate authorization of an additional 140,000 tons of Buna-S capacity per year; (3) the immediate institution of a refinery conversion program to yield a total of 100,000 tons of butadiene in addition to that now planned; (4) the immediate adjustment in the rates of construction of present styrene and polymerization plants in order to obtain the maximum production of Buna-S in 1943; (5) the construction of an additional plant for the production of 20,000 tons of neoprene per year; (6) the erection of a 27,000-ton butadiene plant from grain and an associated polymerization plant to produce 30,000 tons of Buna-S, both to be located near the center of grain production; the construction to be started six months hence unless the Rubber Administrator determines otherwise; the process to be employed to be determined in the light of the information then available; (7) the immediate erection of alcohol plants to produce 100,000,000 gallons per year, using recently developed apparatus; the plants to be erected on sites near the grain producing states and located on water transportation.

7. Priorities

If the synthetic rubber program is to succeed *on time*, assured arrangements for construction materials are urgent.

8. Administration

The committee finds that consistency, co-operation between governmental agencies, and adequate management have been lacking. It therefore recommends appointment, by the chairman of WPB, of a Rubber Administrator, to whom he shall delegate full responsibility and authority for all aspects of the rubber program (except for specific limitations where aviation gasoline and toluene for explosives are concerned).

9. Agricultural Program

Action within a month is necessary to remove legal restrictions on acreage and to provide certain farm equipment in order to avoid a whole year's delay in expanding the planting of guayule, which can become a major source of new crude rubber within a few years.

10. Rubber Goods Manufacturing Capacity

The committee recommends immediate steps to increase by 20 per cent the country's capacity to reclaim rubber from rubber scrap. It also recommends a nation-wide survey of rubber milling, mixing, and tire building capacity, to be carried out on about March 1, 1943, in the light of the mixing, milling, compounding, tire building, and vulcanizing arts which then exist for the processing of synthetic rubbers, and that steps then be taken to provide whatever additional manufacturing facilities are found to be necessary to handle the full volume of synthetic rubber production expected in 1944.

11. Scrap Collection

The committee finds the present scrap stockpiles plus current receipts sufficient to feed the reclaim rubber plants at full capacity for the next eighteen months. In the meantime, normal scrap collection should be continued and plans laid for a second intensive drive for scrap, probably about a year hence. It is important that measures be taken for further protection of existing scrap rubber stockpiles.

12. Technical Suggestions for the Rubber Administrator

I

Statement of the Problem

Of all critical and strategic materials, rubber is the one which presents the greatest threat to the safety of our nation and the success of the Allied cause. Production of steel, copper, aluminum, alloys, or aviation gasoline may be inadequate to prosecute the war as rapidly and effectively as we could wish, but at the worst we still are assured of sufficient supplies of these items to operate our armed forces on a very powerful scale. But if we fail to secure quickly a large new rubber supply our war effort and our domestic economy both will collapse. Thus the rubber situation gives rise to our most critical problem.

Our position with respect to this vital commodity may be briefly outlined as follows:

The demands now placed upon us are enormous. Without any allowance whatsoever for civilian passenger car tires, the estimated requirements for the year 1943 are 574,000 tons. This contrasts with the total average over-all consumption in the United States before the war of over 600,000 tons. We must supply not only the needs of our own armed forces but much of those of the military machines of our allies as well. We must equip our buses and trucks and other commercial vehicles and provide on a large scale specialty items for such purposes as factory belting, surgical, hospital, and health supplies. And in addition to all these we *must* maintain the tires on *at least* a substantial portion of our 27,000,000 civilian passenger automobiles. Otherwise an economy geared to rubber-borne motor transport to an extent not approached elsewhere in the world will break down.

To meet these demands we may look to four main sources of supply:

First, our present stockpile of natural rubber and such additions as may come to it from natural rubber imports from Latin America, Africa, and other rubber-producing lands. These are comparatively small.

Second, our present stockpile of scrap rubber, estimated as sufficiently large with yearly additions to operate our reclaiming industry at present capacity through the year 1945.

Third, the production of synthetic rubbers.

Fourth, we possess in the tires of our automobiles a priceless reserve, which must be guarded with greatest care. It represents a stockpile of some 1,000,000 tons of rubber applicable to the uses of our civilian transportation and the needs of the day-to-day life of our people.

Having lost to Japan 90 per cent of our prewar source of natural rubber, chief reliance on new supplies of rubber must be placed on the new synthetic rubber program. But to obtain this in time we must, within two years after Pearl Harbor, have created one of the largest industries in the country. Normally such a development would require a dozen years. To compress it into less than two years is an almost superhuman task.

Our committee is convinced that the government's present program is technically sound. From this time on the important thing is to get on with it without further delay.

In drawing up the recommendations which follow, the committee has sought to find a basis upon which the entire nation can go forward together, uniting our energies against the enemy instead of dissipating them in domestic wrangling. It appreciates that it is asking the public to make sacrifices because of mistakes that have been made and for which the people are not to blame. But wrong things done in the past cannot be cited as a defense for making mistakes in the future. The war demands that we go forward from this point united and resolved to win at any cost.

2

Procedure of the Committee

This committee was asked "to get the facts and make recommendations." To this end, immediately after its appointment it assembled a competent technical staff of approximately twenty-five men of whose competence we had knowledge through firsthand experience. With the aid of this group the committee has endeavored so far as humanly possible in the time at our disposal to get the facts and draw from these facts the logical conclusions.

With the aid of experts in the art of rubber manufacture and rubber compounding and with the assistance of a group of chemists and chemical engineers, we checked so far as possible the chemical processes involved in the government program and those suggested by individuals and companies not yet included in this program. For this purpose members of our staff traveled throughout the eastern, southern, and middle western sections of the country, examining plants, consulting the technical experts concerned with the progress of the program and in the construction of new facilities. With their aid, we also examined carefully the present status of all tests throwing light on the adequacy of the new synthetic materials for military and civilian purposes, as well as the potentialities of numerous materials which have been suggested for the recapping of tires or special uses in the rubber program. We also examined at first hand into the condition and state of protection of the nation's stockpile, which must serve as the essential backlog of our efforts until synthetic materials can be brought into substantial production.

Special checks likewise were made by men competent in business and engineering associated with the committee, as to the rate of construction of scheduled plants and the situation with respect to the allocation of strategic materials to these plants and the granting of the necessary priorities. The capacity of the country to produce the essential raw materials for the development of the synthetic program also was checked. We have endeavored with the aid of competent assistance to evaluate the potential requirements of this country and the United Nations and have made our estimates of the probable supply, present or to come.

In addition to interviewing, through our staff, a number of persons familiar with the various aspects of the rubber situation, we heard formally many officials of the government as well as representatives of industry. A great number of documents from governmental and other sources were put at our disposal, and we examined these records with care. The printed records of hearings before the committees of Congress which deal with this subject run to many pages. We reviewed the evidence thus presented as of value on many points. All the Congressional committees who had interested themselves in the problem were asked for their suggestions or recommendations and many stimulating suggestions were made. Particularly helpful were the committees under the chairmanships of Senators Truman, Gillette, and Murray. In conclusion, it is a pleasure to acknowledge that from all with whom we have been in touch we have received the maximum of co-operation.

3

Analysis of Supply and Demand for Rubber

The natural starting point for a consideration of our national rubber problem is an estimate of the essential needs during each of the next few critical years, and a corresponding estimate of the sources of supply from which these needs may be met. Many such balance sheets of the national position have been drawn up by various governmental agencies during the past eight months, and authoritative revisions must be made from time to time to give warning if our program is running behind expectations, or to give opportunity to make additional important military uses of rubber if the program should run ahead of schedule, or to relax restrictions on civilian driving.

In arriving at the data presented in the following tables, which form the principal bases of the committee's conclusion, we have tried to be neither unduly optimistic nor unnecessarily pessimistic. The figures in each case represent our best judgment of expected performance. We realize, and this should be continually borne in mind, that unanticipated events may change many of these figures substantially. We should also bear in mind that there are many more circumstances which might arise to change the figures unfavorably than there are to change them favorably. Such circumstances are likely to arise for human rather than technical reasons, and some of these circumstances will constitute the basis of recommendations in Sections 7 and 8.

Considering first the anticipated supplies of all types from all available sources, our estimates are presented in Table I. In this table have been included certain additions of neoprene and Thiokol to the present governmental program, in accordance with recom-

TABLE I

SUPPLY

Before any consumption, the supply of rubber available to the United States, as estimated by the committee's staff, is as follows (in thousands of long tons):

	Present Stocks July 1, 1942	*Expected 1942 6 Mos.*	*Additions 1943*	*Additions 1944*
Natural	578	12	41	68
Buna-S	...	0	386	705
Neoprene	...	4	30	59
Butyl	...	0	62	132
Thiokol	...	0	54	60
Reclaim	47	160	360	400

mendations presented in Section 6. However, the recommendations there given for increasing the supply of Buna-S rubber as a safeguard for the critical year of 1943 and a backlog to maintain civilian transportation after 1944 are not included in this table.

This table does not include small amounts of Buna rubbers produced from private sources in 1942.

Against these supplies of natural and/or synthetic rubbers, the presently estimated total requirements for various categories of essential use are presented in Table II. In our calculation the use of synthetic rubbers has been stated in terms of equivalent tonnage of natural rubber by the use of factors depending upon the specific gravities and resistances to wear of the various types of rubbers, as appropriate to the specific uses included under each classification. The item "Private transportation" does not include the reclaimed rubber or synthetic materials necessary to maintain private passenger car transportation, these being shown in Table V. The item "Private transportation" does, however, give the amount of natural rubber which would have to be used in addition to the reclaim and synthetic rubbers of Table V as a cement in recaps and new tires made of reclaim. The item "British deficiencies" shows the expected requirements of the British Empire excluding Canada as its accumulated stockpile of natural rubber is consumed.

TABLE II

The total requirements of natural and/or synthetic rubbers (in terms of natural) are estimated as follows (in thousands of long tons):

	1942 6 Mos.	*1943*	*1944*
Military	138	325	325
Private transportation	1	3	3
Commercial vehicles	28	59	85
Other civilian uses	24	49	50
Foreign countries	74	117	103
British deficiency	0	24	106
	265	577	672

The item "Commercial vehicles" in Table II refers primarily to passenger buses and trucks whose operations are controlled by the Office of Defense Transportation with co-operation of the Office of Price Administration in matters of rationing. Under the ODT steps have been taken to conserve rubber through consolidation and rerouting of commercial traffic, and as this is written, by an order requiring a certificate of necessity and imposing gasoline rationing. Our committee believes that further savings can be made through elimination of cross hauls and more stringent substitution of alternative types of transportation not requiring rubber. Our estimates in Table II for commercial vehicles depend upon limitation of speed, conservation of tire wear and maximum proper loading.

The item "Other civilian uses" includes several hundred items such as rubber hose, belting, electrical insulation, storage battery separators, industrial footwear, medical equipment, etc. The committee has carefully examined the program of the Rubber Branch of WPB with reference to the elimination of unnecessary use of rubber in such items or the substitution of lower grades of rubber and is convinced that a thoroughly competent job has been done in reducing the use of rubber in such items to a point at which very little further reduction can be expected in this list. A few remaining possibilities are being actively studied by the Rubber Branch, but the sum total of all such possibilities is estimated to be so small that the time when the nation might run out of crude rubber could not be postponed more than ten days if all such reductions, some involving considerable hardship, were enforced.

An essential part of our rubber supply is in the form of reclaimed rubber secured from the stockpile of scrap rubber. To the estimated 47,000-ton stock of reclaimed rubber on July 1, 1942, is added year by year the additional amounts of such rubber which it is estimated can be produced by the capacity of our rubber reclaiming plants. These plants are not now running to capacity because of the governmentally enforced limitations in allocation of reclaimed rubber to manufacturers. The demands listed in Table III are based on the assumption that all possible excess of reclaimed rubber be allocated to maintenance of civilian passenger car tires. In order to secure these amounts for private transportation, and to insure adequate provision for military and other needs, the committee recommends in Section 10 that plant capacity for producing reclaimed rubber be expanded as rapidly as possible above its present limit of 350,000 tons per year, and the effect of such expansion is reflected in the estimates of "supply."

TABLE III

Supply and requirements of reclaim are estimated as follows (in thousands of long tons):

	1942 *6 Mos.*	*1943*	*1944*
Supply	207	360	400
Requirements			
Military	37	84	84
Commercial vehicles	18	33	43
Other civilian uses	72	146	146
Foreign countries	18	21	21
Balance available for passenger cars	62	76	106

If in the requirements in Table II we substitute the various types of synthetic rubber to the extent that they are expected to be available and for purposes for which they are suitable, we can, from Tables I and II, deduce the amounts of crude natural rubber which we will have on hand at various times, as indicated in Table IV. In deriving this table we have reserved for civilian passenger car tire use all of the Thiokol of Table I (since this material is not suitable for many other uses), and we have also reserved a small amount of Butyl rubber and a considerable amount of Buna-S rubber in 1944 for similar purposes, as shown in Table V. With these reservations the amounts of natural rubber available in the United States are as shown in Table IV.

TABLE IV

Estimated crude natural rubber in the United States, after application of synthetic rubber substitutes (in thousands of long tons):

	1942 *6 Mos.*	*1943*	*1944*
Balance on hand	578	328	224
Added during period	12	41	68
Requirements	262	145	51
Annual excess	...	...	17
Deficiency	250	104	...
Balance carried over	328	224	241

The amount remaining for application to civilian passenger transportation is estimated to be as shown in Table V.

TABLE V

Rubber applicable to civilian transportation is estimated as follows (in thousands of long tons):

	1942 6 Mos.	*1943*	*1944*
Crude natural	1	3	3
Buna-S	0	0	185
Butyl	0	0	15
Thiokol	0	54	60
Reclaim	62	76	106

Two comments on the above tables are important. The first is that the amount of rubber available for civilian passenger car tires is a relatively small residual left over from a very large program, and must absorb the shock of any miscarriage of our plans. The committee has assured itself that a strong effort has been made to hold the military, allied, and other civilian requirements to a minimum. Since the amount left over for civilian passenger tires is a small residue, any unfavorable change in the above figures would tend to squeeze out the amounts left for civilian driving. This is the strongest argument for a drastic program for conservation of the existing tires on civilian passenger cars, since any failure to conserve these tires, combined with either an increase in military requirements or a delay in securing the expected production of synthetic materials, would result in a complete breakdown of civilian passenger car transportation in 1944 or 1945.

The other important comment is that the balances shown for crude rubber in Table IV are very little above the requirements of prudence. This can be illustrated by examining the balance of 224,000 tons expected to be left at the end of 1943. This balance includes the inventories necessary to manufacturers of rubber goods in order that they may continue manufacturing operations without delays, caused by temporary transportation or procurement difficulties. Of this 224,000 tons, about 50,000 tons would represent a thirty-day inventory for American manufacturers, which is none too large. Another 4,000 tons can be considered as a reasonable inventory for Canadian manufacturers. The committee believes that at least 66,000 tons should be considered as an inventory of stocks on hand in Great Britain to permit her rubber goods manufacturing to proceed in case there should be several months' interruption of transportation on account of a possible change in the naval situation in the Atlantic Ocean. Thus about 120,000 tons out of the 224,000-ton balance is to be considered a necessary "working inventory." The balance of 100,000 tons is certainly none too large for safety when one considers that a delay of two months in the presently expected production schedule for Buna-S rubber would completely wipe out this balance. In this connection it must be remembered that a substantial amount of crude rubber must always be in hand to blend with synthetic materials for various important uses.

For these reasons the committee feels that an analysis of the balance sheet indicates: (1) that we can survive the rubber crisis without serious impairment of our military program or domestic economy *if the plans go through on schedule,* but that (2) the margin of safety is uncomfortably small in view of reasonably possible unfortunate contingencies. The committee therefore recommends in Section 6 certain expansion of the present program to aid the civilian driving program and as an insurance against such contingencies.

The committee also recommends that WPB through the Rubber Administrator scrutinize all requirements, foreign and domestic, submitted for rubber to the end that only actual needs be allowed for.

4

Rubber Requirements of the Armed Services

The rubber requirements of the armed services have been stated in terms of over-all tonnage in Table II of Section 3. It would not be appropriate in this report to discuss the individual items which make up these requirements. Suffice it to say that our committee has examined these requirements in some detail and submits the following comments.

It is reassuring to note that the Army has cut its requirements by about 45 per cent; the Navy, by about 35 per cent with expectation of raising this to 45 per cent. These differences are largely on account of the differing types of requirements in these services, and the committee believes that both services have handled their rubber conservation program sincerely and effectively. The committee accepts at full value the statement that substantial further reductions cannot be made without a serious reduction in military efficiency. It also recognizes that large combat losses might, on the other hand, substantially increase the rubber requirements of the armed services above their present estimates.

The following comments amplify the general statement just made and are based upon the committee's examination of the estimates and performances of these services. In general, the estimates are based upon:

(1) a recognition of the dangers inherent in the short supply of rubber;
(2) a sound method of calculation of needs on the present facts as to the size of the armed services (the committee does not attempt to measure the need for the items using rubber, but only the need for rubber is estimated if the items are purchased);
(3) the establishment of an organization to develop and push the conservation program, with competent personnel, keeping in touch with all developments in the conservation of rubber;
(4) a quite complete policy as to the elimination of rubber articles formerly in use in the service and providing for substitutes generally where possible;
(5) a careful examination of all specifications covering rubber goods so as to reduce the crude rubber content, and increase the use of reclaimed rubber or substitutes;
(6) tests for utilization of rayon, nylon, and steel (in place of cotton) which, being stronger, will demand less rubber;
(7) a comprehensive plan for conserving rubber in use and suitable orders and instructions covering its operation.

While there is no adequate measure as to the actual accomplishments in the field, the reports from inspection are encouraging in some spots and discouraging in others, but the organization setup appears sound. In one area of extensive army training maneuvers where previous inspections had disclosed very wasteful practices in the use and abuse of tires, a recent inspection by the same experienced civilian group led to their report that the tires in this area were now being conserved with at least as good care as would be found in an operating fleet of commercial vehicles. This part—the making of the plan effective in the field—will require a vigorous follow-up, training of operating and inspecting personnel, aided by rigid inspections, and adequate disciplinary measures.

All these things can be done readily without interfering with military effectiveness. Three other aspects of conservation of rubber are under study by the services and some progress has already been made, but there is need for careful work and prompt decision as to whether:

(a) the conditions under which equipment will be used permit redesign of the equipment so as to save rubber, for example, the use of steel wheels or rims instead of rubber tires to a greater extent;
(b) the experience in combat does not warrant the use of equipment using either lower grade or less rubber, so that the rubber will not be planned to outlast the remainder of the equipment;
(c) requirements for spares cannot be materially reduced;
(d) inner tube requirements cannot be cut as tubes outlast tires;
(e) depreciation is not less than estimated, due to the conservation plans.

The full utilization of existing inventories through complete inventory control, the avoidance of purchases whenever possible, the scrutiny of all unusable items—both new and scrap—in inventory and providing for their prompt utilization in the armed services, or elsewhere in the war effort are matters now in hand but still demanding rigorous prosecution.

The armed services assure us that this entire program will be carried out to the limit.

The savings expected are not large and if attained they are enough only to provide a small factor of safety required for the whole national program.

5

Tires for Passenger Automobiles

The adoption of a policy for conservation of civilian-owned tires and its enforcement at the earliest possible moment is unquestionably the most urgent item still remaining unsettled in the rubber program. The cost to our war effort of not doing this would far exceed the cost in materials and rubber of doing it.

It must be remembered that practically nothing has been done during this year to supply tires for the 27,000,000 passenger cars now on the road. In normal years about 250,000 tons of crude rubber has been consumed annually in meeting this demand. Many tires are now reaching the point where they will become unusable, and unless something is done at once to provide recaps and a limited supply of new tires we shall be headed for a drastic breakdown in the not far distant future. It has been estimated that by April of 1943, one-half of the tires on passenger automobiles will be worn to the point where they should be recapped. Clearly if such a condition is reached it would not be many months before our civilian economy collapsed.

In the committee's opinion it is unfortunate that the government was not able to institute a tire replacing and recapping program last spring. If it could have been done, many billions of car miles of rubber would have been conserved. It is of the utmost importance that this program be instituted at once together with provisions for adequate tire inspection. Experience has shown that out of every 100 tires ready for recapping only about 60 can be thus repaired. The other 40 tires must be replaced by new tires. It is primarily this fact which sets the limits to any program which can now be instituted for conserving our rubber-borne transportation through a recapping program. If we were to decide tomorrow to provide enough new tires and recaps on the prewar basis of replacement to carry the 27,000,000 passenger cars through 1943, with unrestricted driving as to speed and mileage on the prewar level, some combination of crude and reclaimed, as for example about 200,000 tons of each, would be required. Clearly the allocation of such an amount of crude rubber or synthetic material for the use of civilian passenger cars is fantastic. The committee must emphasize once again that the critical time for the country, as far as rubber for its military effort is concerned, is the third quarter of 1943 and the quarters immediately succeeding. This is evident since many of the plants now under construction for the production of synthetic rubber will not reach full operation until the latter part of the coming year. Our analysis shows that even with the optimistic estimates of the total quantities of new crude and synthetic rubber that will be available the amounts of this that we will be able to spare for the purpose of civilian passenger cars will be sufficient for a recapping and tire replacement program only provided that *strict conservation measures are instituted at once.*

The committee is well aware of the fact that the American people are quite prepared to make any sacrifice that is needed for the winning of this war. No one will complain of hardships or discomfort when he thinks of the young men who are now preparing to give their lives freely on distant battle fronts throughout the world, but the committee does not believe in the doctrine of sacrifice for sacrifice's sake. Neither do we believe that civilian workers should be expected to live in tents and walk several miles to work unless it can be demonstrated beyond the shadow of a doubt that the situation is so desperate that there is no alternative except that of inviting military defeat. Consequently the committee has explored carefully the amount of rubber which can be spared for the purpose of keeping the passenger cars of the country in operation. We realize full well that beyond some point we cannot limit the amount of transportation thus carried throughout the country without severe effects on our war program. Indeed we have been given estimates that point to the fact that unless approximately 50 per cent of our normal annual car mileage can be maintained our normal productive effort would be seriously retarded. Necessary civilian needs are a part of the war effort. Ludendorff complained that the home front crumbled before the war front. We must provide for the bottleneck of lessened automobile transportation before it occurs.

If we could be absolutely certain that all the production of synthetic rubber planned for 1943 would come in on time and that no difficulties would be had in the initial stages of using this material, it might be safe to draw on the existing stocks for the rubber with which to manufacture tires for passenger cars. It is essential, however, that we have a margin of safety for our military effort, and no civilian in this country would ask the government to jeopardize our war machine through lack of rubber in order that he might drive a few miles further in his car.

The average annual mileage of the passenger automobiles before the war has been estimated as approximately 9,000 miles. Today the figure usually quoted is 6,700 miles. It is clear that in the non-rationed areas the diminution in annual mileage is a result of voluntary restriction brought about largely by the fear that no further tires will be forthcoming for the owner of a private car. There is every reason to believe that as soon as a tire replacement and recapping program were [to be] announced without restrictions, drivers would feel that the danger had been passed and would increase both their speed and their mileage to almost prewar levels. If this were done the amount of rubber consumed by any recapping and tire replacement program would reach figures so large as to go beyond our expectations of supply in the critical year 1943—250,000-300,000 tons of Buna-S, almost the entire production if the least optimistic estimate proves to be correct.

Strict enforcement of a speed limit of 35 miles per hour for private automobiles together with adequate tire inspections are extremely important factors in conserving rubber. The committee recommends that these measures be instituted at once on a nation-wide scale. On this basis it would be possible to provide enough new tires and recaps to maintain the program here recommended, if a maximum of 138,000 tons of reclaimed rubber were made available during the next 16 months for the purpose of keeping the passenger cars of the country in operation. (The small amount of crude rubber which is required in connection with the recapping program amounts to only a few thousand tons.) This amount of rubber, supplemented by synthetic materials as shown in Section 6, we believe will enable the nation to maintain approximately the present number of passenger automobiles at an average annual mileage of 5,000 miles.

In order to insure that this mileage will in fact prevail, the committee recommends that nation-wide gasoline rationing be instituted at the earliest possible moment under policies to be determined by the Office of Defense Transportation and implemented by the Office of Price Administration. The committee has examined various alternatives to gasoline rationing as a means of conserving rubber, but by no other procedure can we be certain that the annual mileage will be held to the figure we name. We must have some assurance so that those individuals who are ready to lead in the conservation of rubber will not be taken advantage of by the small percentage of the population who are not ready to follow.

It must be clear that this program would not give every citizen the right to drive 5,000 miles. This figure is an average which obviously means that the mileage for unnecessary driving must be cut very considerably below this figure, in order that essential driving requiring greater mileage may be maintained. The proper distribution of mileage to various drivers is a matter which would be worked out by the responsible governmental agencies.

It should also be stated that, in the committee's judgment, even the above drastic curtailment of driving will be insufficient to meet the situation unless there is further increase in the practice of car pooling and sharing of rides. Extra tires of popular sizes now in the possession of persons who will not need them could be made available for essential uses under a suitable program of pooling through voluntary sale to the government.

Every day of delay in putting the above program into effect will mean irretrievable, unnecessary loss of rubber by America and will build up, if long delayed, a day of disastrous reckoning. The nation is now driving on rubber borrowed from a happier past. Without recaps and replacements the majority of civilian cars would be forced off the road by irreplaceable tire failures.

If by the end of 1943, actual production is realized from the synthetic rubber plants under construction to the extent that is now scheduled, and if the synthetic rubber can be used as readily as it is believed, or if the military and export demand for rubber should actually prove to be substantially less than is now anticipated, it would be possible to draw further upon the stocks of rubber before 1944 for civilian passenger car use. In that case, the restrictions on driving could be lessened, provided that the Rubber Administrator feels sure that by 1944 at least 100,000 tons of Buna-S will be available for tires for civilian driving. In order to make certain that this will be the case the committee is recommending elsewhere such an expansion of the present synthetic program as to provide for this excess synthetic rubber. This, we believe, can be done without interfering with the war program. The drastic conservation measures recommended for the year 1943 may therefore be somewhat relaxed after another twelve months has passed, if the situation in regard to synthetic rubber is as rosy as we may hope.

At this point the committee wishes to correct the erroneous impression which has been spread abroad to the effect that tires on cars standing in the garage will deteriorate almost as rapidly as if they were being driven. This idea is completely wrong. When standing under proper conditions in a garage the deterioration of the tires amounts to only a very few per cent, even in the course of an entire year. The conditions which must be observed are that the tires must not be allowed to stand uninflated, that they should not be allowed to stand on oil or grease, and that the car should be jacked up to relieve the pressure on the tires if the car is to stand for several months without use. High temperature and sunlight also have a deleterious effect. With any reasonable observance of these precautions, cars may be kept in storage with almost complete saving of the remaining mileage in the tires.

In the interim the committee is confident that the American people, once they are acquainted with the true facts in regard to our rubber supply, will gladly accept whatever conservation measures are required.

To sum up, our recommendations, in so far as passenger automobiles are concerned, are as follows:

1. *Immediate institution of a tire replacement and recapping program through the allocation of reclaimed rubber for that purpose.*

2. *Nation-wide gasoline rationing to hold the average annual mileage to 5,000 miles under the general direction of the Office of Defense Transportation.*

3. *Prompt and strict enforcement of a nation-wide speed limit*

not exceeding 35 miles an hour for private passenger cars and trucks.

4. *Compulsory periodic tire inspection.*

5. *A voluntary interim tire conservation program until gasoline rationing can be instituted.*

In order to provide for the recapping program which we have previously outlined it will be necessary to expand immediately the facilities for the production of Thiokol. At present the country has plants for the production of 24,000 tons per year from private sources; this should be enlarged by government-sponsored plants to produce 36,000 tons by conversion of present existing idle plant capacity, giving a final total of 60,000 tons per year. Thiokol is most rapidly produced of all the synthetic materials which are suitable for the retreading of civilian tires. The amount indicated will be needed to help carry civilian passenger tires through the years 1943 and 1944. If prompt action is taken the additional Thiokol should be in production by January, 1943.

Adequate tire inspection is one important element in the conservation program. In general, where industry can be organized to function, great care should be taken not to build a duplicate governmental organization. This has special reference to periodical examination of civilian tires. It would seem very much easier to license recognized tire dealers and repair men who have experienced help and who are fully equipped for the purpose of examining tires and advising as to their maintenance. Such an organization could be created almost overnight. Rationing boards would then be governed by the reports presented to them by those requiring tire recapping or repairs from the information furnished by these examiners. The committee suggests that these examinations be governed by a mileage total instead of elapsed time.

6

The Synthetic Program

The present plans for the production of synthetic rubber as outlined to us by the governmental agencies concerned call for the erection of the following types of plants in the United States:

(a) for the production of neoprene, eventual capacity 40,000 tons per year (in addition to a 9,000-ton plant now in operation by a private company);
(b) for the production of Butyl rubber to yield 132,000 tons per year;
(c) for an over-all production of 705,000 tons of Buna-S. This production of Buna-S involves construction in terms of plants for producing styrene and butadiene and for the copolymerization of butadiene and styrene with the formation of Buna-S.

For the manufacture of butadiene the following processes are scheduled (all figures expressed in the long-ton equivalent of Buna-S):

(1) from alcohol by the Carbide and Carbon Chemical process, rated capacity	242,000 tons
(2) from butane (in natural gas) by a process developed by the Phillips Petroleum Company	50,000 tons
(3) from butane by the Houdry process	16,500 tons
(4) from butylene (obtained by the cracking of petroleum) by a process developed by Standard Oil of New Jersey	283,000 tons
(5) by the cracking at high temperatures of gas and heavy oils (the so-called thermal or refinery conversion processes)	20,000 tons
(6) by combination of (4) and (5) in one locality	93,500 tons

The committee has examined the present status of the government's schedules and estimates that *if the construction program can be met on the dates specified* there will be produced during 1943: 400,000 tons of Buna-S; 30,000 tons of neoprene (in part from private sources). We believe that these processes will ultimately work on a large scale and yield satisfactory products.

Furthermore, our experts estimate that the time required to get the various plants running smoothly under actual operating conditions will not be so lengthy as to cause serious delay. On the other hand, it must be remembered that we are dealing here with a new industry and that in the production of Buna-S three separate manufacturing operations are concerned, no one of which has been carried out as yet on anything approaching the present contemplated scale.

Therefore, until more experience has been gained by the operation of one of the large-scale units at each step, we must consider that a considerable element of risk is present in the picture. The importance of completing rapidly one full-scale plant using each process and the erection of pilot plants is considered in the technical section of this report.

The committee wishes to emphasize once again at this point that the whole question of obtaining synthetic rubbers in adequate amounts in 1943 hinges on the rate of construction of the manufacturing plants. Unless the present situation involving the assigning of priorities and allocating of materials is improved, there is grave danger that there will be serious delays in the completion of the plants and consequent reduction in the amount of synthetic materials produced. Furthermore, unless the administrative changes recommended in a later section of this report are put into effect, conflicting governmental plans with respect to the oil industry may seriously jeopardize the production of butadiene.

We have also examined with the aid of our experts many other processes for the production of butadiene and synthetic rubber. We find that quite apart from their merits or demerits, no one of them could now be substituted in the present program with hope of accelerating the production of Buna-S in the critical year 1943.

We would be blind if we did not see the efforts now in progress on the part of many companies to have a part in the development of a large new industry with vast postwar possibilities. This has been accentuated in the minds of the petroleum producers by gasoline rationing with its attendant loss of sales. They are thus forced to turn to other products including butadiene. Furthermore, we are not unaware that it is inevitable that once the war is over there will be a struggle amongst various groups for the control of this new industry. But all such considerations cannot affect this committee as to its conclusions. We are concerned only with the production of the largest amount of rubber in the minimum amount of time in order to carry the country successfully through the war. It is our firm conclusion that present processes for manufacturing synthetic rubber and the raw materials required (butadiene and styrene) must not at this late date be changed unless new processes can be shown beyond peradventure to have such advantages over those now employed that more rubber would be obtained in the ensuing months than would otherwise be the case. We have found no such process in the course of our investigations.

The committee finds that there has been considerable discussion between two groups within the oil industry as to whether or not there was a serious conflict between the butadiene program based on butylene and the high-octane aviation gasoline program. With the aid of our experts we have examined carefully into this problem and consulted many technologists in various oil companies as well as discussing the matter with the officials of the Office of Petroleum Co-ordinator. It is our conclusion that, while the possibility of a conflict between the two programs does exist, it need not become serious if the possibility is recognized and if the administration of these two closely related enterprises is properly integrated.

The necessity for the administrative changes along these lines which are recommended elsewhere in this report is further demonstrated by the uncertainty of the stated aviation requirements in both quantity and quality. The evidence clearly indicates that if the present demands for high-octane aviation gasoline and butadiene stay where they now are, there need be no conflict.

If and when the armed services should decide that such larger quantities of high-octane aviation gasoline are needed, there are ways by which this demand can be met by the industry without diminishing the flow of butylene to the butadiene plants.

It is fortunate that the program for the needed plants is generally in the hands of as competent engineers as there are in the country. Probably the most interesting and satisfying part of our study is the confidence we have acquired in the men from industry who have the plans in hand and who are satisfied they can lick the problem in the given time. Their competence and experience, their resourcefulness and ingenuity are the best guarantees we have that they can do so. We have been much impressed with the fact that this stupendous undertaking is only possible because of the highly developed skill of our technologists. No one could have examined the facts before us without appreciating the magnitude and scope of the task; no one could have made this study without realizing that because of the shortsightedness and failure to act on technically sound advice we must now proceed with insufficient experience. On this basis we venture the statement that never on the basis of so little has so much been involved. Under these uncertainties the only recourse is to provide ample margins when in doubt.

The Problem of 1943

The year 1943 is so critical for the rubber situation that the production of 100,000 tons more or less of Buna-S might be a determining factor in the success of our military program. In view of the extremely precarious situation in 1943 the committee recommends the prompt increase of 100,000 tons a year of butadiene over the present schedule, to be obtained by a refinery conversion program. This can be accomplished with a very small expenditure of critical materials. This recommendation is designed to accomplish three ends: (1) fill the gap between butadiene production and polymerization capacity in the early part of 1943 (for the minimum polymerization capacity exceeds that for butadiene production and according to present schedule the two will not come together until the middle of 1943); (2) provide a reserve of stand-by capacity for the later years of the program; (3) furnish valuable insurance against contingencies affecting other plants in the program and provide additional facilities to meet possible increased demands of the armed services.

Due to the pressure from various sources there have been, even in very recent days, belated efforts to change from the present butadiene plants scheduled by the government to the refinery conversion processes. The first thought that occurs to the committee is, "Why now? Why not months ago? Why the sudden activity? And, above all, why substitute at this late date?" We have recommended an *increase, not a substitution,* of a refinery conversion program. We have made this recommendation, in order to produce more rubber during the critical year 1943. We should like to emphasize again that it would be a major blunder to make a further change inside the program at this date by the substitution of one process for another.

To obtain the maximum utilization of the combined refinery conversion program, we recommend a prompt increase in the rate of construction of polymerization facilities and of the styrene plants to balance the program upwards so that the maximum possible amount of Buna-S might be produced in 1943. If this expectation and the optimistic estimates of the present schedule are realized, the Buna-S produced in 1943 might be as much as 450,000 tons. Even this amount will not provide too large a margin of safety when it is recalled that our "carry-over" to 1944, assuming only a 400,000-ton Buna-S production, does not exceed 100,000 tons.

Looking Ahead to 1944

The present plans call for the building of polymerization plants with a rated annual output of 705,000 tons of Buna-S. If the 100,000 short tons of butadiene (equivalent to 110,000 tons of Buna-S) provided by the refinery conversion program are to be utilized when the program is complete, additional facilities for polymerization must be provided and likewise for the manufacture of styrene. While there is evidence that the butadiene plants may produce 15 per cent to 20 per cent above their rated capacity our experts have found no indication that a similar situation exists with respect to the polymerization plants.

The WPB has fixed the total annual output of Buna-S at 705,000 tons. The committee recommends that this figure be raised now by 140,000 tons, and that this be accomplished by authorizing (a) the construction of the additional polymerization facilities and styrene capacity, to be ready by January 1, 1944, which are required to balance upwards the annual production of the refinery conversion program (110,000 tons of Buna-S) and (b) the later construction of a 27,000-ton butadiene plant and a 30,000-ton polymerization plant to be located near the center of grain production. The committee recommends that the Rubber Administrator, about six months hence in the light of the situation which exists regarding the best technical process then proven for the production of butadiene from grain, and in the light of the need for additional Buna-S which may then be estimated, proceed with the erection of the 27,000-ton butadiene plant from grain and the associated polymerization plant. He should also make whatever arrangements are necessary to produce and ship the necessary styrene from the centers of styrene production. If the needs for synthetic rubber and the production program are in balance, making due allowances for civilian driving, he may then cancel the erection of this additional 30,000 tons of Buna-S capacity.

The Secretary of Agriculture has assured the committee that no concern need be felt that the expansion of the butadiene from grain program will interfere with our food supplies. After all food requirements that can be anticipated have been met there will be upwards of 1,250,000,000 bushels of wheat left in this country.

This additional Buna-S, which it will be thus possible to produce in 1944, should provide the margin required for relaxing the restrictions on civilian driving. As we have pointed out earlier in this report, if by the end of 1943 the synthetic rubber manufacture is in satisfactory shape and the military needs for rubber have not increased, it should be possible to allocate considerable quantities of Buna-S for civilian needs. We shall not need the 140,000 extra tons of Buna-S until 1944, when it will be required for tires for passenger cars. Without at least half this amount in that year, a great many passenger cars would be forced off the road; for it is at that time that we shall have to begin to repay the rubber which we have been borrowing, so to speak, by running our cars without a tire replacement and recapping program during the past eight months.

By delaying the construction of the extra polymerization facilities for six months we shall in all probability prevent a serious conflict between this eventual expansion of the Buna-S program and other aspects of the war program. There is every reason to believe that the shortage of critical materials will be less acute six to eight months from now, and this will certainly be true in regard to facilities for fabricating special chemical equipment.

Our recommendation for additional 27,000 tons of butadiene capacity to be located near the center of grain production is made with this time schedule in mind. This plant (together with the corresponding 30,000-ton Buna-S plant) need not be started for another six months. There will be relatively little cost to the war effort involved in its construction for the reasons just given in regard to the easing of the situation in respect to the fabrication of equipment. Furthermore, another advantage will accrue. At that time—six months hence—it will be possible to judge the relative merits of two processes for the manufacture of butadiene from grain which are not now in the government program, namely, the Publicker process using alcohol and that employing butylene glycol developed by the Department of Agriculture in Peoria. This latter method involves a special fermentation of grain. These two processes should be carefully compared with the alcohol process developed by the Carbide and Carbon Company and now a major part of the government's plans. At present insufficient data are at hand for an evaluation. A few months from now this will no longer be the case.

It is clear to the committee that new facilities for producing alcohol from grain must be provided. More alcohol may be required for the production of butadiene in plants under construction; if not, the extra capacity will be useful in the explosives program. The estimates we have obtained from the most reliable sources vary, but in all likelihood a considerable quantity of additional alcohol must be on hand in 1943 and 1944 to meet both the synthetic rubber and the explosives program. We recommend that these facilities be erected on a site near the grain-producing states and located on water transportation. By the use of recently developed apparatus, alcohol plants can be constructed with little expenditure of critical materials.

If the Rubber Administrator should decide that the plants for the production of the additional 30,000 tons of Buna-S which we recommend should be constructed during late 1943, they should be located near the center of grain production and such units should if possible be operated under the control of an independent local group. Diversification of the synthetic rubber industry from the point of view of both geography and control seems important to the committee. Another element in the competition would be provided if this recommendation is carried out.

We may sum up our recommendations in respect to the Buna-S program as follows:

1. There should be no further changes in the plans now laid for the construction of the scheduled plants—the time to freeze has passed in view of the urgency of 1943.
2. The authorization of an additional 140,000 tons of Buna-S capacity per year.
3. Proceed immediately with a conversion of refinery plants to produce a total of 100,000 tons of butadiene by this process, this being in addition to the butadiene now planned from other processes in the present program.
4. Promptly make an adjustment in the construction rates of the present styrene and polymerization plants, in order that the maximum amount of Buna-S may be produced in 1943.
5. Expand the polymerization and styrene facilities to be ready on January 1, 1944, to balance upwards the entire program.
6. About six months hence, in the light of the situation which then exists regarding the best technical processes then proven for the production of butadiene from grain, and in the light of the need for additional Buna-S rubber which may then be estimated, proceed as indicated with the erection of a plant to produce an additional 27,000 tons of butadiene from grain through alcohol or butylene glycol and with the erection of an associated additional polymerization plant to produce 30,000 tons of Buna-S, both to be located near the center of grain production. Also make whatever arrangements are necessary to produce and ship the necessary styrene from the centers of styrene production.
7. Proceed promptly with the erection of an alcohol plant to produce 100,000,000 gallons of alcohol per year, by the use of recently developed apparatus. This plant could be erected on a site near the grain-producing states and located on water transportation.

Finally, as a further margin of safety, considered only from the point of view of filling military needs, *we recommend the construction of an additional plant for the production of neoprene to the* *extent of 20,000 tons a year capacity. We make this recommendation because* neoprene is the one synthetic material of a quality to be the full equivalent of natural rubber for combat and heavy-duty tires, either by itself or in combination with Buna-S.

The relatively high cost of this substance in terms of critical materials required for the construction of the plant and electric power needs is offset by its special significance in the rubber program. As an insurance against the distant possibility that we may be cut off from all supplies of natural rubber, we feel that the expenditure involved to provide an additional margin of safety is not too great.

Four large rubber companies already have developed their own polymerization facilities, each one differing somewhat from the others. Each represents the best efforts of a separate group of keen technical men. Last May, Rubber Reserve decided to standardize all the new polymerization plants which were to be constructed; this means, in essence, also standardizing the operation.

The design that is now ready is a compromise of the ideas of four separate technical groups. It may or may not incorporate the best ideas of each; on this point grave doubts have been expressed to the committee. At all events, no one has ever operated such a standardized plant. The need for the immediate construction of one such standard plant so that experience with its operation can be obtained at the earliest moment is evident. It is our recommendation, therefore, that one of the standard plants now on the schedule be rushed to completion as quickly as possible.

The recognition of the importance of technological competition leads us to make two recommendations in regard to the operation of the polymerization plants:

First, one or more corporations controlled by the smaller rubber companies and chemical companies interested in polymerization should operate a certain number of these standard plants.

Second, at the same time, to keep the competitive urge to improve the new art of polymerization, we recommend that as part of the program each of the four large rubber companies be allowed to expand their facilities according to *their own design,* if they so prefer. We feel sure that the pride of authorship, as strong among technical men as among artists, under these conditions will yield in a short time a rich harvest to the nation. Adoption of this second recommendation would not retard the program, for the expansion should be provided in that portion of the program we have recommended which requires additional polymerization facilities to be ready about January 1, 1944, to balance the refinery conversion program.

The nation as a whole is endeavoring to provide for the development of essentially novel manufacturing operations on a vast scale. How this program is managed and the spirit in which it is carried forward seem to us of great significance. Unlike the production of ammunition, the enterprise has implications for the postwar period. For a double reason, therefore, the nation is concerned lest special groups play too large a part in the construction and operation. For the rapid development of the new art this committee is fearful lest the influence of governmental policy serve to discourage the beneficial rivalries of the best brains in industry. We believe, therefore, that, on the one hand, there should be complete interchange of information and, on the other, as much competition in research, development, and operation as possible. Such, after all, are the conditions applying in the field of laboratory science where during the last hundred years tremendous strides have been made. Competition and co-operation in this new national effort, we believe, should go hand in hand.

In concluding this section of the report which deals with the synthetic program, the committee wishes to make special mention of the fact that there are a number of materials in the offing which give promise of considerable significance in the future development of rubber substitutes.

In particular, Flexon, which is very similar to Butyl rubber, is now undergoing careful tests to determine its utility in the manufacture of tires and as a recapping material. Flexon has an advantage over Butyl rubber, in that it can be made more quickly and the plant involved does not require any large amount of critical materials.

The production would be limited, however, by the amount of solid carbon dioxide (dry ice) that would be available. The process is a wasteful one from the point of view of isobutylene, a raw material which is also of great value to the aviation gasoline program. As the tests of Flexon stand today, the committee does not feel that it can recommend the inclusion of any large production in the present program. However, in the course of a relatively short time the art of manufacture may be improved and one of the chief present drawbacks, namely, the lack of uniformity in different samples, may be overcome. If later tests prove the usefulness of this substance, its production then could be undertaken in considerable quantities.

Another rubber substitute which we are not recommending in our program, but which is nevertheless in an interesting state of development, is the material known as "noropol," prepared by a series of chemical reactions from soya bean oil. The process of manufacture seems entirely feasible, but the tests have not yet gone far enough to demonstrate the worth of the material in the manufacture of tires or recaps. It will undoubtedly have value as a substitute for rubber in certain mechanical goods.

Several other developments of a similar nature have been called to the committee's attention, but all are as yet in the laboratory stage. The committee hopes that experimentation will continue and facilities be provided so that these new substances which show real promise may be tested thoroughly and eventually find their proper place in the national economy. Necessity requires the country to stop tampering with the present synthetic rubber program in order to produce the maximum amount of usable material in the coming year. It would nevertheless be most unfortunate if this situation should prevent the development of other materials or new methods of manufacture.

7

Priorities

The committee wishes to emphasize and re-emphasize the absolute necessity of having the maximum amount of synthetic rubber produced in the year 1943. As we have said before, this turns largely on the rate of completion of the plants now scheduled. No one of these plants of any considerable capacity has been completed as yet. Many of them are not yet even started. We have found that, although there is every reason to believe the construction schedule can be met so far as the time of fabrication and construction is concerned, there is grave doubt whether the plants will actually be erected as planned unless something is done at once to change the situation in regard to the flow of materials to the fabricators.

We therefore recommend that urgent attention be paid to this phase of the rubber problem. We already have pointed out the dangerous situation the country would face if even four months of delay in the program should occur. Indeed, it is clear that the whole problem of critical materials is intimately associated with the problem of producing sufficient synthetic rubber in 1943 to tide us through the crucial year, and the President has asked us to make a report on critical materials.

Much has been said of shortages in critical materials. There are two kinds of shortages: the first where there is not enough to go around for essential purposes; the second type of shortage is that where, though sufficient exists, it is short in the sense of not being available when and where it is urgently needed. There are a few materials short in the first sense, but many have been short in the sense of failing to be where needed when needed.

This has been due to permitting materials to be used for purposes not essential to the conduct of the war; to the lack of a vigorous policy of conservation, inventory control, and the finding of substitutes; and most of all, to the changing, complicated, and ineffective efforts at material distribution and priority control.

Shortages have been accentuated by superimposing upon the heavy military demands and delayed conversion of civilian industry to war purposes, a vast war construction program approximating seventeen billion dollars. This program will be nearing completion by the end of this year and will thus release large amounts of construction materials. It is estimated that 70 to 80 per cent will be finished about January 1, 1943, and all about July 1, 1943.

After this, provided vigorous measures are taken to increase supplies, find substitutes, press research work, complete the process of conversion, effect the utmost in conservation, inventory control, standardization and simplification, and above all to perfect a simple, sound, and workable system of priorities for the distribution of materials, unless demands are greatly increased, shortages should be much reduced and the bottlenecks in critical materials become fewer.

There has been often an attitude of complacency and a failure to take the vigorous measures necessary to increase supplies, working closely with the industries concerned. There has been some disposition to accept the "impossible" instead of trying to overcome it.

The military men must decide what things come first in war production, but it is the duty of this committee to point out that unless the flow of materials for the construction of these synthetic rubber plants is insured there will be no rubber in the fourth quarter of 1943 with which to equip a modern mechanized army.

8

Administration

The committee finds that a number of different government agencies have had overlapping jurisdiction in regard to the synthetic rubber program. This has caused delay and confusion. In particular the conflict between Rubber Reserve and OPC has complicated in recent months the bringing in of new facilities for the production of butadiene from oil. The committee has been unable to determine, in spite of many inquiries, as to where the responsibility has lain for many of the decisions which have been made in the last eight months.

The failure of the government to provide a clearly recognized group of independent experts who would make technical decisions has added greatly to the public confusion and uncertainty. The reliance on one part-time technical adviser, aided by committees drawn from industry has, in the opinion of the committee, been insufficient for the development of an entirely new industry involving an investment exceeding $600,000,000. The technical adviser has testified that on more than one occasion he requested the appointment of an adequate technical staff.

It would have been wise administration for the officials in charge of policy to have delegated to a competent technical staff the function of collecting information about the various processes. Such a staff should have been relied upon for supplying through regular channels the data on which all important decisions were made. Instead of such orderly methods of procedure we have found many evidences of a chaotic situation in which nontechnical men have made decisions without consultation with subordinates nominally in positions of responsibility.

There have been many adjustments and readjustments—a "stop and go" policy—in the synthetic rubber program. Some of these were inevitable; some appear to be the result of bad administration.

There is clear evidence that the situation with respect to the alcohol supply was altered between the fall of 1941 and the spring of 1942. What had once been a deficiency became an apparent surplus. As a result of this change the proportion of alcohol- and petroleum-based processes in the synthetic rubber program was altered. A more adequately staffed organization might have foreseen earlier the changed situation and altered the program a few months earlier.

As another example of faulty administration we may mention the failure to obtain early in this year the detailed information concerning the Russian process for making synthetic rubber. Russia has been manufacturing synthetic rubber successfully for more than ten years. It would seem natural to have endeavored to benefit from this experience as soon as rubber became of major concern to the United States. If the Russian offer made in February to exchange men and information had been accepted and Russian engineers with blueprints of manufacturing had been rushed to this country last winter, it is conceivable that plants for producing synthetic rubber by the Russian process might well be now on the way to completion. To date we have no detailed information as to the process and no samples of Russian tires have as yet been obtained. Every effort ought to be made to obtain this information.

The dissemination of full information concerning the compounding of Buna-S to all companies has become an accomplished fact only in the last few days. An agreement was entered into on July 3rd of this year between the Rubber Reserve Company and the four large rubber companies. According to this agreement, Rubber Reserve alone was permitted to give out information to the other rubber companies. But in fact it did not do so for some six weeks in spite of repeated efforts of the Rubber Branch of WPB to have the information released. In view of this situation one hardly needs to point out that there has been very imperfect co-operation between the Rubber Reserve Company and the Rubber Branch of WPB.

Because of the record briefly summarized above, we recommend:

A complete reorganization and consolidation of the governmental agencies concerned with the rubber program.

The War Production Board must assume full responsibility for the rubber program in all of its phases. We therefore recommend a directive from the President ordering the Rubber Reserve Company and all other government agencies to act in all matters relative to the rubber program as directed by the chairman of WPB.

To discharge adequately the responsibilities which we recommend that the chairman of WPB explicitly assume for the entire rubber program, full authority must be centered in a single official. We therefore recommend that the chairman of WPB appoint a Rubber Administrator and delegate to him full and complete authority in regard to the manufacture of synthetic rubber, including research, development, construction, and operation of plants. This single official, who must be a man of unusual capacity and power, must also have full charge of all matters connected with rubber within the WPB. It should be his duty to formulate policies and administer the operation of the rubber program subject only to the chairman of WPB, who should divest himself of all direct concern with these matters. Good administration dictates that the Rubber Administrator use the available facilities of other government agencies in the execution of the program, but his decisions and not theirs must control.

We recommend that particular care be directed to the establishment of a Technical Division, under the immediate control of the Rubber Administrator. We also recommend that the Construction Division of Rubber Reserve be designated by the Rubber Administrator as the agency to supervise the construction of all plants under the rubber program.

It will be a matter of great importance to have the Technical Division adequately staffed and provided with branches in charge of all the various phases of research and development, except for the production of butadiene from petroleum which is referred to in the next recommendation.

The Rubber Administrator, acting on authority delegated by the chairman of WPB, should have the sole responsibility for supervision of operation of *all government plants* engaged in the production of rubber. In the execution of that responsibility he may utilize other agencies of the government upon their agreement thereto, but shall not be required to do so, and he shall cancel such arrangements when satisfactory results are not obtained.

Funds must be made available at once to WPB to provide for the staff under the Rubber Administrator and to enable him to place such contracts as he may deem necessary in connection with research and development.

We further recommend that the Petroleum Co-ordinator be directed by Presidential Order to act on specific directives from the chairman of WPB, acting through the Rubber Administrator, to explore all methods for the production of butadiene from petroleum and natural gas products and recommend new proposals to the Rubber Administrator for his consideration and action.

The construction of all plants and equipment concerned with the production and purification of butadiene from petroleum should be under the authority of the Rubber Administrator, who we recommend shall designate the Construction Division of Rubber Reserve to carry out this function.

This provision is necessary in order to unify control of the construction program and make certain that no delays ensue by reason of conflicting authority and personalities. The Petroleum Co-ordinator should have supervision of the operation of the plants for the manufacture of butadiene from petroleum and natural gas products after completion of construction, but he should be directed not to modify the presently authorized construction program or the plans for operation except as approved by the Rubber Administrator.

We further recommend that in the Office of Petroleum Co-ordinator there be created a new Technical Division responsible for research and development in connection with all problems of the manufacture of butadiene from petroleum; funds for this purpose should be provided to OPC.

This specific delegation of responsibility to the Petroleum Coordinator is made in order to secure complete co-ordination of the butadiene program with other petroleum and natural gas requirements, especially for aviation gasoline and for toluene for explosives.

As the situation develops it may be desirable for the funds required for the entire rubber program to be put directly at the disposal of the chairman of WPB for the purposes of the Rubber Administrator instead of, as at present, indirectly through RFC.

The most important part of the plan is obviously the choice of the right man for the position of Rubber Administrator. He should be a thoroughly competent operating and manufacturing executive, preferably with experience in the rubber industry. The demand for speed and the vital need for this man to start with experience and knowledge of the problem make it important that the man chosen be of proven integrity and enjoy the public's confidence and that of the rubber industry as well. We cannot stress too much the importance of choosing the right man for this work, for no plan of organization can bolster up a weak man sufficiently to meet the difficult problems he must face.

One of the problems presented to this committee has been the difficulty of determining the future needs of the war program for rubber and the components required for the manufacture of synthetic rubber and substitutes. This difficulty arises from the unpredictable character of the war operations as to location, kind of war, and equipment employed under various conditions. In spite of these and other such difficulties, there is need for determining the requirements on an authoritative basis. Every aspect of the rubber problem must be under continuous review by a man whose sole responsibility it is. The most we can do is to appraise the present situation and indicate a sound course for the future.

A program can be no better than its administration; therefore we place special emphasis upon these series of recommendations and wish to state that unless they are followed there can be no assurance of the successful development of the synthetic rubber program within the time required.

9

Agricultural Program

Various plants which can be grown in the United States have been suggested as sources of rubber. Thomas Edison's experiments with goldenrod are an example. Kok-saghiz, a Russian dandelion, is considered promising in the U.S.S.R. as an auxiliary source of rubber, and seeds have been sent to the United States for test planting. However, the two agricultural possibilities which show most promise for the United States are guayule and Cryptostegia.

Guayule is a shrub grown freely in Mexico and the American Southwest. It contains a high percentage of rubber which is extracted from the entire plant. Best yields are obtained after four years' growth, but the shrub can be harvested any time after two years.

The Department of Agriculture has undertaken a large program of guayule cultivation in California, based on an initial independent planting of 500 acres in 1930. With seeds on hand and the expected harvest this month, there will be sixty-six tons of seed available for further planting. The seeds must be planted in a nursery and after one year transplanted to the field. The plans call for planting an acreage increasing to about 180,000 acres by the end of 1944. If this program is carried through, it is anticipated by the department that there will be crude rubber available from this domestic guayule rising from 600 short tons in 1942 to about 33,000 in the fall of 1944, about 47,000 tons in the fall of 1945, and increasing thereafter.

The committee believes that these estimates are overoptimistic but that the project is inherently sound and should be supported. The committee therefore recommends that this program be given every possible support as the principal source of crude rubber which could not be lost to us short of conquest of American territory. In order to proceed with this program, however, certain things must be given immediate attention since the program will be delayed one year unless the following actions are taken before about October 1st.

(1) Authorization must be secured to plant additional acreage. There is a question as to whether or not existing legislation would prevent the planting of more than 75,000 acres of guayule. This

restriction, if it exists, must be removed very promptly if the program is to go forward on a really significant scale.

(2) The second item is the procurement from WPB of adequate priorities to secure the amount of farm equipment which would be required to prepare the land and plant the seeds. This, again, must be done very promptly to meet the fall planting season.

There are additional requirements for the success of the program, which are sought by the Department of Agriculture and to which the committee gives its support.

Cryptostegia is second in importance among rubber-producing plants capable of substantial scale production in the United States. This vine will grow wild in Florida and other southern states. It contains only 2 or 3 per cent of rubber, but this is of high grade and can be secured from the leaves harvested each year from the perennial vines. A plan to plant these vines extensively this year has met with relatively small success, owing to a delay in securing authorization for the gathering and purchase of Cryptostegia seeds from wild-growing vines in Mexico. This authorization was another instance of "too late," and was secured just after the seeds had scattered. There is little to be lost and much might be gained by pursuing this program vigorously when the next opportunity arises next year.

10

Rubber Goods Manufacturing Capacity

A very important consideration in connection with the synthetic rubber program has to do with the capacity of the country to manufacture rubber goods out of the natural and synthetic rubbers which will be available. It would be obviously foolish to carry through a program of plant construction for the manufacture of synthetic rubbers only to discover too late that the factories for the manufacture of tires, electrical insulation, footwear, and other rubber goods have insufficient manufacturing capacity to handle the material. The committee has made a survey of these facilities and finds that, as matters now stand, there may indeed be a deficiency of factory capacity to handle the synthetic rubber when it comes into full production.

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The committee's findings and recommendations in the matter of manufacturing plant capacity are given below under three headings: rubber goods manufacturing capacity, recapping capacity and reclaim rubber capacity.

1. *Rubber goods manufacturing capacity.* The significance of this problem is indicated by the following facts:

(a) The largest previous year's use of rubber goods in the United States was 775,000 tons of crude rubber in 1941.

(b) The largest monthly production in the history of the rubber manufacturing industry used at the rate of about 1,000,000 tons per year of crude rubber,—a rate which could not be continuously maintained.

(c) The present governmental program calls for the procurement of about 68,000 tons of crude rubber and approximately 910,000 tons of synthetic rubber substitutes in 1944. The recommendations of this committee would raise the total of these synthetic materials to about 1,100,000 tons.

(d) The processing art as developed at present requires more time, on the average, to fabricate than for the same tonnage of natural rubber. The committee estimates that, on this account, the manufacturing capacity today for synthetic rubber is between two-thirds and three-fourths of what it would be for handling natural rubber.

These facts would indicate that the capacity of the country would have to be increased substantially to handle the quantities of synthetic rubber which will be produced in 1944. However, the following compensating factor must be taken into account:

(e) During recent months technical developments in the processing arts have proceeded very rapidly and the time required for the manufacture of synthetic goods is being reduced. For example, during the short existence of this committee, means have been found for doubling the speed with which milling and mixing operations can be performed with Butyl rubber. Similar advances are being made in handling the other synthetic rubbers. There is reasonable expectation, therefore, that the intensive technical research program, now being carried on by the rubber companies, will substantially increase the speed with which synthetic rubber goods can be manufactured and therefore increase the manufacturing capacity of the factories.

For this reason *the committee recommends that the Rubber Administrator institute a survey of milling, mixing, and tire building facilities, on about March 1, 1943.* This survey should determine the extent to which these facilities must be expanded in view of the processing and tire building art at that time so as to handle the expected volume of synthetic rubber in 1944, after allowing for export of rubber stocks.

The committee is informed by the rubber manufacturers that a decision on this matter made by April of 1943 would permit the manufacturing companies to add whatever additional manufacturing facilities might be required, in adequate time to meet the manufacturing schedules of 1944—provided the necessary priorities are given for the procurement of the necessary equipment.

2. *Recapping facilities.* The total recapping capacity of the United States, exclusive of the tire building facilities of the tire manufacturers, is approximately 16,000,000 passenger tire recaps per year. This might be increased to 19,000,000 by operating at full capacity with extra shifts. The program recommended by the committee for tire replacement and conservation may call for as many as 25,000,000 recaps per year. To meet this deficiency *the committee recommends utilization of tire molds of the tire recapping plants* so as to meet any excess demand for tire recapping.

3. *Reclaim rubber capacity.* The program of recapping for the conservation of civilian passenger tires, contemplates principally the use of reclaimed rubber. Other essential uses of rubber goods also call for reclaimed rubber. The armed services have gone far in substituting reclaimed rubber for natural rubber wherever circumstances permit, as a measure for the conservation of crude rubber. All these demands for reclaimed rubber will somewhat exceed the capacity of the present rubber reclaiming plants of the country and indicate the necessity for providing some increase in this capacity.

The committee is convinced that the quickest and most economical manner of securing increased rubber reclaiming capacity is by working through the existing experienced reclaiming companies rather than by erecting new and independent reclaiming facilities to be operated by a relatively inexperienced group.

The committee therefore recommends that the reclaim rubber manufacturers, through their National Rubber Reclaimers Association, be requested to submit to the Rubber Administrator a program for increasing by about 20 per cent the present rubber reclaiming facilities of the United States, and that authorization be then given to carry through such measures as may be necessary in the form of priorities, financial aid or contracts to secure this increase in rubber reclaiming capacity during 1943.

Several methods have recently been reported for increasing the useful qualities of reclaimed rubber. At least one of these is reported to involve only the use of chemicals which are not difficult to obtain in the present war economy. The committee recommends that every encouragement be given to the further development and application of these new processes. Such encouragement could take the form of priorities for procurement of the necessary experimental materials and also financial aid, if necessary.

II

Scrap Collection

No one can estimate with certainty the amount of scrap rubber in the United States. A reported 450,000 tons of scrap rubber were collected in the drive inaugurated by the President last June. This gross tonnage should yield about 350,000 tons of reclaimed rubber, but there is reason to believe that the actual amount of scrap collected is considerably below the above figure because of duplicated reporting of collections.

There have been sensational claims regarding the amount of scrap rubber still uncollected in the country. The committee has investigated some of these claims and has found them utterly without foundation in fact.

It is nevertheless true that the rubber now in the scrap piles of the country, together with anticipated current receipts, is sufficient to feed the rubber reclaiming plants at full capacity for about eighteen months. During this time further scrap collections will continue through the normal operations of scrap collectors and junk dealers. In addition to this supply the armed services have instituted, as part of their program of rubber conservation, an inspection system which will insure that damaged tires from military vehicles will be repaired if possible, and if not capable of repair will be assembled through scrap collecting agencies and thus fed into the nation's scrap stockpile.

Still another supply of scrap rubber will come automatically if new tires are rationed to civilian drivers in accordance with the recommendations of this report, since a condition for the procurement of a new tire will be the turning in of the worn-out tire for scrap.

With these supplies of scrap rubber in sight there will be adequate time for the careful preparation of another national scrap rubber drive well in advance of serious depletion of the existing stocks. The committee recommends that this drive be carefully prepared in advance to secure its maximum effectiveness, and to this end suggests that the Rubber Administrator take the initiative in selecting and directing the proper agencies for the organization and conduct of this drive. The committee further believes that these steps can most advantageously be undertaken about a year hence.

Elsewhere in this report the committee makes a number of recommendations in regard to the increased production and more efficient use of the reclaimed rubber produced from this scrap.

12

Technical Suggestions for the Rubber Administrator

As a result of the study made by our experts the committee has been in a position to evaluate a number of technical points in connection with the rubber program. Therefore we have a number of recommendations to make of a minor nature which we should like to pass on to the man who, we hope, will be in charge of the rubber program as Rubber Administrator. We shall assume that he will immediately place a highly competent man on a full-time basis in charge of his Technical Division, and it is to that man in particular that these suggestions are directed.

1. We recommend the immediate installation of one or more small commercial pilot plants using the catalyst system developed by Standard Oil of New Jersey operating on butylene feed stock. These should be completed with fractionating towers and refining systems to the end that they may serve as training plants for the study of any difficulties that may be experienced in bringing the large units into operation at rated capacity, and for trying out suggested means for improving the over-all operations.

2. We recommend that one of the large-scale plants operating on this same process should be given as high priority rating as possible to insure that it is completed by March, 1943, so that experience may be gained on the full-scale operation of this plant. Although our experts have no doubt that the engineering data provided by the small-scale experiments are adequate for the design of the large plants, it is clearly a difficult and somewhat uncertain matter to make the transition to the full large-scale plant which must be operated.

3. We believe that the purification of butadiene deserves further investigation both in the laboratory and in the pilot plants.

4. The committee has explored new and novel substitutes for conventional rubber tires, largely through access to a very full survey of such devices conducted by a special committee of the Society of Automotive Engineers at the suggestion of the National Inventors' Council.

Among these devices one stood out as possessing promise of giving relief to the less essential drivers in urban areas during the next few critical years. It is the "sandal" developed by one of the large rubber companies, and consisting of a section of carpet impregnated with asphalt and easily fitted over an ordinary tire which has been too far worn to be used further with safety. On asphalt or concrete street, and at very moderate speeds, these sandals have a life of between 1,000 and 2,000 miles. Using no critical materials and easily manufactured, they may provide temporary relief to drivers who may otherwise be unable to continue driving their cars. The committee considers this to be an interesting possibility in the emergency and recommends that it be further studied.

5. The committee recommends that the policy of encouraging

inventors and research groups working on the development of rubber or rubber substitutes should be adopted. This encouragement might take the form of granting priorities for critical materials, where the amounts required are not excessive, for experimental and pilot plant development.

6. Recognizing the necessity for providing a real incentive to conserve crude rubber by finding ways of substituting synthetic, we favor the plan that was suggested by the Synthetic Rubber Section of the Chemical Branch of the War Production Board. This provided for a greater than proportionate increase in a manufacturer's synthetic rubber allocation if he could increase the percentage of synthetic rubber in his product.

Inadequate supplies of synthetics have forced postponement of this plan for the time being, but we suggest that it be reinstated in the program when large-scale production of synthetic rubber is attained. A further incentive for increasing the use of synthetics may be provided, within the limits of product specifications, by raising the price of crude relative to synthetic rubber.

7. Polyvinyl resins are now being used as rubber substitutes at a rate which corresponds to a saving of approximately 22,000 tons of crude rubber per year. Other substitutes are under consideration, but there is no well-defined clearinghouse in any government agency at the present time for promising materials. Suggestions come in to the Rubber Reserve Company, War Production Board, the OPA and various other government organizations, but center at no definite point, with the result that there is duplication of effort and delay in evaluating such new materials. This should be centered under an official reporting to the Rubber Administrator.

8. There appears to be considerable confusion in regard to the military involving rubber substitutes. Several branches of the Navy and the Army each have been searching for rubber substitutes and are in competition with each other to obtain scarce materials. The Rubber Administrator should furnish the proper liaison for the armed services and should center research along these lines under his own control.

9. The committee suggests the institution of a prompt survey to determine the number of chemical engineers and other technically

trained men who will be required to operate the synthetic rubber plants now under construction. And if this survey indicates a serious shortage of such technical talent, that the Man Power Commission be called upon for assistance in devising a policy for meeting the situation.

10. Inspections of a large number of crude and scrap rubber stockpiles and examination of the methods being used for their protection have convinced the committee that this situation is generally satisfactory. A number of spots were found, however, where protection is definitely inadequate. While commending the inspection program now set up by Rubber Reserve Company, the committee suggests the advisability of more adequate protection through additional armed guards wherever a hazardous situation is found to exist. These stockpiles constitute some of the most critical possessions of the nation.

11. The committee also suggests the introduction into the manufacture of "camelback" for the retreading of civilian tires, the practice of adding up to 20 per cent of finely ground tire treads into all reclaimed rubber tread stocks. This practice will improve the wearing qualities of the reclaimed rubber required for their production. This will be equivalent in its results to a further increase of between 10 per cent and 20 per cent in the capacity of the reclaim rubber plants.

CHRONOLOGY OF GOODYEAR'S LIFE

1800—Born at New Haven.

1816—Forsakes plan to enter ministry to work at his father's factory at Naugatuck.

1818-21—Serves apprenticeship in storekeeping at Philadelphia and returns to work in his father's factory.

1824—Marries Clarissa Beecher, Yankee.

1826—Returns to Philadelphia to open the first retail hardware store in the United States, a shop serving principally as an outlet for his father's manufactures.

1830—After severe illness and a poor start in business, Goodyear falls into bankruptcy and is tossed into debtors' prison, having voluntarily assumed personal responsibility for all the store's debts.

1832—Becomes interested in the manufacture of rubberized cloth and launches his own experiments with rubber.

1835—Again in jail for debt, he continues his experiment there and discovers that magnesium prevents surface stickiness of rubber.

1836—Discovers a formula for processing crude rubber with quicklime and water. Wins medals but fails to perfect a successful formula.

1837—Discovers that treating rubber with nitric acid enables it to resist heat. Opens factory and store in New York, but both are victims of the hard-hitting financial panic of 1837. Goes to Boston and sells manufacturing license for $5,000.

1839—First discovers process called vulcanizing.

1840—Failure to procure help to complete the process leaves him the task of working out details with primitive and inadequate home equipment.

1841—Applies for caveat for patent for vulcanizing.

1842—Gets capital to build a small factory at Springfield, Massachusetts.

1844—United States issues Goodyear a patent covering discovery of vulcanization. British patent office issues an almost identical patent to Thomas Hancock, two weeks earlier, thereby invalidating Goodyear's British concessions.

1845-51—Years of toilsome patent litigations.

1851—Goodyear wins patent decision in United States, goes to England but fails to gain reversal of Hancock's patent.

1853—His wife Clarissa Beecher Goodyear dies, and Charles marries Juliette Wardell.

1854—He goes to France and places a costly exhibit at the Paris Exposition.

1855—French patent refused on grounds of technicality. While serving time in jail at Clichy, Goodyear receives Cross of the Legion of Honor.

1856—Returns to England, where he is thrown into debtors' prison. On release he goes to Bath in the hope of regaining his failing health.

1858—Returns to the United States to find his business affairs badly managed.

1860—Dies heavily in debt in a New York hotel room while hurrying to the bedside of his daughter, who is critically ill.

BIBLIOGRAPHY

1. *Rationed Rubber and What to Do about It,* Williams Haines and E. A. Hauser. New York: Knopf, 1942.
2. *Rubber and Its Uses,* Harry L. Fisher. Brooklyn: Chemical Publishing Company, 1941.
3. *The Chemistry and Technology of Rubber,* edited by Carroll C. Davis and J. T. Blake. New York: Reinhold Publishing Corporation, 1937.
4. *The Science of Rubber,* edited by K. Memmler; trans. by R. F. Dunbrook and V. N. Morris. New York: Reinhold Publishing Corporation, 1934.
5. *India Rubber Manual,* John Ferguson. Colombo, Ceylon: A. M. & J. Ferguson, 1899.
6. *Rubber Red Book,* Annual Directory of the Rubber Industry. New York: Rubber Age Publishing Company.
7. *Latex and Its Industrial Application,* Frederick Marchioma. New York: Rubber Age Publishing Company, 1933-1937.
8. *The Rubber Industry: A Bibliography,* P. W. Parker, Leather and Rubber Division, Bureau of Foreign and Domestic Commerce, Department of Commerce, Washington, D. C., 1935.
9. *Guide to the Literature on Rubber,* Bureau of Standards, Department of Commerce, Washington, D. C., 1941.
10. *Plantation Rubber,* G. Stafford Whitby. London: Longmans, Green & Company, 1920.
11. *Le Caoutchouc,* Paul Bary. Paris: Dunod, 1923.
12. *Rubber: Production and Utilization,* C. Beadle and H. P. Stevens. London: I. Pitman & Sons, 1911.
13. *Modern Progress in Rubber Compounding,* Charles R. Boggs. Boston: Simplex Wire and Cable Company, 1931.

14. *Bud-grafting and Planting Manual,* Rubber Research Institute of Malaya. Singapore, 1939.
15. *Polymerization and Its Application in the Fields of Rubber, Synthetic Resins and Petroleum,* Burk, Thompson, Weith, and Williams. New York: Reinhold Publishing Corporation, 1937.
16. *Rubber: Its History and Development,* Firestone Tire and Rubber Company. Akron, 1922.
17. *Chemistry and Technology of Rubber Latex,* C. Falconer Flint. London: Chapman & Hall, Ltd., 1938.
18. *The Reign of Rubber,* by William C. Geer. New York: Century Company, 1922.
19. *Rubber as an Engineering Material,* B. F. Goodrich Company. Akron, 1941.
20. *Gum Elastic and Its Varieties, With a Detailed Account of Its Applications and Uses,* Charles Goodyear. New Haven, 1853-1855.
21. *Rubber and Gutta Percha,* Imperial Institute. London: Darling & Son, 1912.
22. *The Uses of Rubber in Commercial Horticulture.* London: Rubber Growers' Association, Inc., 1937.
23. *Rubber and Its Relatives,* International Bureau of American Republics. Washington, D. C.: Government Printing Office, 1909.
24. *India Rubber and Other Plastics,* Eighth Congress of Applied Chemistry, Washington and New York, 1912. Concord: Rumford Press, 1912.
25. *Chlorkant Schukanstrichnittle,* Fritz Kolke. Berlin: Union Deutsche Verlagsgesellschaft, 1938.
26. *Rubber and Rubber Planting.* Cambridge: Cambridge University Press, 1913.
27. *Rubber and Automobiles,* Colin Macbeth. London: Rubber Growers' Association, Inc., 1933.
28. *Rubber and Railways,* Colin Macbeth. London: British Rubber Publicity Association, 1939.
29. *The Rubber Tree Book,* W. F. de Bois Maclaren. London: Maclaren & Sons, Ltd., 1913.

30. *Kautschuklacke und Kautschukkitte,* Otto Merz. Berlin: Union Deutsche Verlagsgesellschaft Zucigniederlassung, 1933.
31. *Recherches et Expériences sur le Caoutchouc,* Dr. Lucien Morisse. Paris: A. Challamel, 1908.
32. *Rubber and Its Uses in Mining.* Kuala Lumpur: Federated Malay States Rubber Propaganda Committee, 1926.
33. *Rubber: The Handmaid of Civilization.* Philadelphia: Nicaragua Rubber and Agricultural Company, 1899.
34. *The Physiology and Diseases of Hevea brasiliensis.* London: Dulaw & Company, Ltd., 1911.
35. *Rubber: Physical and Chemical Properties,* Dawson and Porritt. Croydon, England: Research Association of British Rubber Manufacturers, 1935.
36. *The Book and Shoe Manufacturers' Assistant and Guide,* William H. Richardson. Boston: Higgins, Bradly & Dayles, 1858.
37. *Rubber and Footwear.* London: Rubber Growers' Association, 1926.
38. *Rubber,* Philip Schidrowitz. London: Methuen & Company, Ltd., 1911.
39. *Rubber Manufacture,* Hezzleton E. Simmons. New York: Van Nostrand Company, 1921.
40. *An Economic View of Rubber Planting,* Robert Solioa. Singapore: Kelly & Walsh, 1931.
41. *Estate Rubber: Preparation, Properties and Testing,* O. de Vries. Batavia: Drukkereyen Ruygrok & Company, 1920.
42. *The Whole Art of Rubber Growing,* William Wickerly. London: West Strand Publishing Company, 1911.
43. *Hevea brasiliensis or Pará Rubber,* Herbert Wright. Colombo, Ceylon: A. M. & J. Ferguson, 1908.
44. Fourth Congress of International Association for Testing Materials, New York, 1938.
45. *Annual Survey of American Rubber Chemistry,* Engineering Bulletin, Carnegie Institute of Technology. Pittsburgh, 1938.
46. *The Chemistry of Rubber,* B. D. W. Luff. London: E. Benn, Ltd., 1926.

47. *How to Judge Rubber Investments,* Frederic W. Knocker. London: A. Mory, Ltd., 1910.
48. *The African Rubber Industry,* Cuthbert Beatty. London: T. Bale Sons & Danielsson, 1911.
49. *African Rubber Vines,* E. de Wildeman. London: International Rubber Congress, 1911.
50. *The Reforms in the Belgian Congo,* by M. Wendelen. London: International Rubber Congress, 1911.
51. *Borrocha Natural e Synthetica,* Conferencia Realizada. Rio de Janeiro: Mollwo Perkins, 1912.
52. *The Chemistry of Rubber,* Harry Lynn Fisher. Passaic, N. J., 1930.
53. *The Colloid Chemistry of Rubber,* Paul Stamberger. London: Oxford University Press, 1929.
54. *Proceedings of the Rubber Technology Conference; London, 1938,* edited by Dawson and Scott. Cambridge: W. Heffer & Sons, Ltd., 1938.
55. *Cultivation of Ficus elastica,* Claud Bald. Calcutta: Thacker, Spink & Company, 1906.
56. *Red Rubber,* E. D. Morel. Manchester, England: National Labour Press, 1919.
57. *Rubber Regulation and the Malaya Plantation Industry,* Harrison Lewis (vice-consul, Singapore). Washington, D. C.: Government Printing Office, 1935.
58. *Who's Who in the Rubber World,* edited by A. S. Manders. London, 1914.
59. *Diseases and Pests of the Rubber Tree,* Arnold Sharples. London: Macmillan and Company, Ltd., 1936.
60. *Exposicão Nacional de Borracha de 1913 Monagraphia,* Ministerio da Industrie e Commercio, Republic of Brazil. Rio de Janeiro, 1913.
61. *The Rubber Producing Companies.* London: Mincing Lane Tea and Rubber Share Brokers' Association, Ltd., 1917.
62. *The ABC to Rubber Planting Companies in Malaya, Sumatra, and British North Borneo,* M. Sidney Parry. London: F. G. Mathieson & Sons, 1911.

63. *Rubber as a Popular Investment Field.* London: Redway, Mann & Company, Ltd., 1917.

64. *Rubber Companies in the Netherlands Indies,* A. G. N. Swart. Amsterdam: J. H. deBussy, 1914.

65. *The Rubber Position and Government Control,* A. Philipson. London: P. S. King & Son, Ltd., 1924.

66. *Government Control of Crude Rubber: The Stevenson Plan,* Charles R. Whittlesey. Princeton University Press, 1931.

67. *Charles Goodyear: Connecticut Yankee and Rubber Pioneer,* P. W. Barker. Boston: G. L. Cabot, Inc., 1940.

68. *The Romance and Drama of the Rubber Industry,* Harvey S. Firestone, Jr. Akron, 1932.

69. *Annals of Rubber.* New York: India Rubber World.

70. *The Early History of the Rubber Industry,* B. D. Porritt. London: Rubber Growers' Association, 1927.

71. *Rubber: A Story of Greed and Glory,* Howard and Ralph Wolf. New York: Covici, Friede, 1936.

72. *India Rubber Man: The Story of Charles Goodyear,* Ralph E. Wolf. Caldwell, Idaho: Caxton Printers, 1939.

73. *Laws for the Protection of the Rubber Industry,* Decrees of the State of Pará, Brazil, November 6, 1909, to November 6, 1911.

74. *India Rubber Goods Manufacture* by "Factory Manager." London: Maclaren & Sons, Ltd., 1920.

75. *Technology of Rubber,* Kurt Gottlob. London: Maclaren & Sons, Ltd., 1927.

76. *Handbuch der Gummivaren Fabrikation Ein Praktisches Helfsbuch für Fabrikanten Chemiker.* Dresden: Steinkopft & Spreyer, 1906.

77. *Opportunities for Handicapped Men in the Rubber Industry,* Morris and Paul. Cambridge: Bureau of Vocational Guidance, Division of Education, Harvard University, 1936.

78. *The Planting Engineer,* Charles Reid. Colombo: Times of Ceylon Company, 1939.

79. *Rubber Machinery,* Henry C. Pearson. New York: India Rubber World, 1915 and 1920.

80. *The Great India Rubber Case;* H. Day vs. C. Goodyear on the Motion for a Perpetual Injunction on the Equity Side of the Circuit Court of the United States. Trenton: March, 1852. Ford Collection, New York Public Library.

81. *Normal Aging of Compound Rubber,* Harlan A. Depew (a thesis). New York: Columbia University Press, 1928.

82. *Plantation Rubber and the Testing of Rubber,* G. Stafford Whitby. London: Longmans, Green & Company, 1920.

83. *The Rubber Industry in Brazil and in the Orient,* C. E. Akers. London: Methuen & Company, 1914.

84. *The Future of Rubber, Whither or How,* C. F. Dawson. London, 1934.

85. *America Should Produce Its Own Rubber,* Harvey S. Firestone. Akron, 1923.

86. *The World Trade in Raw Rubber,* Ernest Hecht. London: International Rubber Congress, 1911.

87. *Rubber: Its Production and Marketing,* F. R. Henderson. New York: Helin and Company, 1926.

88. *Le Caoutchouc, Etude Economique et Statistique,* José Carlos de Maudos. Paris: Soares, Cillard, 1928; London: Constable & Company, 1930.

89. *Rubber Statistics, 1900-1937,* P. W. Barker, Leather and Rubber Division, Department of Commerce, Washington, D. C., 1938.

90. *The World's Struggle with Rubber,* James Cooper Lawrence. London and New York: Harper & Brothers, 1931.

91. *Traduccao Devidamente Auctorizado do Relatorio Sobre o Valle do Amazona Sua Industria du Borracha e outros Recursos,* E. E. Akers. Rio de Janeiro: Journal do Commerccia de Rodreques, 1913.

92. *Brazilianos e Yankees,* Helio Labor. Rio de Janeiro: Pimenta de Meleo e Cia, 1926.

93. *The Rubber Industry of the Amazon,* Joseph Froid Woodroffe. London: J. Bale Sons & Danielsson, Ltd., 1915.

94. *Particulars Concerning Rubber Cultivation in the Netherlands Indies.* The Hague, 1931-1932.

95. *Nationality of Ownership of Rubber Estates in Malaya,* Donald H. Grist, Bulletin 2, Agricultural Department, Federated Malay States. Singapore, 1936.
96. *Report of the Commissioners Appointed by His Excellency the Governor of the Straits Settlement.* Singapore: Government Printing Office, 1921.
97. *The Rubber Country of the Amazon,* Henry Clemens Pearson. New York: The India Rubber World, 1911.
98. *Rubber Industry of the United States,* P. W. Barker, Leather and Rubber Division, Department of Commerce. Washington, D. C.: Government Printing Office, 1939.
99. *The Rubber Industry,* Gladys Deckseiger and Others, WPA, Work Project 6073-1040. New York, 1937.
100. *The American Rubber Industry,* Walter H. Dickerson. New York, 1936.
101. *Exchange of Cotton and Rubber:* Agreement between the United States of America and Great Britain. Signed at London, June 23, 1939. Washington, D. C.: Government Printing Office, 1939.
102. *Les Caoutchoucs Africains,* Alfred Deweure. Brussels, 1895.
103. *Report on Rubber in the Gold Coast and Sierra Leone,* W. H. Johnson, Colonial Office Reports Series 28. London: Darling & Son, Ltd., 1904.
104. *Rubber in Uganda,* R. Fyffe. London: International Rubber Congress, 1911.
105. *Rubber Problems in French West Africa,* Auguste Chevalier. London: International Rubber Congress, 1911.
106. *Experiment Station Yields of Hevea, 1891-1929,* G. H. Eady, Report No. 18, Agricultural Department, Gold Coast Colony. Accra, 1930.
107. *Austrian Trade in Rubber Products,* Carrol H. Foste. Washington, D. C.: Government Printing Office, 1923.
108. *Across the Andes,* Charles J. Post. New York: Outlook Publishing Company, 1912.
109. *Fordlandia, Brazil,* Pan American Union Bulletin, Vol. 67, pp. 4-15. Washington, D. C., 1933.

110. *Rubber Cultivation in Brazil,* Pan American Union Bulletin, Vol. 47, pp. 60-75. Washington, D. C., 1918.

111. *The Hevea Tree in the Amazon Valley,* Carl D. LaRue, U.S. Department of Agriculture Bulletin No. 1422. Washington, D. C.: Government Printing Office, 1926.

112. *A Crise Amagonica e a Borracha,* J. Mendes. Pará, Brazil: Topagraphia Stantos, 1908.

113. *A Travers l'Amérique Equatoriale: l' Amazonie,* Auguste Plane. Paris, 1903.

114. *Rubber Production in the Amazon Valley,* William L. Schurz, Department of Agriculture. Washington, D. C.: Government Printing Office, 1925.

115. *Improvement of the Yield in Hevea,* Frederick Sumner. Singapore: Kelly & Walsh, 1930.

116. *A Pathological Survey of the Para Rubber Tree in the Amazon Valley,* James Robert Weir, Department of Agriculture Bulletin No. 1380. Washington, D. C.: Government Printing Office, 1926.

117. *Rubber Planting in Mexico and Central America,* Olsson-Seffer. Singapore: Kelly & Walsh, 1901.

118. *El Caucho,* M. L. Erale. Circular 13, Estación Central Agronomie, Santiago de las Vegas, Cuba.

119. *Hanbach voor de Rubbercultuur in Nderlandsch-Inde met Medewerking,* Dr. P. Arens. Amsterdam: J. H. deBussy, 1921.

120. *Rubber in the Netherlands East Indies,* Neil Van Aker. New York: Netherlands Chamber of Commerce, 1923.

121. *Experimental Tapping of Hevea Rubber Trees at Bajeux, Haiti, 1924-25,* Loren G. Polhamus, Department of Agriculture Technical Bulletin No. 65. Washington, D. C., 1927.

122. *The Ceara Rubber Tree in Hawaii,* Jared G. Smith, Bulletin 16, Hawaii Territory Agricultural Experiment Station. Washington, D. C.: Government Printing Office, 1908.

123. *Liberia Rediscovered,* James C. Young. Garden City, N. Y.: Doubleday, Doran and Company, 1934.

124. *Pahang,* Willard C. Bush. New York: The Macmillan Company, 1938.

125. *Coffee and India Rubber Culture in Mexico,* Matias Romero. New York and London: G. P. Putnam's Sons, 1898.

126. *Possibilities for Para Rubber Production in the Philippines,* Vane, Muzzall, Bushell, Baldwin, etc. Special Report, U.S. Department of Commerce, Washington, D. C., 1925.

127. *A Rubber Plant Survey of Western North America,* H. Monroe and T. H. Goodsen. Berkeley: University of California Press, 1919.

128. List of References on Artificial or Synthetic Rubber, Library of Congress, Division of Bibliography, Washington, D. C.

129. *Story of Neoprene.* Wilmington, Del.: DuPont de Nemours and Company, 1937.

130. *Kinsthlicher Kautschuk für elektrische Isolierungszwecke,* Dr. I. Kurt Geisler. Berlin: J. Springer, 1922.

131. *Synthetic Rubber,* W. J. S. Naunton. London: Macmillan and Company, Ltd., 1926.

132. *Synthetic Rubber,* S. P. Schotz. London: E. Benn, Ltd., 1926.

133. *A Rubber Plantation in New Jersey.* Yardville, N. J.: Thiokol Corporation, 1936.

134. *Les Caoutchoucs Artificiels,* L. Ventou-Duclaux. Paris: H. Dunod et E. Pinat, 1922.

135. *La Régénération des Caoutchoucs,* Paul Barry. Paris: L'edition technique, 1930.

136. *Universal Standard Grading of Scrap Rubber,* Alfred W. Leslie. London: Maclaren & Sons, 1924.

137. *Rubber and Agriculture.* London: Rubber Growers' Association, 1934.

138. "Rubber Coating for Abrasion and Corrosion Resistance," Leonard Church, *Chemical and Metallurgical Engineering,* Vol. 40, No. 9, September, 1933.

139. *The Rubber Crisis,* Gourgie and Parkinson. London: London General Press, 1938.

140. *The Productivity of Labor in the Rubber Tires Industry,* John Jean Gaffer. New York: Columbia University Press, 1940.

141. *Ohio Wage Earners in the Manufacture of Rubber Products,*

1914-28, Amy G. Maher. Toledo: Information Bureau on Women's Work, 1930.

142. *Industrial Valley,* Ruth McKenney. New York: Harcourt, Brace and Company, 1939.

143. *Rubber in Chemical Engineering,* H. P. Stevens and M. B. Donald. London: Rubber Growers' Association, 1933.

144. *Manual of Accounts and Budgetary Control by the Rubber Industry,* Accounting Committee of the Rubber Association of America. New York: Ronald Press Company, 1926.

145. *The Rubber Position and Government Control,* A. Philipson. London: P. S. King and Son, Ltd., 1924.

146. *The Valuation of Rubber Estates for Valuers, Investors and Planters,* F. C. Peck. Singapore: Kelly & Walsh, 1914.

147. *Proceedings of the Rubber Technology Conference Held Under the Auspices of the Institution of the Rubber Industry in London on May 23-25, 1938.* London: W. Heffer & Sons, Ltd., 1938.

148. *Report from the Select Committee on Putumayo Atrocities.* London: His Majesty's Stationary Office, 1913.

149. *The Putumayo, the Devil's Paradise: Travels in the Peruvian Amazon Region and an Account of the Atrocities Committed on the Indians Therein.* London: T. F. Unwin, 1912.

150. *The Lords of the Devil's Paradise,* George Sidney Paternoster. London: S. Paul and Company, 1913.

151. *El Libro Rojo del Putumayo,* Norman Thompson. Bogotá: Arboleda y Valencia, 1913.

152. *The Upper Reaches of the Amazon,* Joseph F. Woodroffe. London: Methuen & Company, 1914.

153. *Reports, Proefstation voor Rubber, 1929-1937.* Buitenzorg, Java.

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