COMMON COMMODITIES OF COMMERCE.

RUBBER

PLANTATION HEVEA TREES

PITMAN'S COMMON COMMODITIES
OF COMMERCE

RUBBER

PRODUCTION AND UTILISATION OF THE RAW PRODUCT

BY

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AND

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PREFACE

THIS little book is intended to serve as an introduction to the study of Rubber, and deals both with the production of the raw material and the subsequent manufacturing processes.

A good deal of interest is now taken in Rubber from different points of view. During the last few years we have seen the successful development of the Plantation industry with which we have been closely associated. Our consulting practice also brings us into contact with the rubber manufacturing industry to which the attention of the public has been drawn owing to the popularity of the motor-car.

It is hoped that this book will be found suitable to the requirements of the average reader who is desirous of obtaining general information on the subject. In a narrower circle the book should prove useful to planters who wish to get some idea of the methods employed by manufacturers for the utilisation of their raw material, while those interested in manufactured goods will, we believe, be more particularly interested in noting the methods employed for treating the latex and curing the rubber on the plantations.

We are much indebted to Mr. J. K. Burbridge for reading through the proofs, and to Mr. P. M. Matthew, Mr. Herbert Wright, and various firms of rubber machinery manufacturers for some of the photographs and illustrations.

The space at our disposal has necessitated a very brief treatment of all the matters dealt with, but it has been our aim to make the book as comprehensive as possible.

THE AUTHORS.

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RUBBER

PART I

THE RAW MATERIAL

CHAPTER I

INTRODUCTORY

RUBBER, or india-rubber, was the name originally given to a material of West Indian origin used for removing pencil marks. To the English chemist, Priestley, in the eighteenth century is given the credit of this discovery. Rubber in a modified form is still used for this purpose, although at the present day other commercial applications of far greater importance have to be considered.

Central and South America may be taken as the home of the more important rubber producing trees, and, consequently, it is natural to turn to Spanish sources for the earliest historical mention of this substance. We have early reports of games played by Indians with elastic balls made from the gum of certain trees, and Christopher Columbus is said to have seen the natives playing with rubber balls in the Island of Haiti.

For a long time india-rubber was nothing more than a chemical curiosity. One of its first applications was that of waterproofing cloth. India-rubber dissolves easily in many organic fluids, such as turpentine and naphtha, and on evaporation of the latter the rubber is left again in the form of a film. This film may be said to be impervious to water—water-resisting would be a better word, for as a matter of fact, when immersed in water, it slowly swells and absorbs a small quantity. However, by spreading a layer of rubber solution on cloth it is easy to render it waterproof, and these garments have been known as mackintoshes ever since the early days when they were made by a firm of that name. The firm of Mackintosh is still one of the largest in the rubber manufacturing trade, and the works in Manchester, extended of course, cover the ground occupied by the original waterproof manufactory.

Rubber, however, is not an ideal substance with which to treat a wearing material. Even the best qualities of rubber get soft and sticky in hot weather, and it is safe to say that, had it not been for the discovery of a radical nature by which these difficulties were overcome, rubber could never have been adapted to the numerous commercial uses to which it is now put.

This discovery, which was made in the year 1839 by the American, Goodyear, consisted in heating the rubber with sulphur under carefully regulated conditions, when some sort of chemical reaction takes place and the resulting product is no longer sensitive to the ordinary seasonal changes of temperature, and in addition to this, its strength and elasticity are actually improved. This process, known generally as vulcanisation, was discovered independently by Hancock in London, who, later on, came to an arrangement with the Mackintosh firm by which the process was applied to the manufacture of waterproofs. The original firm of Hancock's in the Goswell Road are still manufacturers of rubber goods. Hancock also found the means of uniting pieces of india-rubber into one mass by the process of mastication or kneeding, a discovery of prime importance for the manufacture of rubber goods. Nowadays practically all commercial rubber goods go through the vulcanising process, the only exception of importance being the rubber tape used for the first layer surrounding the copper conductors of electric cables, for although the cable may be heated to a vulcanising temperature for the purpose of vulcanising the outer layers which contain sulphur, the first layer of pure rubber tape next to the conductor remains unaffected.

CHAPTER II

THE PARA RUBBER TREE AND RUBBER LATEX

EVERYONE is familiar with common milk weeds or spurges: when the stem is broken a milky juice exudes; but whereas such milk or *latex* yielding plants are comparatively rare in temperate climates, they are exceedingly common in the tropics. Many of the largest trees in the tropical jungles of South and Central America, the Continent of Africa, India, Ceylon and the Malay Archipelago, exude a milky juice when the bark is cut or damaged, and the leaves or twigs torn or snapped across. This milky juice has its origin in a system of capillary vessels, which are found both in the primary, that is to say first formed, tissue of the stems and leaves, and also in the secondary tissue, generally in the under layers of the bark, and sometimes also in the sap-wood of the tree trunk and branches.

Under the microscope the milky juice, or, as we will now call it, latex, consists of innumerable minute globules of oily appearance, which vary individually in size and also in average size, according to the tree from which the latex is obtained. The size may be taken as somewhere in the order of one ten-thousandth of an inch in diameter (2 μ or 3 μ). The analogy with animal milk, which consists of a liquor containing tiny globules of milk fat, is at once apparent. The latex globules, however, do not consist of fat, but of resins and *caoutchouc*. Very many trees yield a latex from which only resins or resin-like substances are obtained. These are practically valueless. Others yield some caoutchouc with a larger or smaller proportion of resin,

Old Hevea Trees near a Cemetery in Perak

Road with Monorail on a Rubber Plantation and their commercial value may be taken as roughly proportional to the percentage of the former. The latex of the *Hevea Braziliensis*, or Para rubber, contains only three or four per cent. of resin, and yields the finest commercial rubber.

The term "resin" is used in a general sense, as there are innumerable resins obtained from different trees, each of which, if considered from a chemical standpoint, consists of complex mixtures of different individuals. For our purpose, we need take no account of these; at the most it is only necessary to distinguish between hard and soft resins. The former is a preferable constituent of raw rubber.

Terminology

The native Indian word for rubber is "cahuchu," and this was first adapted in the form "caouchouc" (German, *Kautschuk*) as a synonym for rubber. The word in English is now generally used to signify the chemical substance or hydrocarbon (compound of carbon and hydrogen), which is the essential ingredient of raw rubber. It forms the main portion of commercial raw rubbers of medium and good qualities. *Raw Rubber* is the natural product as obtained direct from the trees, and consists of caoutchouc in intimate mixture with resin and other substances. In the badly prepared native rubbers it is mixed up with all sorts of grit and dirt, besides being very wet. When the raw rubber is freed as far as possible from these impurities and dried, it is ready for vulcanising and converting into the manufactured india-rubber goods with which we are familiar.

We will now describe the botanical sources of the more important commercial raw rubbers, and the methods employed for coagulating the latex and preparing the raw rubbers for export.

Para Rubber

Hevea Braziliensis. This tree, as its name implies, is a native of Brazil. It is found in the extensive forests drained by the Amazon and Orinoco rivers and their tributaries. It occurs, however, not only in Brazil, but in Bolivia, Peru and other parts of tropical South America. The raw rubber is found in commerce under various names according to the method of preparation and source of supply. The brands known as fine hard Para, hard and soft cures, are the best raw rubbers known, and preferred by manufacturers to all others. The name Para is derived from the chief port on the Amazon from which the rubber is shipped. Inferior grades of the same rubber are Para Entrefine, Negro Heads, Matto Grosso, Cameta, Bolivian Para, Caucho and Peruvian Ball. The inferior grades are partly derived from other species of genus *Hevea* and are not smoke-cured. *Hevea Braziliensis* thrives in the hot damp forests of the Amazon valley, in what are known as the "islands" in the delta of the river, and also in the higher lands lying back from the valley of the river. The climate of this region is extraordinarily uniform, the annual mean temperature being about 80° F., and the daily range usually between 75° and 90°. The annual rainfall is from 80 to 120 inches.

The general habit of the Para rubber tree will readily be seen from the various illustrations. It attains a height of over 60 feet and a girth of 8 to 10 feet. The leaves are characteristically three-lobed, the flowers are individually small and inconspicuous, but are borne in little sprays, and are succeeded by dry fruits, each containing three seeds about the size of large Kentish cob nuts, and with the curious brown and black mottling so characteristic of seeds of many plants of this family, *e.g.*, the castor-oil bean. The seeds are very oily and soon lose their vitality, so that special precautions have to be taken to transport them successfully over long distances when required for propagation. When ripe the hot sun causes the capsule to burst with a sharp report, and the seeds come rattling down in all directions.

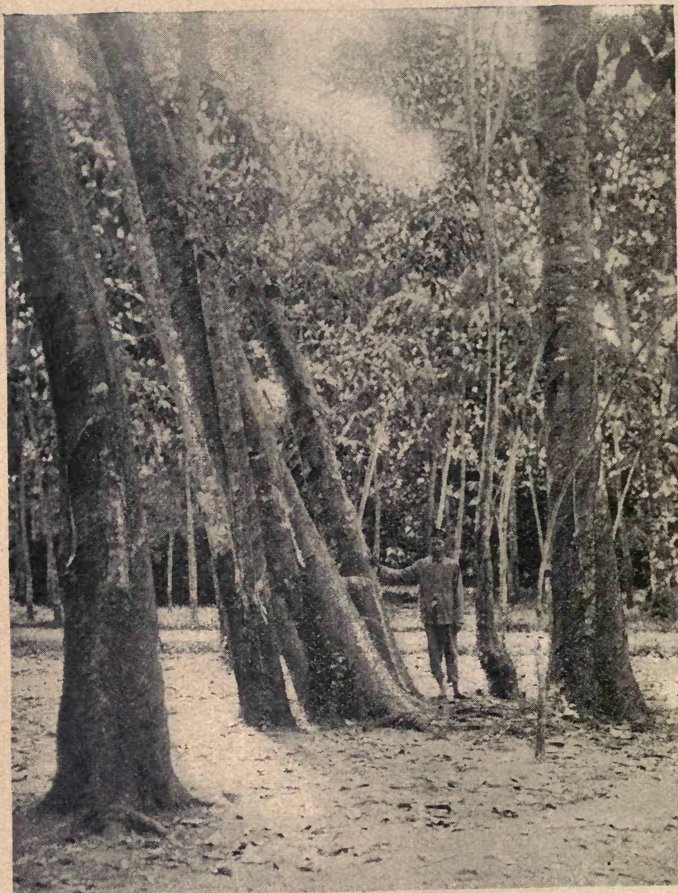
Collection of Wild Rubber

In Brazil the trees are tapped during the dry season, which varies in different districts. The rubber collectors, or *seringueiros*, search the forests for suitable trees, which should not be less than about two feet in girth. An incision is made in the bark with an axe or cutlass, and a receptacle fastened immediately beneath. The latex begins to run at once and is caught. A number of cuts are made in each tree, a cup fastened under each, and allowed to remain for a few hours. At the end of this time the flow of latex has ceased and the contents of all the little cups transferred to a larger vessel. The next step is to convert the still liquid latex into solid rubber. A fire is lighted and nuts of various species of palms placed on it. These produce a dense smoke. A kind of paddle is dipped in the latex and held in the smoke. The rubber coagulates or dries down, forming a thin layer on the paddle. This is then dipped into the latex and again smoked. Another layer is deposited on the first, and the process is continued until a sufficiently large mass of solid rubber has been collected on the paddle. It is then removed and is ready for sale and export. In this extremely simple yet effective manner is carried on, year after year, the preparation of rubber on the Amazon.

The smoke-cured fine Para comes into commerce in the form of " loaves " or large rounded masses, brown to black on the outside but white or greyish in the interior, with a peculiar smell of smoked fish. The other brands are also produced in rounded irregular masses of various sizes, dark on the outside where the rubber has dried, and pale in the interior where it is still wet. In some of the inferior grades a certain amount of putrefaction has set in and the rubber when cut open smells very unpleasantly. This is particularly marked in the inferior African rubbers.

Plantation Para Rubber

A new source of supply, which bids fair to compete on a large scale with the South American *Hevea* rubbers, has come prominently into public notice during the last year or two. This is derived from plantations of *H. Braziliensis* trees in the Malay Peninsula, Ceylon and the Malay Archipelago generally. At present the output is relatively small, somewhere about six per cent. of the world's supply for 1909. This is accounted for by the fact that only a few of the planted trees have, at present, reached maturity. There are very few trees indeed on the plantations exceeding ten or twelve years of age, and on the average trees do not yield rubber until they are four or five years old, even under the most favourable conditions. It should be understood, however, that maturity in this respect is rather a question of development than age of the tree. This rubber forms the various brands of plantation rubber which differ broadly from the native rubbers in the greater care taken in their preparation, and the fact that they are marketed dry instead of wet, that is, with seldom more than one per cent. of moisture ; whereas native rubbers may contain anything up to fifteen or twenty per cent. Plantation rubber is sold in the form of large blocks, oblong sheets (sometimes smoke dried in imitation of Brazilian fine hard), biscuits, or small round sheets, and crêpe, or long strips with irregular surface, and in other forms.



OLD HEVEA TREES IN THE MALAY PENINSULA
(*India Rubber Journal*)

Introduction of the Para Rubber Tree in the East

In 1876 Ceylon received from the Royal Botanic Gardens, Kew, some 2,000 seedlings of *Hevea Braziliensis*. The seeds had been collected in Brazil by Mr. H. A. Wickham, forwarded to Kew, and despatched thence to Ceylon in Wardian cases. A Wardian case, it may be said, is essentially a small portable glass-roofed box, in which plants are placed with a supply of soil and moisture so that they can be sent long journeys without injury. This is of particular importance to the plant. The cost of the experiment was borne by the Indian Government, but Ceylon was selected as having a more suitable climate, and the young seedlings were mostly planted out in a special garden at Heneratgoda, in the hot and moist region of the island. As early as 1877–8 young plants raised from cuttings were distributed to Madras, British Burma, and the Straits Settlements, and after the first flowering in Singapore in 1881, when seedlings became available, the work of distribution was continued, and Australia, Fiji, the West Indies, Seychelles, and the West Coast of Africa are amongst the widely separated places into which Para rubber plants have been introduced. The use of Wardian cases is the most satisfactory manner of transport over long distances, the seeds germinating *en route*, but very successful results have been attained with carefully dried fresh seeds packed in tins in dry powdered charcoal and cocoa-nut fibre, dust or sawdust.

Methods of Cultivation

It was at first thought that the plant would only grow on moist, preferably periodically inundated ground, and near the sea level. This, however, has proved not to be the case, and good results have been attained in Ceylon up to an elevation of 2,000 feet, and in some cases even higher, but the growth is then much slower, and the trees are much older before they can be tapped.

It is interesting to note that whereas the tree was introduced first in Ceylon, the Ceylon trees did not fruit until 1885, while the Singapore trees first fruited in 1881. The other requirements are practically those indicated as existing in the Amazon valley, *i.e.*, a rainfall of about 100 inches per annum, and a mean annual temperature of about 80° F. The plant grows very rapidly from seeds, the seedlings being raised in nurseries. These usually consist merely of patches of land, where the soil has been prepared and fenced in if necessary. After one or two years' growth, the tops of the young plants are cut off, the plant pulled out of the ground, and the root trimmed. The young plants, known in this state as "stumps," are then planted out in the open and generally throw out fresh shoots after remaining dormant for two or three months. The distance the plants are set apart depends on circumstances, but if fifteen feet by fifteen feet is adopted the result will be about 200 trees to the acre. If eighteen feet by eighteen feet we get 135 trees to the acre, whereas twenty feet by twenty feet reduces the number to 109. In the early days it was considered advisable to plant comparatively closely, and tap the trees until they become crowded, and then by removing the worst give the others room for further development. In this way a large yield would be obtained during the first two or three years after the trees came into bearing. It has been found, however, that it is not easy to remove trees closely planted without damaging their neighbours, and the roots and stumps left in the soil are always a source of danger, as encouraging white ants and fungus pests.

Catch Crops and Clean Weeding

During the first four years, catch crops, such as groundnuts, cassava, bananas, cotton, etc., can be grown. Sometimes the rubber plants are set amongst matured coffee or tea, with the idea of removing the coffee or tea altogether later on, *i.e.*, gradually transforming a tea or coffee estate into a rubber estate.

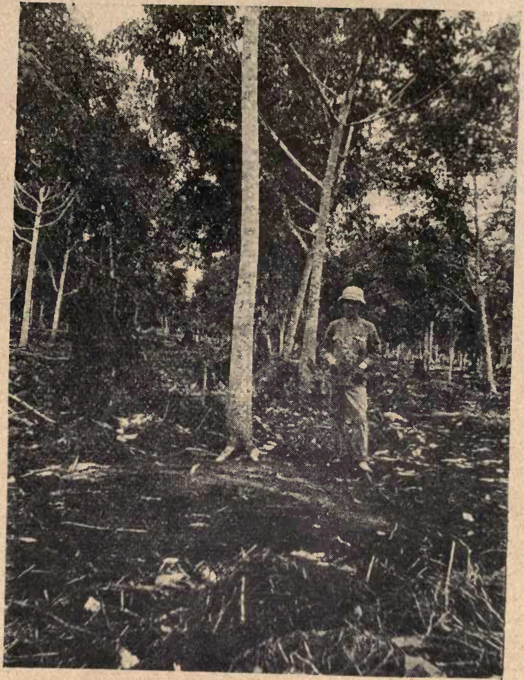
Some of the most experienced planters, however, do not grow any catch crops but keep their estates clean weeded from the start, holding that in this manner the trees develop more rapidly and reach maturity more quickly. This, of course, only applies to estates planted up in freshly cleared jungle land.

There is still some difference of opinion on these questions of catch crops and clean weeding. It would, however, appear that rubber planted among tea or coffee does not grow so rapidly in the early stages as on newly cleared land. Much rubber in the Malay Peninsula has been planted on land from which one or more crops of cassava have been taken. This latter is an exhausting crop and the land is usually abandoned after the third crop. It is only to be expected that the growth of rubber trees on such land will be somewhat retarded, at any rate during the early stages. The same applies to old coffee land. As regards clean weeding, it would at first sight appear a mistake to leave the land between the young trees bare and exposed at one time to the heat of the tropical sun, and at another to the wash of tropical rains, but it has been found in practice that if the weeds are to be kept from choking up the young trees the only practicable course is to keep them out altogether; and in many cases where plants such as the wild passion flower or crotalaria have been planted to cover up the soil it has been found impossible to keep the luxuriant growth in control, or they have not effectively prevented the spread of *Lallang,* and they have had to be got rid of altogether at considerable expense. In the Malay Peninsula cleared land is choked up with a miscellaneous growth in a very short time ; a few heavy showers followed by a few days of sunshine, and land which was bare soil will be covered with a thick growth of weeds, which in two or three months may reach a height of five or six feet. Prominent among these is the *Lallang,* a very course grass growing to a great height and exceedingly difficult to eradicate.

Pests and Diseases

It has been the general custom to leave the stumps and half burnt tree trunks on the land to be planted after the jungle trees have been felled and burnt off. The ground is thickly strewn with them and they take years to rot away and disappear. A large stump may be seen in the forefront of the illustration (see opposite) where the trees shown are about five years old. The more progressive estates are now clearing the timber off the land in spite of the considerable expense involved as the rotting wood harbours a dangerous fungus pest, *fomes semitostus* which attacks the roots of the *Hevea* tree with fatal results. This fungus has been found on trees of all ages, and if allowed to spread would destroy acres of rubber in two or three years. It is very common all over the Malay Peninsula, although not difficult to cope with if detected and dealt with in the early stages ; the affected tree is dug up, burnt, and the pit limed, while its immediate neighbours are surrounded by a shallow trench, so that if the fungus has spread to these as well they are isolated from the rest of the plantation.

Fomes semitostus forms white thread-like filaments on the roots of the tree and spreads from one tree to



Five Years' Old Hevea Trees with old Jungle Stumps

Old Hevea Tree in Singapore Gardens Tapped whole Herring-bone those adjoining where the rootlets interlace. On dead wood it forms fructifications, and the spores may be spread by natural agencies to distant parts of the plantations. There are other fungus growths, such as *nectria* (canker), which attacks rubber trees, but *fomes* is the most dangerous so far reported. There is also the Botryodiplodia or "dieback." White ants (*termes gestroi*) give a little trouble on some estates, and when the trees are young damage is often done by wild deer. The latest disease is the *corticium Javanicum* from the Island of Java, which has been detected both in the Malay Peninsula and Ceylon. It forms a pink growth on the branches.

Systems of Tapping

As it is pretty obvious, some trees will be lost by one means or another and the *vacancies* are filled in with fresh *supplies*. At a certain stage in their growth, seldom less than four years after planting out, the trees are ready for tapping. The time when tapping can begin depends on the trees attaining a sufficient size, which is judged by measuring the girth three feet from the ground; eighteen or twenty inches is usually considered sufficient. Of course, trees planted at the same time do not all reach this stage together. It is usual to go out into the field where the trees are "coming into tapping" and "mark out" those that have attained the required size by scoring them with a V shaped gouge along the lines where the cuts are to be made.

A great many arrangements of cuts have been tried, most of which have been abandoned. The system now usually adopted is the "herring-bone" or a modification of this, the "half herring-bone." In the former case, cuts are made on the bark, branching at an angle of about 45° on either side of a shallow vertical groove four or five feet long which serves to guide the latex oozing from the side cuts. The tree is furnished with a little tin spout at the bottom of the vertical cut from which the latex drips into a cup placed at the base of the tree. (Fig. *a.*)

The process of tapping, which may be done every day, or at less frequent intervals, consists in paring away a thin shaving of bark from the lower surface of the branch cuts. This opens the latex vessels, the ends of which become eventually plugged when the flow ceases and are opened again at the next tapping. In this way the bark of the tree is gradually pared away from above until the whole of the bark on one side of the tree is removed. All the while, however, fresh bark is re-forming. The branch cuts are made of such a length that they extend as nearly as possible one quarter round the tree. Each day a thin shaving is pared away so that the cut descends at the rate of an inch in twenty to twenty-five days. When all the bark is pared away from one side of the tree, a fresh herring-bone is then marked out on the opposite side of the trunk. In this way the whole of the bark of the lower four or five feet of the tree is removed, usually in about three or four years, by which time the renewed bark is ready and old enough to be tapped again.

The half herring-bone modification (see Fig. *b*, page 19), as its name implies, consists of branch cuts on one side only of the vertical channel. In this way the bark is renewed at only half the rate as in the whole herring-bone, as only one quarter of the tree trunk is in tapping. If desired, however, tapping may be done twice as often, or the tree may be tapped on two sides at the same time ; in either case the bark is removed as quickly as in the first system. Systems of tapping are shown in illustration (Figs. *a*, *b*, and *c*). The basal

Hevea Rubber Tree showing Basal V Tapping

Tapping Twenty-five Years' Old Hevea Rubber Trees. Half Herring-bone System

V is a system used on some estates (see Fig. *c* below). Where it is desired to tap more heavily, a second V may be made higher up the trunk.

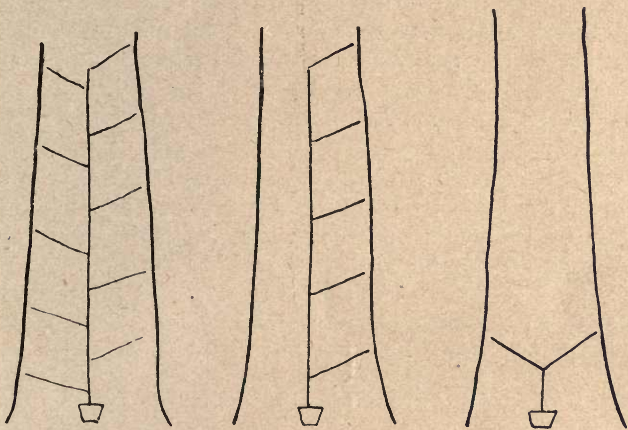


FIG. *a* WHOLE HERRING-BONE — FIG. *b* HALF HERRING-BONE — FIG. *c* BASAL V

WOUND RESPONSE AND COLLECTION OF LATEX

The latex flow is very irregular, individual trees yielding a varying quantity. A good milker will usually show a falling off after a few weeks or months, while other trees which have been poor yielders increase their flow. Sometimes one tree out of several hundreds will yield ten or twenty times the average quantity and sometimes trees run dry altogether and yield nothing. When a tree is tapped for the first time the flow is almost negligible and only a few milky drops issue from the freshly pared surface, but each day the quantity increases until the full flow is obtained. This suscepti-bility of the bark to repeated wounding is known as the

" wound response," and is the reason why much larger yields of rubber are obtained than the early planters originally anticipated.

Rubber estates are usually partitioned up into divisions of a few hundred trees, to each of which is apportioned one or more tapping coolies whose business it is to tap the trees. A start is made at sunrise, as the flow of latex is better early in the morning. The bark shavings are kept as they contain rubber which can be extracted from them. A little latex, too, remains in the branch cuts which dries down and can be stripped off. These form two of the varieties of plantation " scrap " rubber. A coolie goes round with a pail an hour or two after tapping when the latex has ceased to flow and empties the cups and the pails of latex are taken to some central station for coagulation and further treatment.

Latex Coagulation and Rubber Drying

The treatment of latex in the rubber factory depends on whether or not it is intended to wash the coagulated rubber in the ordinary two roll rubber washing machine, as the latex always contains bits of bark, shavings, leaves, twigs and other impurities, besides lumps of coagulated rubber. If the rubber is not washed it must be freed from these impurities by straining through a fine mesh sieve. It is usually first thinned down with water. The strained latex is poured into shallow circular or oblong rectangular pans of enamelled iron and to each is added a small quantity of diluted acetic acid with stirring. After standing a few hours the whole sets to a solid mass like a junket, but much tougher and harder. The next day the cakes are taken out and most of the liquor squeezed out either with a rolling pin on a board, if the cake is small, or by passing through an ordinary wooden mangle. Nowadays, on large estates making sheets, steel rolls with diamond-shaped markings have come into fashion. The circular pans produce "biscuits" and the rectangular pans "sheets." The first plantation rubber was made in the biscuit form as the planters used soup plates, the first things that came handy for coagulating their rubber in. The biscuits and sheets must, however, be dried before they can be packed for export, and for this purpose are laid out on wire gauze shelves, or else hung up in a loft out of the sunlight, but with as good a ventilation as possible. Drying rubber is a long and tiresome process, particularly in a climate where the air, although hot, is at times practically saturated with moisture. The drying may take several weeks. The white surface turns dark like the surface of a cut apple and the mass gradually shrinks until it eventually gets translucent, the last traces of moisture showing through as white patches where the sheet is thicker, and therefore slower in drying. The sheet is not properly dried until the rubber is everywhere translucent. Recently on some of the plantations in the Malay Peninsula sheet rubber has been exposed to the smoke of a wood fire and marketed as "plantation smoked sheet," a special virtue being attributed to the action of the smoke. This, however, is open to question, although smoked sheet has certainly fetched better prices than the unsmoked variety. The hot smoke certainly helps to dry the rubber and preserve it. For some purposes the colour of the rubber is of some importance and a premium is put on very pale sheet or biscuit.

This effect is easily obtained by dipping the freshly coagulated rubber into boiling water, or otherwise heating the rubber, which destroys the *euzymes* or ferments which produce the darkening in colour. Pale rubber may be obtained by other methods.

The process for the production of sheet or biscuit rubber is not well adapted to working on a large scale, although convenient where the output of the plantation is small. When the output is large a different method is usually adopted, although part of the rubber may be worked up in the form of sheet. In such cases the latex is coagulated in a few large containing vessels in the place of a large number of smaller ones and the coagulated rubber is then washed in a stream of water while being passed repeatedly between the rolls of an ordinary rubber washing machine. The machine flattens out the rubber into long strips usually eight or ten inches wide with an irregular uneven surface due to the tearing action of the rolls. This when dried comes on the market as crêpe. The scrap rubber from various sources being dirty is generally washed and sold in crêpe form. It may usually be distinguished by its dark colour from the best grades which are pale. Plantation rubber is also marketed in the form of lace, worm and block. These are of minor importance with the exception of block rubber, which is turned out in particular by one estate which exports some of the best rubber from the East.

The best plantation rubber, whether it be dark or pale, is always translucent, except after exposure to winter cold, when it becomes opaque. The "frozen" rubber is easily thawed and regains its transparency. Owing to the fact that plantation rubber is thoroughly dried before exporting, cases of putrefaction are rare, but some trouble is occasionally experienced with sheets and biscuits, owing to the growth of mildew on the surface. A good deal has been written about "tacky" rubber, or rubber which on arrival in Europe is found to be soft and sticky, or partially decomposed. This is not uncommon with some of the lower grades of wild rubber, but is now seldom met with in the plantation product

CHAPTER III

OTHER RUBBER-YIELDING TREES

Castilloa (*or Castilla*) *Elastica,* the Spanish name of which is Ule Fig (t), is a native of Central and some parts of South America. It has been extensively planted in Mexico and other parts of Central America, and to a lesser extent in Malaya and Ceylon. The plant has been known to science longer than any of the other rubber-yielding plants, and was first described by Cervantes at a meeting of the Royal Botanic Garden of Mexico, in July, 1794, and copies of his original published description, with a figure of the foliage and flowers of the plant, are still in existence, although now very rare. The rubber passes commercially under a great variety of names, mainly denoting the country from which it has been obtained. Of the various brands of the wild or native prepared rubber, the following may be mentioned :—Guayaquil, Panama, Costa Rica and Honduras whose products are marketed in various forms ; sheets are exported from Guatemala, Nicaragua and Mexico.

The Castilloa tree is known under several names locally. For instance, the name "caucho," is often given to it, although this term is also applied to an unsmoked rubber coming from the upper reaches of the Amazon, and probably derived from different varieties of Hevea. Just, too, as there are several varieties of the species of Hevea, there are also several varieties of *Castilloa,* and the qualities of the rubber from these different varieties differ considerably. The produce of one tree is said to contain so much resin as to be of very low commercial value, and there seems some question as to whether certain of the plantations in Mexico and Central America have got hold of the right tree.

The Central American rubber tree is found in the forests of its native country, but it does not follow from this that it should be grown in forests or under the shade of other trees, when efforts are made to cultivate it. It would appear that one reason why it is only found in forests is due to the fact that its seeds are very thin-walled and are rapidly killed if left exposed on open ground under the fierce heat of the tropical sun. When artificially sown, cared for, and shaded in its early stages, the plant in other countries has been found to grow more quickly, and to give better results in the open than in the shade. It develops into a very large tree, sometimes more than 150 feet in height, with a rather smooth, light grey bark, and is easily recognised in the young state amongst other trees by its peculiar branches bearing on either side a row of large leaves, generally about one to one and a half feet long.

Unlike the Hevea a continuously moist climate and swampy or boggy land does not suit the Castilloa tree. It requires a hot climate, but alternating wet and dry seasons are preferable, and the soil should be a deep loam. It has not proved a success in the Malay Peninsula where it grew well at first, but the tree, after a few years, especially in wet situations, began to die off at the tops. Even in suitable climates like Mexico, the trees can seldom be tapped till they are seven or eight years old, while as a rule, they should be older still, as the rubber from young trees, as Weber showed years ago, contains a very high percentage of resins.

The trees cannot be tapped in the same way as Hevea, as the latex starts clotting and the rubber globules begin to separate as soon as the latex exudes from

ROAD ON A RUBBER PLANTATION SHOWING
YOUNG HEVEA TREES

FACTORY ON A RUBBER PLANTATION

the cuts in the trees. This interferes with the flow and makes it difficult to collect it in a cleanly manner. The bark of the Castilloa, too, is harder and it does not show the "wound response." The trees are therefore tapped at intervals of a few months only, but then yield many times what would be obtained from a single tapping of Hevea trees of the same age. On standing, the rubber globules rise to the surface of the latex like cream and they may be conveniently washed by stirring up repeatedly with fresh quantities of water and then drawing off the wash waters from the bottom, or by centrifuging in the same way as cream is separated in a cream separator. It is not easy to get the globules to unite to a cake of rubber; heating is usually necessary or alcohol in some form may be added. Much of the rubber is obtained from latex which is allowed to dry down on leaves or on the trunk of the tree itself. A coagulant used by the natives consists of a decoction of the stems of a convolvulus that grows wild in the district.

A characteristic of the rubber is the very dark colour of the dried outer surface, the latex from this tree containing a dark colouring matter. There is, however, no reason why the rubber should not be obtained as pale in colour as Para rubber by properly washing and centrifuging. The plantation brands are generally in sheet or crêpe form. The best qualities are excellent as raw rubbers but not equal to Hevea. Even the best prepared rubber contains more resin than Para, something like six or seven per cent. as against two or three per cent. in the latter, and from the behaviour of the rubber on vulcanisation we are inclined to think that there is some essential difference in the caoutchouc hydrocarbon quite apart from the amount of resin in the Para rubber.

Ceara or maniçoba rubber is obtained from the

Manihot glaziovii, a tree of the Spurge order (Emphorbiaceae). This tree grows only to a medium height, but is remarkable on account of the rapidity of its growth and the early age at which it begins to yield rubber, which may be put at three to four years. The rubber comes chiefly from the province of Ceara in the Brazils; it is translucent and of a yellow to brown colour. In parts of Bahia, large plantations have been started of another species of Manihot, the Jequie *Manicoba* or *M. dichotoma*. Seed and plants of *M. Glaziovii* were brought to Kew in 1786 by Mr. Cross, and thence transmitted to Ceylon where it was planted in considerable quantity long before the planting of Hevea came into vogue. The yields of rubber have, however, been disappointing, and the writer has heard planters complaining of the expert advice on which they planted Ceara in those days when they might just as easily have planted Hevea.

As stated, Ceara rubber tree grows with tremendous rapidity, plants raised from seed often reaching to ten or more feet in height within one year and thirty feet by the end of the second year. Once seen the trees are easily recognised by their spreading habit, their five-lobed, curiously bluish-grey leaves, and the bark is thin and very hard; it peels off in thin sheets or strips, like that of a silver birch. The plant will thrive in places absolutely unsuited to most cultivated plants. Rocky and stony soils of poor quality and arid districts present no obstacles to it. Trees raised from seed can be tapped when about four to six years old. The thin outer layers of bark are usually removed, and either the whole surface scraped sufficiently deep to allow the latex to escape, or incisions made here and there with a knife. The latex is very liquid and flows readily.

Plantation Ceara from Ceylon is brought into the market in the form of clear pale biscuits which have

Ceara Rubber Tree (*India Rubber Journal*) fetched as good a price as Para biscuits. We have found that Ceara rubber more closely resembles Para than any other in its behaviour on vulcanisation. Generally speaking, however, the Ceara rubbers are inferior to the corresponding Para grades.

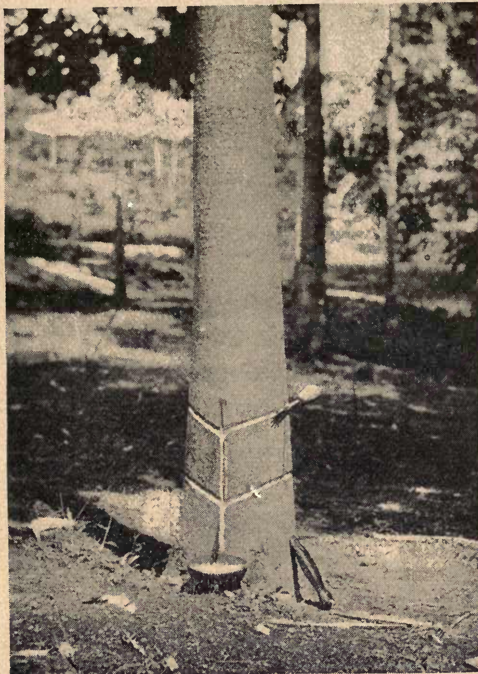
Rambong and Assam Rubbers

These are derived from the *Ficus elastica,* a tree growing to enormous size in Assam and various parts of Malaysia. Like the well-known Banyan tree it throws out aerial rootlets which fix in the soil and rapidly increase in thickness so that the fully-grown tree is supported on a tangle of trunks instead of one central one. These frequently have exactly the appearance of props fixed as if to bear up the branches. The leaves are fleshy and of a rich dark green colour, the new shoots are enveloped in a bright red sheath. The plant is familiar to most people as the India-rubber plant, to be seen in houses and conservatories in this country. It is extremely hardy and has been largely planted in the East, particularly in Assam and Java, where it is also indigenous. The latex, which is very white in colour, flows rapidly on cutting the bark, but the wounds must be made deep to obtain a good yield. Fresh cuts require to be made at each tapping and the tree has an inconvenient habit of throwing out aerial rootlets from old wounds. Ant heaps are very frequently found on the base of the trees so that tapping has other drawbacks. The latex remains liquid for almost any length of time, but can be coagulated by heating and stirring or by adding an alcoholic liquid. It may also be coagulated by mixing with a small proportion of Para latex. When acid is added to the mixture the coagulation of the Para carries the Rambong latex with it, although the latter is by itself not coagulated by acids. Of course, the rubber may be obtained by allowing the latex to dry down, as often happens, on the branches and trunk of the tree. Sometimes mats or leaves are placed on the ground underneath the trees on to which the latex is allowed to drip.

The freshly-coagulated rubber is often pink in shade, as also is the wood of the tree. This is probably due to a ferment in the latex, and it is difficult to prepare the rubber in such a way as to keep it pale in colour. Good qualities and carefully prepared rubber fetch high prices, but like the Castilloa even the best grades are inferior to Para. They contain a higher percentage of resin, usually five to six per cent., but rather less nitrogenous constituents. The yield of rubber at a single tapping, and where a large number of cuts are made, may be considerable, but it is impossible to give an average figure as it depends entirely on the size of the tree. The trees can be made to yield when four or five years old, but much labour is entailed in tapping young trees, and this is one reason why they have proved disappointing to planters. On many plantations in the East, they are being cut down to make room for Hevea trees.

Funtumia Rubber

Lagos silk rubber is the product of the *Funtumia elastica*, a native of tropical Africa. It will often be found referred to as *Kickxia elastica*, but the true Kickxias are all Malayan, whilst the Funtumias are African plants. The tree occurs in Liberia, the Gold Coast, Lagos, and Southern Nigeria, the Cameroons, the Congo and Uganda. Until quite recently it was thought to be entirely confined to the West Coast of Africa, but Mr. M. T. Dawe, in the course of his botanical exploration of the Mabira Forest, Uganda, found it there also, an important discovery materially altering our ideas of its



Hevea Rubber showing two Basal V's
(*India Rubber Journal*)

Rambong (*ficus elastica*) Rubber Tree

geographical range. Funtumia belongs to the same natural order as the Landolphias, and, like them, is related to our common garden Periwinkle. Its flowers are white or yellow and the seeds are very characteristic, each bearing a beautiful silky plume about two inches long, by means of which they can float through the air like thistledown, and may often be found travelling about through "West Coast" forests.

Quite a number of companies have been formed during the last few months to develop rubber estates on the West Coast of Africa, and Funtumia trees are expected to provide much of the rubber. The tree has also been cultivated on a large scale by a company holding concessions in the Mabira Forest of Uganda, and the rubber there is washed by modern machinery and sent home as clean, although rather dark coloured crêpe. The latex, like that from the Castilloa and Ficus trees, is not easily coagulated, and similar means have to be adopted, that is, heating, etc.

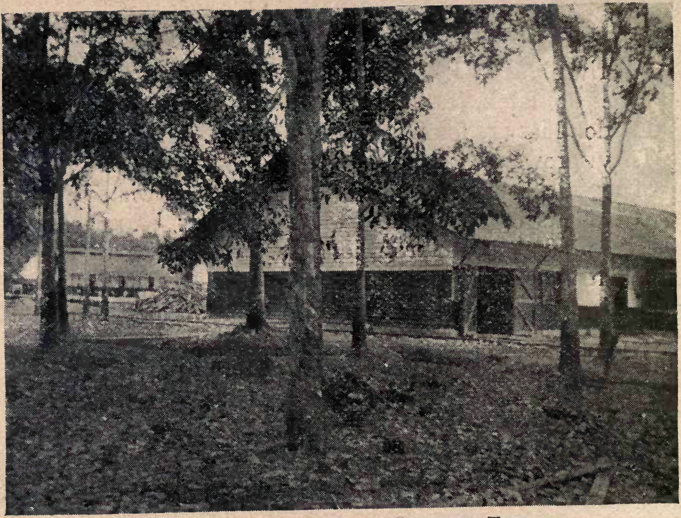
The rubber is of good quality and the native produce comes on the market in "lumps" and in other forms. The collection and exportation of this rubber, now so important an industry in many parts of the West Coast, is quite a modern development. As noted in the Colonial Report on Lagos for 1905, "Merchants took up the idea with enthusiasm. With startling suddenness the easy-going native awoke to the fact that wealth abounded in the forest round him and learnt for the first time that in sitting under his own fig tree he had been unconsciously reposing in the shade of the family bank."

Landolphia Rubbers

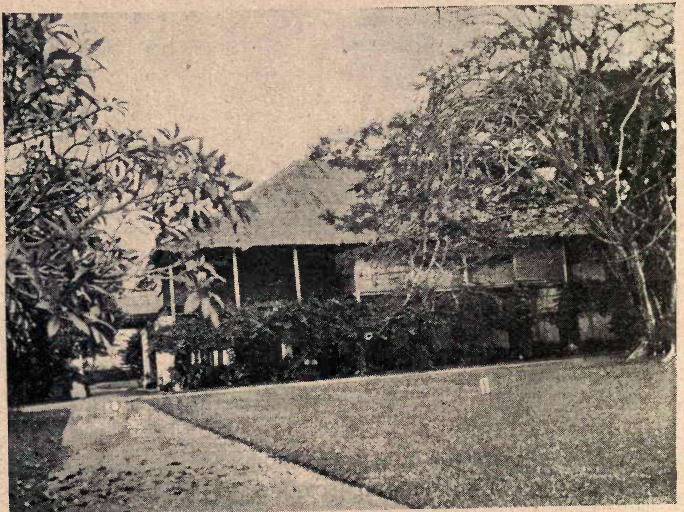
These rubbers are obtained from various species of the genus Landolphia, popularly known as vine rubbers, as they are climbers. They correspond to the British "periwinkles" (*Vinca*), whose stems also yield a milky juice or latex, although not rubber-yielding. The Landolphias are found mostly in Africa and Madagascar. They grow to a great size, climbing to the tops of the highest trees and developing heavy twisted rope-like stems of hard wood. Many species bear sweetly scented flowers in profusion often succeeded by large brightly coloured and sometimes edible fruits.

Of the many species of Landolphia we may mention some of the more important which give a good class of rubber. On the more northerly parts of the West Coast the chief rubber producer is *L. Hendelotii*, which further south gives place to *L. Owariensis*. This latter is one of the most widely distributed species, not only on the coast but in Nigeria and the Congo. In the latter district the *L. Foreti* is also common. On the East Coast the principal source of rubber is the *L. Kirkii*, and various other species are found in Abyssinia, Uganda and Madagascar, *e.g.*, *L. Madagascariensis*.

Collection of the rubber has up to now been mostly in the hands of natives. The methods are naturally very primitive. The thick woody stems are hacked with knives and the latex which exudes is caught in earthenware vessels and coagulated with acid juices, or allowed to drip on to leaves and there dry down. It is also recorded that in some parts the native smears the latex over his body and strips it off when it is coagulated. One can well understand that the native is not too particular in his methods and the African rubbers are among the dirtiest on the market. The stench emitted on washing in the factory, has in some cases been so repulsive that their use has been restricted in spite of attractive prices. Several companies have been recently formed to exploit the Landolphias in the forests of Central Africa and Madagascar. These companies aim



FACTORY SHOWING HEVEA RUBBER TREES IN THE FOREGROUND



BUNGALOW ON A RUBBER PLANTATION

at taking lightly built washing machines of special design into the forests, erecting them in suitable central positions so as to be able to wash the rubber on the spot shortly after coagulation, and to export a material which should fetch much better prices than the African brands at present generally do.

The so-called root rubber is also obtained from a species of Landolphia, viz., *L. Henriquesiana*, but is not really obtained from the roots but from the rhizomes or underground stems. There is also a rubber obtained from the tuber of the Ecanda. Samples examined by the authors were clean and the rubber was of fair quality.

Inferior Grades and Pontianac

We have now learnt something about the more important rubber-yielding trees and the methods by which the rubber is extracted. There are, however, other natural products which may be classed as rubbers, although of inferior quality, however carefully they may be prepared. As already explained, there are numerous tropical trees which yield a latex consisting of caoutchouc or caoutchouc-like substances with a large proportion of resinous constituents. In this group must be classed some of the species of castilloa, ficus, etc., which yield a rubber of low commercial value, but there are a large number of others not previously mentioned which may be grouped in this class. We have examined such products collected both in Africa and the East. Of these the most important is Gutta Jelutong, also known as Pontianac or Dead Borneo, a soft white or grey mass containing a large percentage of moisture and coarse impurities which are difficult to remove. It is derived from different species of *Dyera*, in particular *Dyera Cistulata*, and may be prepared for manufacturing purposes by heating with a quarter to half its weight of linseed oil. The thick semi-liquid mass is then strained through fine mesh gauze under pressure, or the straining may be carried out without the addition of oil by using sufficient pressure and keeping the mass hot enough. In this form it is largely used, especially on the Continent, for compounding with other rubbers in the manufacture of certain classes of cheap rubber goods. A large company has recently been formed for the purpose of collecting this material on a very large scale in Borneo and the Malay Peninsula, and refining it on the spot by removing part of the resins.

Guayule Rubber

This account of the commercial raw rubbers would not be complete without a reference to Guayule rubber, which is obtained from a shrub growing wild over large tracts of country known as " bush prairies " in Mexico. The rubber is not obtained by tapping, but the shrubs are gathered whole, or we may say harvested, and taken to large factories where the material is worked up on scientific lines. Considering the unpromising character of the raw material, the rubber obtained is surprisingly good and quite equal to the lower grades of native prepared African rubbers.

The shrub belongs to the natural order Compositæ, and is known botanically as *Parthenium Argentatum*. It usually grows to a height of two to three feet, the wood is hard, yellow in colour and heavy. It contains 90 % of the rubber in the plant. The leaves are of a silvery green, and the flowers small and whitish in colour. It grows best on a shallow rocky soil at a considerable altitude with small annual rainfall, and a wide variation in temperature.

The shrubs are cut down and delivered to the factory where they should be worked up as quickly as possible.

The plants are cut up and ground so that when mixed with water the rubber floats to the surface leaving the heavy wood and debris at the bottom. It is, however, better to grind with weak caustic soda solutions which dissolve part of the resins and most of the dark gummy colouring matters, so that a pale amber-like product results. This is capable of further purification by suitable solvents. In spite, however, of this treatment samples analysed by the authors showed seldom less than 15 % of resinous matter, while dark cruder products contained over 20 % besides much moisture.

At the present rate of consumption, we are told that the supply of shrub will not last longer than another five years, seeing that the plant is very slow to reproduce itself and is being rapidly exterminated in order to keep the large factories properly supplied with raw material.

PART II

MANUFACTURING PROCESSES

CHAPTER IV

In previous chapters we have described the production of raw rubber from the latex and we shall now proceed to show how this rubber is made up into manufactured goods.

The raw rubber is stored in vaults at the wharves in the ports as it is received. Of these London and Liverpool are of first importance. Here it is sampled, that is to say, a few pieces are removed as nearly as possible representative of the whole consignment. On these samples the rubber is subsequently sold. Fortnightly auctions take place at the commercial salerooms in Mincing Lane, where plantation rubber is bid for on basis of these samples which have been previously open to the inspection of the buyers.

Rubber Washing

Arrived at the factory, the first process consists in washing and drying the raw rubber. Of course, most of the plantation rubber is clean and dry and hardly requires any further treatment. The reverse, however, is the case with other rubbers, and so accustomed are manufacturers to washing and drying all their raw material that when plantation rubber first came on the market they insisted on putting this, too, through the machines, and for many purposes still continue to do so. Now, however, many plantations have justly acquired a reputation for rubber free from all dirt and moisture, and as we pointed out three or four years ago, manufacturers are now satisfied in many instances to take these brands as they are without further treatment.

It must not be forgotten that as yet plantation rubber forms only a small proportion of the world's total output (say six per cent. for last year, 1909), so that the washing and drying departments of the rubber factory are still fully employed.

While on this topic mention should be made of a tendency both in this country and on the Continent to erect factories solely for the purpose of washing, drying, and preparing rubber. It is agreed that these processes can be carried on more economically on a large scale where a number of different brands can be treated, and if necessary, blended to give the manufacturer a raw material of the exact grade and quality he requires. How far matters will develop on these lines must be left for the future to decide; large manufacturers will probably prefer to wash their own rubber if the drying room space at their disposal is sufficient for their needs.

The process of washing rubber in the rubber factory is carried out in exactly the same manner as on the plantation, but as the manufacturer has usually a much dirtier material to clean and one which has got hard and dry, especially on the surface, the rubber requires some preliminary treatment before it is ready for the rolls. The raw rubber, if in large lumps, is cut to smaller pieces, usually by hand. These pieces are thrown into a tank containing water kept warm by a pipe carrying live steam. The dry rubber gradually absorbs moisture and swells and the lumps get softer and can be better treated between the rolls. The length of treatment in hot water varies with the nature of the raw material, which is removed as soon as it is sufficiently soft. Sometimes the boiling process is carried out first so as to make it easier to cut the rubber up.

It is difficult to describe the action of washing rollers to those who are not familiar with this type of machinery. As one roll moves faster than the other, there is a sort of grinding or tearing action on the rubber which is held back on one side by the slower moving roll and dragged forward by the other ; at the same time it is submitted to considerable pressure. The net result of passing once or twice between the rolls is to reduce the rubber to the form of sheet with a very torn and irregular surface. To give the rolls a better grip they are grooved on the surface with spiral or diamond-shaped markings. Under the combined influence of the squeezing and tearing action, particles of dirt, bark, etc., are forced out, in some cases thrown out by the elastic rubber and carried away in the current of water which is kept playing on the rubber all the time. From the grooved rolls the sheets are taken to the smooth rolls which have a similar action to the former but reduce the rubber to a much thinner and more even sheet. This facilitates the next process, the drying.

Modern washing-rolls (Fig. 1), are very strongly constructed and are now usually driven direct from the main shafting by spur wheels and pinion, with a suitable clutch, belt driving being unsuitable, owing to the uneven strain. They are frequently provided with safety appliances, so that they are readily thrown out of gear in a moment by pulling a lever, as their crushing power is tremendous, and there is a possibility of a careless operator getting his hand drawn in. The driving-shaft and clutch are seen in the lower part of the machine. The handle of the safety lever is immediately above the rolls. Pulling this releases a lever

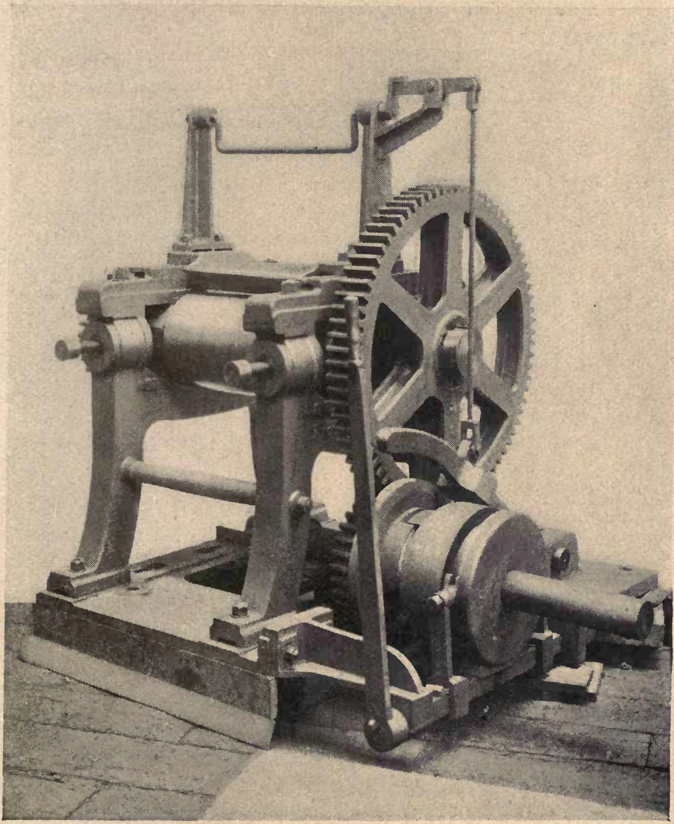


FIG. 1.—RUBBER WASHING MILL WITH CLUTCH
(*Joseph Robinson & Co.*)

which allows a heavy arm to drop and throws the clutch out of gear. The two screws seen in front of the machine are for the purpose of adjusting the distance between the rolls.

There are two other types of washing machines used to a limited extent. The first of these, the Universal Washing Machine, has only recently made its appearance on the market, and we have good reports of its working. It consists of a pair of rolls in a deep trough, the rolls move at the same speed, and are much more deeply grooved than the ordinary washing rollers and work under water. The rolls are made with peculiar wavy grooves and are placed at the bottom of the trough. The impurities are carried away through gratings in the sides of the vessel. It is well adapted to some grades of rubber, requires little attention, being more or less automatic; the charge of rubber is put in and the machine left for half-an-hour or longer till the washing is complete.

The other type is also partly automatic, and is used for low-grade African rubbers. It is similar in build to the papermaker's hollander, and consists of an oval trough with centre partition, between which and one side a heavy roll revolves carrying bars or knives. The trough is filled with water and the rubber is opened up between the bars of the roll, and similar bars fixed on the bottom underneath the roll, and washed clean.

Rubber Drying

The drying is carried into effect by hanging up the strips from the washing machine in festoons in dark or darkened chambers provided with a good natural draught. Most authorities are in agreement to the effect that the more gradually the rubber is dried, the better the results obtained when the rubber is made up into vulcanised goods, but no satisfactory explanation has, so far, been forthcoming, and the statement requires some modification. There is no doubt that the mechanical treatment to which the rubber is subjected in the process of washing, impairs the physical qualities, or as it is usually expressed, tends to destroy the "nerve"; but this only to a slight extent if the treatment is not carried too far. On slowly drying and stoving subsequent to drying, the rubber gradually regains its lost properties of "nerve."[1] The same thing applies to an even greater extent to rubber in the process of mastication. Whatever the explanation, the fact remains that most manufacturers have found by long experience that slow drying is beneficial. Moreover, it is not easy without special appliances to dry rubber rapidly. Water passes out very slowly from the inner layers to the outer layers of a sheet of raw rubber, and if the outer layer be dried down too rapidly, it forms a hard impervious skin on the surface through which the water from the centre passes out extremely slowly. This can only be got over by keeping the outer surface soft by raising the temperature and this is held by many to impair the quality of the rubber. The failure of many attempts to dry rubber rapidly by means of air draughts produced by fans is accounted for by the formation of this thin hard skin on the surface. In rapid drying, the surface water comes off quickly enough, but the subsequent rate of drying shows no improvement.

Much difficulty is sometimes experienced in drying low grade African rubbers. The washed rubber is soft and

[1] Nobody seems to be able to give a satisfactory definition of the meaning of the word nerve as applied to raw rubber, but the term is in constant use. The word nerve may be taken as summing up those characteristic physical qualities peculiar to india-rubber.

weak, due partly to the nature of the caoutchouc itself and partly to matter of a resinous nature and complex nitrogenous substances formed by over-heating in transit. Other decomposition products are present, due to careless treatment in coagulation, and excess of nitrogenous and other fermentable matters. These rubbers get sticky and begin to flow in warm weather, and are not strong enough to hold together when hung, so have to be dried on trays.

Of recent years, other means have been adopted for drying rubber, especially where additional space for drying-rooms is a consideration. The principle employed consists in heating the rubber to a temperature of about 100° F. or thereabouts in a closed vessel, and at the same time, exhausting the air, so as to produce a vacuum. This process is carried out in so-called vacuum dryers, such as Passberg's or Pintsch's, which consist of a large steam-jacketed box provided with removable trays on which the rubber is spread. Underneath each tray is a series of steam pipes connected with the jacket and supplied with exhaust steam. After filling and replacing the trays the box is hermetically closed with swing doors and the air and moisture rapidly removed by a powerful exhaust pump. At first the water comes away very rapidly from the rubber and can be seen pouring off through an observation glass attached to the condenser, but as the drying proceeds, the water evaporates more slowly and the temperature, which has been kept low by the rapid evaporation, begins to rise. Manufacturers are divided in opinion as to the merits of vacuum drying, owing to the temperature to which the rubber is heated in the process. Where not used for drying rubber, however, these dryers may be found very useful for minerals, so-called "drugs" and other ingredients of rubber mixings.

Loss on Washing

In the course of washing and drying, most commercial rubbers lose considerably in weight, as might be expected; partly through removal of grit, bark and other impurities, conveniently classed as dirt, and secondly through loss of water. As already explained, plantation rubbers being almost always clean and dry lose practically nothing; the only exception in this class, are some of the scrap rubbers, but even these are nearly, if not quite dry and have generally been washed before shipment. On the other hand, the very best grades of wild rubber give considerable loss on washing, even the standard fine hard Para loses from fifteen to twenty per cent., chiefly due to removal of moisture. Low grades of wild rubber may lose fifty or sixty per cent.

We give here a table showing the loss on washing of the more important brands of raw rubber:—

	Botanical Source	*Loss on washing per cent.*
Para, hard cure	*Hevea*	15 — 20
Para, soft cure	,,	10 — 15
Negro heads or Serwamby	,,	30 — 50
Mattogrosso or Virgin	,,	15 — 25
Cameta	,,	40 — 50
Peruvian ball or Caucho	,,	20 — 40
Ceara Scraps	*Manihot*	25 — 35
Mangabeira	*Hancorina*	30 — 40
Red Kassai	*Landolphia*	20 — 30
Massai or Sierra Leone Niggers	,,	20 — 35
Gaboon balls	,,	25 — 35
Upper Congo	,,	10 — 30
Mozambique ball	,,	10 — 35
Pinky Madagascar	,,	20 — 40
Panama	*Castillo*	15 — 30
Assam	*Ficus*	10 — 40
Pontianac or dead Borneo	*Dyera*	10 — 50
Guayule	*Parthenum Argentatum*	20 — 35

Manufacturers must, therefore, take very carefully into account the probable loss on washing when purchasing their raw material. Tables have been compiled giving the average loss on washing of the different commercial grades, and by reference to the correct column the purchaser can see at a glance what he is paying for his rubber when washed and dried, given a certain price for the crude unwashed material and a certain loss on washing.

The above list is in no sense complete, but is intended to give some idea of the variations in loss on washing and drying of various commercial brands. It will be seen from some of the wide limits given in the table, that it is very difficult to give figures for the loss, owing to the great variations in different shipments. It must not be supposed that the quality of the washed rubber is in any way connected with the loss on washing; thus, Cameta, which may lose half its weight, is a better class rubber than Peruvian ball, which loses much less.

CHAPTER V

COMPOUNDING AND MIXING

Vulcanisation

This term is applied to the process by which rubber is made to combine with sulphur, with the formation of the material termed vulcanised rubber. This differs in certain respects from the original raw rubber in possessing greater strength and being less influenced by changes of temperature.

The process of vulcanisation may be brought about in several ways. The rubber may be immersed in a bath of molten sulphur. On raising the temperature, combination sets in spreading gradually from the outer surface to the interior. The method is of historical interest, being one of the first discovered, and adapted to a time when the means of mixing and compounding rubber goods was unknown.

The method employed in the great majority of cases consists of bringing the rubber into intimate admixture with finely powdered sulphur and heating the mass either (1) in moulds, or (2) between steam-heated plates in a press, or (3) between layers of cloth, or (4) simply unconfined and resting in a layer of chalk. The vulcanisation process is commonly termed "curing," and the last-named method is known as the "open cure."

For the sake of completeness we may here mention the other system of vulcanisation which is carried out on a considerable scale for high-class goods made up from thin sheets, termed "cold cure." It consists of dipping the articles into, or otherwise applying a solution of sulphur chloride in a solvent, such as carbon bisulphide, to the surface of the rubber. With the help of the solvent the sulphur chloride penetrates into the rubber and both the sulphur and the chlorine combine with the rubber to vulcanise it.

Mastication

In order to bring the washed and dried rubber into such a condition that it can be mixed with sulphur and other ingredients it is masticated, that is to say, worked or ground between rolls till it is soft and dough-like in consistency. The plant usually employed consists of two steel or chilled iron rolls with smooth faces and so geared that one roll moves faster than the other. Except for details in build these rolls resemble the ordinary washing machine, but in addition they are hollow and bored for the purpose of steam-heating, and are so arranged that the workman can turn on steam for heating or cold water for cooling as desired.

A pair of mixing-rolls are shown diagrammatically in Fig. *d*, geared direct to the main shaft. In front are screws for adjusting the distance between the rolls, and on the top are adjustable cheeks on either side for confining the compound and preventing it spreading over the ends of the rolls. In the figure the same machine is shown in section and elevation.

The operator from long experience judges the temperature with his hand, and varies it according to the grade of rubber on the rolls. When the rubber is soft and of poor quality the temperature can be kept low, indeed, if raised too high the rubber would stick to the rolls and become unworkable. By correctly adjusting the temperature the sheet of rubber follows the slower moving roll, which is immediately in front of the operator, and forms a continuous band round this roll on gradually bringing the rolls up to one another. One roll has the bearing blocks fixed while those of the other are adjusted by screws on either side of the operator.

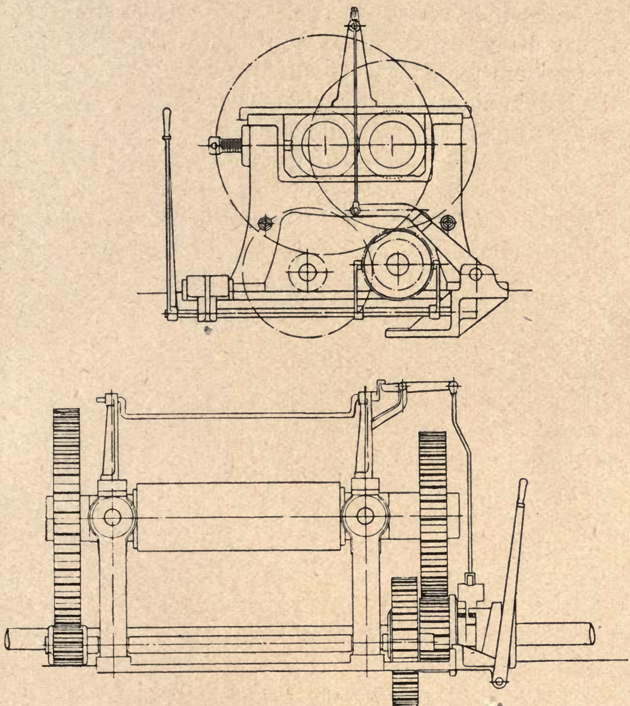


FIG. *d*.—DOUBLE-GEARED MIXING MILL
(*J. Robinson & Co.*)

The temperature of the rolls with a good-class rubber is such that the hand can just be kept upon them. The friction produced during mastication gradually raises the temperature and hence the necessity for a cold water supply to keep the rolls from getting too hot. Great care is needed when cold rubber is first put into the machine and it is not until it gets warm that it begins to flow and work easily. It is, therefore, common to provide a hot plate or steam chest, that is, a flat box steam-heated on which the rubber intended for mastication can be warmed before putting into the machine. Large mixers may be rolls three feet long, and a foot and a half in diameter, although, perhaps, the commoner sizes are of rather smaller dimensions.

When sufficiently masticated, an operation which may take up to half-an-hour or so, the rubber should be soft enough to " take up " the mineral powders, sulphur and other ingredients, but it is usual to put the rubber aside for a time after masticating before proceeding further with the mixing.

Mixing

The mixing is carried out on the same machines as the mastication. These are, as a matter of fact, usually known as mixing-mills, or perhaps more shortly as "rolls." The operator has given to him on a tray all the necessary ingredients which have been carefully weighed out ready for the batch of mixing. He starts with the rubber on the rolls and as soon as this is soft enough he adjusts the distance between them so that the layer of rubber carried round on the near roll is just too thick to pass round it without being carried against the further roll so that the plastic mass heaps itself a little between them as shown in the illustration (Fig. *e*), in which A is the slower moving of the two rolls.

The operator then dusts the " drugs " or minerals on to the top of the rolls so that what is not at once caught up and buried in the rubber remains in the space between the rolls and is gradually absorbed instead of at once falling between them. When all the minerals have been emptied on to the rubber, probably half or more will have fallen between the rolls and have been caught on a tray immediately underneath. The operator sweeps the powders out of the tray with a small hand-broom and dusts them on to the rubber again repeating the process until the whole of the minerals are absorbed. To help the mixing it is a good thing to slit the rubber at an angle half-way across with a knife pressed against the roll as it moves in front of the operator and then folding the flap over on to itself. This helps to get the mixing uniform and prevents the layer of rubber merely passing

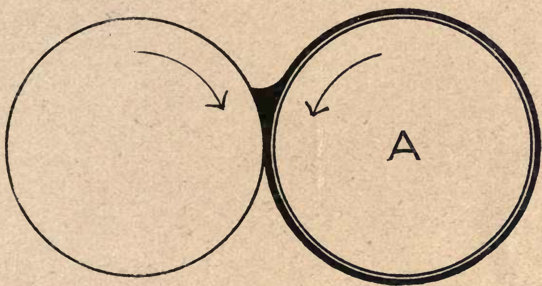


FIG. *e*.—ILLUSTRATING POSITION OF RUBBER AND ROLLS DURING MIXING

round and round on the roll without drawing the mineral in with it. The rolls are next brought up close to the "grind" and the whole of the batch passed through once or twice with the purpose of producing a complete admixture and breaking down any lumps of mineral imbedded in the rubber. After opening the rolls a little and passing through a few times more, the mixing is finished and the mass can be sheeted to any desired thickness or otherwise moulded as may be required.

The great art in mixing consists in distributing the

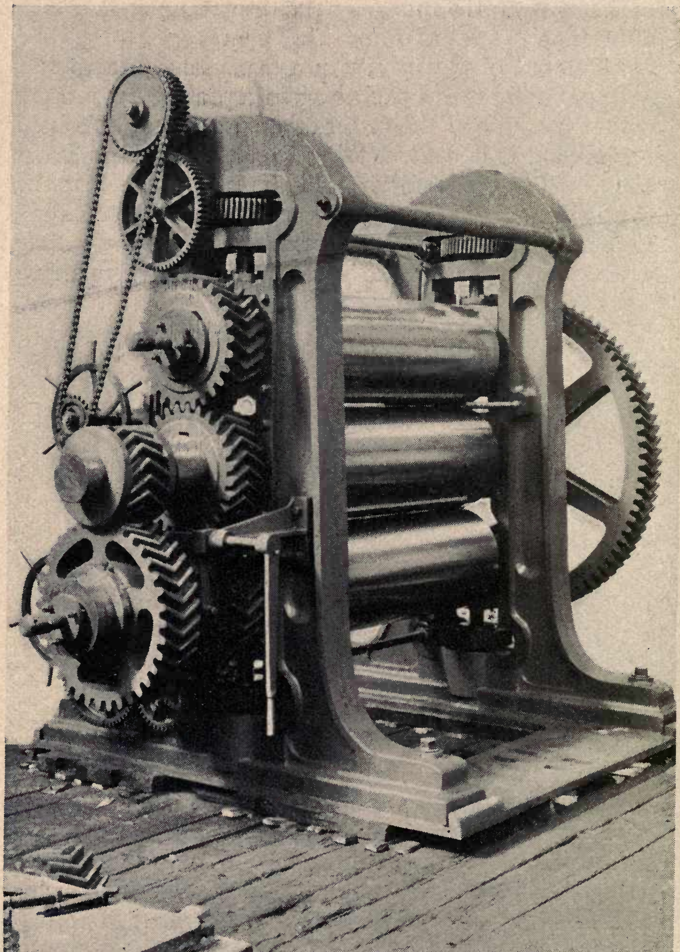


FIG. 2.—THREE-BOWL CALENDER WITH DIFFERENTIAL GEAR FOR FRICTION CALENDERING

minerals uniformly and regularly throughout the entire mass of rubber without overworking it.

Both the operations of masticating and mixing can be carried out on the same machine, but in large works separate machines are used at the different stages of treating the rubber. Thus, one machine may be kept running simply for the purpose of warming up the cold rubber which has got hard on standing and getting it into the plastic condition ready for mixing in the next machine.

Calendering

For most purposes the rubber-mixing is next taken to the calendering rolls. The simplest possible form of calender consists of two perfectly true and smooth rolls one superimposed upon the other, the mass of mixed rubber being fed in between the rolls on one side and passing out in the form of a sheet on the other. The sheet so produced is led to a wooden roll on to which it is wound between a layer of cloth as fast as it forms. Most calenders consist of three or more rolls and the sheet formed between the first two is led round the lower and then between this and the one below it and so on. The sheet obtained is, of course, more even and regular than would be produced by one pair of rolls only. The calender rolls are bored for steam-heating as when warm the rubber is, of course, softer and more plastic.

A three-bowl calender, as shown (Fig. 2), is the type most commonly met with. In this machine the two bottom rolls are doubly geared so that by means of a clutch, the lever for which is seen in the foreground on the left of the illustration, they move either at the same speed or the lower one moves more slowly. The latter combination is used when friction calendering. This will be better understood by reference to the accompanying diagram (Fig. *f*), which shows the disposition of rolls, rubber and cloth when in process of calendering.

A B and C are the three rolls in section. The rubber compound is applied at F and is compressed to a

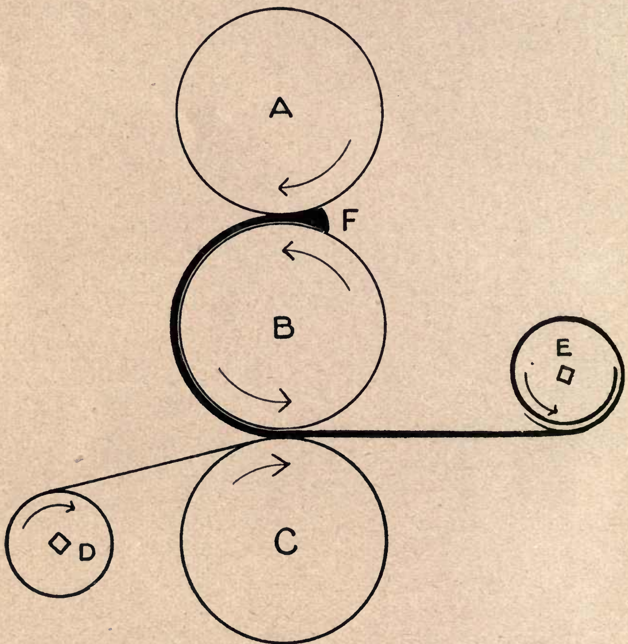


FIG. *f*.—ILLUSTRATING POSITIONS OF RUBBER, CLOTH AND ROLLS DURING CALENDERING

sheet between the rolls A and B. It passes round the roll B and then between the rolls B and C where it is rubbed on to the upper surface of a layer of cloth from the wooden roll D. The two pass on together and are wound on the wooden roll E, the layers of cloth preventing the layers of rubber from adhering to one another.

With very adhesive compounds an additional separating cloth is used. If now the roll C move slower than A and B the friction of the roll B on the surface of the rubber will force it into the cloth so that it adheres firmly. This arrangement is frequently used for permanently coating a cloth with a layer of compound as in the manufacture of heavy waterproof sheeting and tyre canvas.

CHAPTER VI

Ingredients of Mixings

We have referred to sulphur and minerals as ingredients of rubber-mixings in addition to the rubber itself. It must not be supposed that the former are always used for purposes of adulteration, or even for what may be termed legitimate cheapening of the rubber goods. The sulphur, of course, is necessary for vulcanisation, but some of the minerals confer valuable qualities on the vulcanised rubber. Others must, however, be described as "fillers"; they do not add appreciably to the strength or durability of the rubber goods, but only harden them.

Besides sulphur and minerals, or "drugs" as they are technically termed, a large number of other substances are used in compounding rubber. Of these we may mention ground rubber waste, reclaimed rubber, rubber substitutes, certain oils and waxes, such as the common fatty oils and paraffin wax, lamp black, bitumen, etc.

Some account of these ingredients of rubber-mixings will now be given :—

Sulphur

This element is almost always employed in the form of flowers of sulphur, obtained by allowing the vapour of sulphur to condense in cold brick chambers. The sulphur so produced is in a very finely divided form. This is desirable in order to produce an intimate mixture of the sulphur with the rubber. To a small extent precipitated sulphur is used. This is obtained by treating solutions of alkaline sulphides with acids and then washing and drying the white precipitate formed. It is said to be more active than flowers of sulphur.

Zinc Oxide

This is one of the most expensive but, at the same time, most serviceable of minerals for rubber-mixings. It has a slight toughening effect on the rubber and is used in the manufacture of cable coverings and for other high-class goods.

Chalk

This may consist of carbonate of calcium, having the same chemical composition as natural chalk, also commonly known as whiting, or it may consist of ground talc, a magnesium silicate also known as "French chalk." Although chemically different, both these substances are inert as far as a rubber-mixing is concerned and both serve as useful fillers. The specific gravity in both cases is about the same, namely, 2·7, which is considerably lower than that of zinc oxide, and most other minerals.

The specific gravity or density of the minerals used in the manufacture of rubber goods is a matter of great importance. When buying goods the purchaser is careful to take the specific gravity into consideration; a pound say of a solid tyre of low gravity will go much further than one of higher gravity, as in reality a certain bulk, not weight of the tyre, is required to go round the wheel. In the early days of the rubber industry, the gravity was also a measure of the quality of the goods, as the larger the proportion of rubber the lower the gravity. The gravity of pure washed dried rubber is well under unity, it floats on water, while the minerals with which it is compounded, have mostly a gravity of over three, chalk being the lightest in common use. In the same way the trade speaks of floating qualities, meaning thereby a rubber compounded with so little mineral that when vulcanised, it still floats on water. The rubber manufacturer has to keep down the gravity of his goods to within certain limits, and as the gravity of the goods depends chiefly on the gravity of the components, the use of much mineral, or mineral of a high gravity necessitates the use of a large proportion of a low gravity constituent to counteract its effect. At one time, this could only be done by the addition of genuine new rubber; nowadays, however, there are a great many substances, such as the rubber substitutes, oils and waxes and some of the reclaimed rubbers and bodies like lamp black, all of which tend to lower the gravity of the average rubber goods. If, however, the gravity is of little or no value as a test of quality, it will remain of considerable commercial importance so long as goods are sold by weight and not by bulk.

Magnesia

Of other minerals with relatively low specific gravity the carbonate of magnesia finds extensive employment. Its specific gravity is about the same as that of its chemical analogue, the carbonate of lime or chalk. Carbonate of magnesia, or as it is often termed, "magnesia," is sold to the rubber manufacturer in two forms, the "heavy" and the "light." Not that there is any appreciable difference in gravity, but the latter is either more finely divided or in a flaky form, so that the least breath of wind is enough to raise it in clouds. For this reason, it is not easy to handle in the mixing-mill. The difference in nature between the heavy and light magnesia is due to a modification in the manner of preparation, the distinction being a very old one. It originated in preparations for medical use and will be found in all the pharmacopœias.

Carbonate of magnesia has a toughening effect on the rubber with which it is compounded. Magnesia proper, that is, the oxide of the metal magnesium, is even more effective in this respect and is especially useful for rubber-mixings when the rubber used contains much soft resins. Instead of magnesia a little lime can be added, but lime is rather a dangerous chemical for rubber mixings, and it is much safer to use magnesia, although the latter is more expensive.

Litharge

Lead in the form of litharge or oxide of lead is another chemical which has a toughening action on rubber and is an essential ingredient for some classes of mixings. It is one of those substances which are known as sulphur carriers, that is to say, they combine with the sulphur added to the mixing and then pass this sulphur on to the rubber, with the result that the rubber enters into combination with the sulphur much faster than it otherwise would do. This has the effect of causing the rubber to vulcanise or " cure " more quickly. Rubber vulcanised with sulphur and litharge is always black in colour as the litharge, by combination with the sulphur, forms lead sulphide, a black substance. Unfortunately litharge is a very heavy body. The heaviness of lead is common knowledge, and what applies to metallic lead applies to a greater or less extent to its salts, that is lead in combination with other elements. The specific gravity of litharge is over nine.

Sulphide of Antimony

Perhaps the best known sulphur carrier is the red or golden sulphide of antimony, in which two parts of antimony are combined with five parts of sulphur. There is another sulphide of antimony which contains three instead of five parts of sulphur. This latter is known as the " trisulphide," the red sulphide being the " pentasulphide," and according to theory, the pentasulphide parts with some of its sulphur to the rubber being thereby reduced to trisulphide which by combination with part of the sulphur which was added to the mixing, reforms pentasulphide, this parts again with a portion of sulphur to the rubber, and so on.

Rubber can be satisfactorily vulcanised with very small quantities of sulphur in the presence of sulphide of antimony. Rubber can even be vulcanised with sulphide of antimony without the addition of any sulphur whatever, but this is said to be owing to the free sulphur commonly present in commercial samples of sulphide of antimony. It is, however, quite conceivable that the pentasulphide might vulcanise rubber of itself parting with a portion of its sulphur and being thereby reduced to trisulphide. Antimony sulphide is of a medium specific gravity, about four and a half. Its chief drawback, from the manufacturer's standpoint, is its price, which is something in the neighbourhood of eighteen pence a pound, while other minerals average from about twopence to a penny a pound or less.

Antimony sulphide is the mineral that should be used for the manufacture of red rubber. We say "should be," because it is largely replaced by cheaper substances, such as oxide of iron, which are quite inert and do not act as sulphur carriers. People commonly think that red rubber goods are of better quality than white or grey ones. It is difficult to understand how this notion got about, but there was at one time some justification for it. Red rubber goods were rather dearer when sulphide of antimony was the only substance in common use in their manufacture and there was less danger of over-vulcanising goods containing sulphide of antimony without sulphur. The red mineralized rubber goods of a well-known firm may be taken as an example of this type of mixing. We shall see that over-vulcanised goods rapidly deteriorate.

Barytes and Lithophone

Another mineral with a specific gravity of above four and a half is the substance "barytes," or sulphate of barium. It is chemically inert and is useful as a filler just as in the colour trade, where it is often found as an adulterant of white lead. By precipitating sulphide of zinc on to barytes a colour termed lithophone is produced. This has a better covering power than barytes and is used in rubber mixings. The quality and price depend mostly on the proportion of sulphide of zinc it contains; this chemical being the more expensive ingredient.

Colours for Rubber Goods

This practically completes our list of the more important drugs, although numerous others could be mentioned, which are occasionally used or added for special purposes. Thus, vermillion, a sulphide of mercury, and a yellow sulphide of cadmium are used as well as sulphide of antimony for producing red and yellow shades. It will be noticed that these colours belong to the group of chemical substances termed sulphides, that is, combinations of the metals in question with sulphur. The reason being that very few coloured substances outside the sulphides themselves are able to withstand the action of sulphur and heat in the vulcanising process. All the usual organic dyes, such as the well-known coal-tar colours, are killed on heating with sulphur under these conditions; indeed, it is not an easy business to find colours, for vulcanised rubber cured in the heat. Where it is desired to colour the rubber black, and if litharge is not admissible, the manufacturer has the choice of a variety of carbon blacks or lamp blacks. The specific gravity of these bodies is only about two, so that they have the additional advantage of counteracting the effect of heavy minerals. They also toughen the rubber and are, therefore, frequently employed. Some of them tend to make the rubber porous, especially if the quantity exceeds three or four per cent. Porosity is one of those defects in rubber goods that occasionally arise and give the rubber manufacturer a good deal of trouble. The causes of porosity are numerous and difficult to trace. Open cure goods, such as solid tyres, are particularly liable. On cutting open a piece of the finished rubber it is seen to be permeated with small air-bells which naturally detract from its strength and quality.

Oil and Oil Substitutes

We now come to the other ingredients used in rubber mixings, of these "fatty oils" and oil substitutes are among the more important. Of the fatty oils, castor oil, linseed oil and rape oil are those most frequently employed, but the quantity taken is generally quite small. Most of the oil remains unaltered in the rubber after vulcanising, but some of it combines with the sulphur in a similar manner to rubber itself. By heating together the oil and sulphur in a suitable iron pan as a preliminary operation, the two combine and on cooling there remains a soft dark red to brown jelly with a sulphurous smell. This is the "dark substitute" of commerce which is used to a large extent in medium and low-grade mixings. A small quantity, say five per cent., does not detract much from the physical qualities of the rubber, in fact in some cases the addition of two or three per cent. may be actually beneficial. It should not, however, be used in the compounding of goods which are to be much exposed to a moist atmosphere, or to steam, the reason being, that oils are much less resistant to the action of steam and moisture than rubber, on which they have no decomposing action. What applies to oil applies equally to combinations of oil and sulphur. Rubber containing much oil substitutes perishes rapidly when exposed to a moist heat. On this account the government departments, such as the Admiralty, who purchase large quantities of rubber goods, specify that these shall stand a moist heat test. In this test the rubber is heated for four hours in a moist heat temperature of 320° F, a temperature considerably higher than the boiling point of water and which is only reached on heating in a closed vessel under pressure, such as a steam-generating boiler.

There is another class of india-rubber substitute, termed "white substitute" in contradistinction to the brown substitute just described. It is prepared by the action of sulphur chloride, a brown fuming liquid on one of the oils already mentioned, such as colza, rape or linseed, or a mixture of two or more of them. It forms a light white spongy mass having the appearance of white froth and contains chlorine as well as sulphur in combination with the oil. The reader will remember that rubber may also be "cold cured" by treatment with sulphur chloride (see under vulcanisation). In order to better control the action of the sulphur chloride, it is diluted with petroleum spirit and the mixture is well stirred during the process. The "white subtitute" is sometimes used in the place of brown in rubber mixings, although with doubtful advantage. Its use is best confined to cold-cured goods (which see). The white substitute is subject to the same defects as the brown.

Artificial or Synthetic Rubber

While on the subject of india-rubber substitutes reference may be made to the numerous attempts in recent years to produce a substance which shall be a rubber substitute in a real sense. We mean a substance having to some extent at least both the physical properties and also the chemical nature of natural india-rubber. An immense amount of work has been done in this direction, and a reference to the files in the Patent Office will give an adequate idea of the extraordinary combination and manipulation of materials that have been brought forward to this end. The result can only be described as complete failure, no real substitute in the above sense has ever been discovered. As an example, a favourite subject matter for this type of invention relates to the substance obtained by allowing bichromate of potash to act on gelatine. This produces a fairly tough elastic body but with that the similarity with rubber ends. The fact is, the peculiar properties of india-rubber are probably bound up with, and only occur when carbon and hydrogen atoms are joined up with one another in some form of chemical combination which is only met with in the natural product and the only effective substitute possible is one built up artificially by a series of chemical reactions so as to produce this particular type of combination. In other words, rational investigation on these lines should aim at the production of what is termed "synthetic" rubber.

Before the research chemist can synthesise he must study the decomposition products of the substance he is aiming to produce. A man must first discover the sort of materials of which a house is built and the manner in which they are superimposed, that is, their relative position to one another, before he is able to produce a replica of the building. In a similar way the chemist by breaking down stage by stage the molecules of which india-rubber is composed obtains, as it were, a plan of the composition of the substance; he is then able to set to work to reconstruct on well ascertained lines. So far considerable progress has been made, particularly during the last year or two, and we have a plan of the india-rubber molecule which seems to answer pretty well to the way it behaves. There seems no doubt that by a roundabout method one chemist at least has succeeded in building up a body which if not identical with india-rubber must be closely allied to it, as this body has to a modified degree all the characteristic properties of rubber. We are, however, still a long way from the goal, for not only have we to make rubber synthetically but to do so *on a commercial basis.* It is fully expected that the rubber plantations will eventually be in a position to turn out the clean dry produce at a price, all told, not exceeding one shilling per pound. The chemist must, therefore, be in a position to manufacture a synthetic product as cheaply as the natural product can be grown if he is to be successful—unless, indeed, the synthetic product should turn out to be the better—a by no means impossible contingency, just as the synthetic dye-stuffs—the coal-tar dyes—are far stronger colouring matters than the vegetable dyes, and have almost entirely replaced the latter. The most recent work in this direction is the subject matter of a patent taken out by a Dr. Hoffmann working for the Baeyer Co. of Elberfeld. A product resembling caoutchouc is obtained by condensing divinyl $C_4 H_6$ (from acetylene and ethylene), and heating it in solution in benzine.

WAXES

Waxes, in particular mineral waxes, such as common paraffin wax, are added in small quantities to some rubber-mixings. Paraffin wax is inert and fills up the pores and thus tends to preserve the rubber. It is often found, for instance, in the rubber of cable coverings.

It is hardly necessary to refer here to any more of the long list of substances which have been employed at one time or another in rubber-mixings, usually for some special purpose.

Reclaimed Rubber and Ground Waste

There remain for consideration the utilisation of waste vulcanised rubber. This can be done in at least two ways. (1) The waste rubber articles can be ground to a fine powder and used in this form for compounding with the minerals and other ingredients of the mixing, or (2) the waste rubber can be subjected to some chemical or physical treatment by which it partially regains those properties which allow it to be used to some extent in place of new raw rubber.

With regard to the ground waste there is little to be said. Rubber with thirty per cent. or more of mineral can easily be ground to powder between the ordinary mixing-rolls. Recently a new type of grinding-mill has been introduced—a sort of nutmeg grater on an improved plan, and, of course, power-driven. It will grind almost any sort of rubber including floating waste.

Ground waste in a rubber-mixing can only be regarded as a sort of filling and cheapening agent. We do not wish to convey the impression that it has no legitimate use. Like rubber substitutes, and many other substances employed, it becomes a necessity to the manufacturer catering for a public who give the preference to a cheap and necessarily inferior article rather than pay a reasonable price for a good one.

Another method has recently come to the fore, or at least a modification of the above for the utilisation of ground waste. The waste is placed in moulds without any addition of unvulcanised rubber and the powder is then subjected to considerable compression by hydraulic means and while still under pressure the mould is screwed down. It is then placed in an oven and heated just as when vulcanising under ordinary conditions. On cooling and opening the mould the ground waste is found to have amalgamated to a compact block, to all appearance identical with an article produced in the ordinary way. This reformed rubber is almost equal, so far as physical properties are concerned, to the original vulcanised articles from which the waste was produced. More recently a patent has been taken out for a refinement of this process, which it is claimed marks a considerable advance. The ground waste is mixed with a small quantity of volatile oil before compression, and the volatilization of this oil drives out the air from the interstices of the particles of ground rubber resulting in a more compact product. A company has recently been floated to work these patents, and articles made by the process exhibited a short time back appear excellent. The only drawback to the process would appear to lie in the cost of the moulds, which must be strong enough and so constructed as to allow of compressing the rubber to the required degree, and keeping it compressed during heating.

The second method of utilising waste rubber referred to and termed "reclaiming" has assumed enormous proportions of late years. Not only have the larger rubber factories their own reclaiming plant and processes, but huge buildings have been erected, especially in the United States of America, devoted entirely to reclaiming. Numerous brands suited for different classes of rubber goods have been put on the market. Although many of the processes have been patented they are largely worked as trade secrets, and little is generally known concerning them beyond the broad outlines of the treatment to which the waste is put. In some processes acids are used on the ground waste to remove fibrous material. The waste is generally heated with dilute sulphuric acid in boilers under pressure. It is well known that weak acids have a tendering effect on cotton. If, for instance, "cotton-wool" be heated with very dilute sulphuric acid, say of two or three per cent. strength for five minutes and then be washed free from acid and dried, the cotton will be found to have become quite rotton so that it can be crumbled to powder between the fingers. The principle is made use of in a number of cases where cotton has to be separated from a more valuable material, as, for instance, in the separation of wool from rags consisting of cotton and wool woven together, the wool, like all animal fibres, is unaffected by the weak acid while the cotton is rotted out. India-rubber is one of the most inert of natural products and withstands the action not only of weak acids but also of their chemical antithesis, the alkalies, as we shall see later. After the acid treatment the tendered fibre can be washed or dusted out.

Besides this chemical process there is a purely mechanical one by which most of the cotton fibre can be removed. This consists of some form of mechanical contrivance known as a "devil," by which the rubber is torn to pieces and the fibre reduced to very short lengths or mere dust. Air blasts are provided by which this fibre and dust are carried away leaving behind the specifically heavier mineralised rubber compound. Of course, not all the waste contains fibre—this only applies to some classes such as india-rubber hose, heavy waterproof sheeting and such materials; they form, however, a very important part of the rubber reclaimer's raw stock. The next process consists in heating the ground rubber with oils; the particular oils or mixtures of oils used differ with different makers, but it is generally understood that resin oil forms the main ingredient.

Resin oil is obtained by the distillation of resin, which itself is the residue left in the retorts after the distillation of crude turpentine. The mixture of oil and ground waste is heated to a rather high temperature, often above the usual temperature for vulcanising, and effects a softening of the rubber so that the mass regains some of the plasticity it possessed previous to vulcanisation, and can be rolled into sheets or otherwise manipulated between the rolls.

We have already explained that the vulcanisation of rubber, considered from a purely chemical standpoint, consists in the combination of rubber with sulphur, the extent to which this takes place depends, firstly, on the temperature to which the mass is heated and, secondly, on the time during which the heating takes place. The higher the temperature and the longer the time the further the chemical reaction proceeds, and the larger the proportion of sulphur which enters into combination with the rubber. There is, however, the limit beyond which it is not safe to go as the vulcanised rubber when over-cured goes rotten either at once or after keeping for a time, according to the extent to which the safe limit has been overstepped.

Regarded in a chemical light and from another point of view, vulcanisation is a sluggish reaction, it proceeds slowly and to produce the effect required in a reasonable time it is necessary to add a good deal more sulphur to the rubber than will actually enter into combination with it. In a vulcanised rubber article we, therefore, have part of the sulphur "combined" and part uncombined or "free" and this, of course, applies to rubber waste.

The free sulphur detracts considerably from the value of waste, from the point of view of the reclaimer working a process as outlined above. When the ground and purified waste is heated with oil to a temperature above the vulcanisation point, further combination with free sulphur present may take place and an inferior product results. For this reason reclaimers prefer a waste, such as old galosh or rubber shoe in which the free sulphur present is a minimum and some of the best reclaim is derived from this source.

More recently an "alkali" process has been introduced which would appear to constitute a considerable technical advance on its predecessors. The ground waste is heated in boilers under pressure with a weak solution of caustic soda which dissolves out the free sulphur; at the same time the rubber is softened, and after thorough washing the residue can be dried and united to form a homogeneous mass on the rolls. It is stated that heating with oil is not required, but obviously with the removal of the free sulphur, no danger would attend such an operation. Washing the boiled waste requires to be thoroughly performed; it is a common experience that ground rubber retains residues of alkali with great persistency.

It is claimed by some makers that their product is really a *devulcanised* rubber. In other words, they claim not only to have removed the free sulphur and to have imparted a degree of plasticity to the hard and often perished waste, but also to have removed some portion at least of the sulphur which was in combination with the rubber, so that the reclaim is both chemically and physically reconverted to material of the nature of raw rubber. This, however, is very doubtful. Although the rubber is not devulcanised the reclaiming process imparts to the waste the chemical capacity of taking up more sulphur when remanufactured and vulcanised in the ordinary way. This is more easily understood when we remember that vulcanised rubber contains only two or three per cent. of sulphur in combination with the rubber. During vulcanisation we can imagine that a change takes place in the complex rubber molecule *besides* the chemical combination with sulphur. This change in complexity may be reversed by reheating the vulcanised rubber *after removal of free sulphur.* This would appear to be the underlying principle of all reclaiming processes and is in conformity with what we know of the general behaviour of such substances.

From the description of the reclaiming processes already given, it will be seen that little, if any, of the minerals in the waste are lost. The reclaim will, therefore, correspond in this respect with the waste, and a floating reclaim can only be prepared from a floating waste. Attempts have been made to remove the mineral matter and no doubt this could be done to some extent. Acids, of course, will dissolve out the oxides and carbonates of most metals—other minerals could, perhaps, be separated by taking advantage of their high specific gravity, but when all is said and done minerals are required more often than not in the goods for which the reclaim is intended and to remove minerals from the reclaim at considerable expense only to add them again in the subsequent compounding of the new mixing would hardly seem to recommend itself as an economical operation. The most that can be said is that the reclaim when purchased by the rubber manufacturer, has an unknown amount of mineral of unknown origin and is, therefore, difficult to allow for, when compounding with the other ingredients. The determination of mineral in a reclaim is not a difficult operation, and if the quantity of reclaim used is small the presence of mineral is not a serious objection. As to the advantages or disadvantages of using reclaim, much the same must be said as in the case of other cheapening agents.

or as some will say, adulterants. Many reclaim rubbers are very poor stuff indeed, being little better than ground waste held together with boiled oil and sticky resinous compounds. Other grades, such as that obtained from rubber shoes, may be employed with advantage even in goods which have to stand much more wear and tear. So much depends on the quality of the reclaim and the proportion used. Much of our modern industrial advance is based on the successful utilisation of waste materials, and the same may be said of waste rubber as of other things. There is every justification for the use of reclaimed rubber, but it cannot be said to successfully replace raw rubber, nor should it be used in the manufacture of best quality high-grade articles. The Admiralty specify in their contracts that no reclaimed or recovered rubber be used in the manufacture of their goods, and they, no doubt, act wisely in making this condition so long as they demand the best quality goods and are prepared to pay for them.

CHAPTER VII

VULCANISATION

IN the last chapter we outlined the vulcanisation process and the matter has also been referred to when speaking of rubber-reclaiming methods. We shall now consider vulcanisation in more detail and, in the first place, vulcanisation by heat with a short description of the plant employed.

The conditions under which rubber goods are vulcanised depend, of course, on the proportion of sulphur taken. As the sulphur reacts with the rubber and not with the minerals—with certain exceptions—the proportion of sulphur should always be reckoned on the raw rubber and not on the whole mixing. Allowances must be made for ingredients which react with sulphur, such as reclaimed rubbers, and also in those cases where sulphur carriers such as red sulphide of antimony or litharge are used. The proportion of sulphur to rubber when reckoned as a percentage on the latter varies in practice from three to forty per cent. The larger proportions of sulphur are used in the manufacture of hard rubber commonly termed vulcanite or ebonite.

In order that rubber may combine with sulphur it must be heated above the melting point of the latter. At this temperature the rubber itself becomes soft or semi-fluid according to quality, and this has to be taken into consideration in mixings for goods intended to be "open cured," such as solid tyres, rubber tubing and the like, as they are liable to sag during the cure. Where moulds are used the thickness of metal of which they are made and the conductivity of the metal and the rubber compound itself have all to be taken into consideration when fixing the time for vulcanisation. The moulds used in rubber works are usually of iron and substantially constructed in two or more parts held together by bolts screwed up so as to confine the rubber to the space between them. The rubber compound as it comes from the rolls is fairly soft and plastic so that it takes the shape of the mould. The temperature and time of heating are interdependable. If the time is prolonged the temperature can be kept lower and, *vice versa*, by raising the temperature the time can be shortened. From the manufacturers' standpoint, and for economy in working, the time of heating is shortened as much as possible. For some very cheap goods, such as heel pads, the time is cut down to fifteen or twenty minutes, by which means a very large output is obtained with the minimum number of moulds and vulcanising capacity. Or again, to take an instance more familiar to the general public, reference may be made to the rapidly vulcanising compounds used for repair of motor tyres. These vulcanise in fifteen to twenty minutes, so that a burst tyre is quickly repaired and the motorist on the road again.

The length of time and temperature—or put shortly, the cure—required depends on the quality of the rubber used for the mixing. Of all varieties Para rubber cures faster than any other, whether smoked from the West or air-dried from the East. The method of preparation has also an influence on the rate of cure, as also the means adopted for drying the rubber and the mechanical treatment to which it has been subjected, as when washing the raw material or during mastication and mixing on the rolls. Working the rubber has a general tendency to retard the rate of vulcanisation. Badly prepared rubber is influenced in a similar manner, and the various scrap grades of Para rubber vulcanise more slowly than fine hard cure.

The rubber-mixing before vulcanisation is soft and plastic. The lower grades of rubber and those containing much resin of low melting point are, of course, much softer than better class rubbers, but even with the best Para the rubber is relatively soft and weak when fresh from the rolls as compared with untreated rubber, owing to the working it has undergone. If, for instance, a corner of a freshly-calendered sheet be stretched out between fingers and thumb it remains extended or only very slowly and incompletely returns to its original shape. When fully-cured it returns almost completely, and at once, but if under-cured, that is to say, if the temperature has been too low or the time of heating too short, it shows an intermediate behaviour, it returns pretty completely, but it takes a long time to do so.

Before vulcanisation two rubber surfaces pressed gently together unite firmly and cannot afterwards be separated. When partially cured the surfaces are still adhesive and stick together, but will separate again when pulled apart. A fully-cured sample shows no adhesive qualities on the freshly-cut surfaces. When we speak of adhesion between surfaces we refer to clean or freshly-cut ones. Dust tends to destroy the tendency to adhesion and this plays a very important part in the manufacture of rubber goods. Where it is desired to destroy the adhesiveness of the surface so as to facilitate handling before vulcanisation, liberal use is made of French chalk which is dusted over the articles. On the other hand, dust must be avoided where two surfaces have to be joined up as, for instance, in building up an india-rubber tobacco pouch from pieces cut from a sheet or in the manufacture of india-rubber shoes.

If the temperature during vulcanisation be too high, or the heating be continued too long, the rubber becomes as it is termed "over-cured." This may not be at once noticeable when the article is examined, but after keeping for a time it loses its strength and may eventually become hard, friable and thoroughly rotten. Great care is therefore required not to exceed the safe limits. If the quantity of sulphur be large and the heating be very prolonged, the product becomes tough and hard by conversion to vulcanite. Raw rubber of good quality is pale in colour and very translucent, or almost transparent, especially in the case of the best plantation brands. When cured it tends to darken in colour, and if over-cured the best pale plantation Para turns orange to brown. If the cure be further prolonged and more sulphur added the colour turns almost black and the rubber becomes opaque.

Vulcanising Pans

Whether mould-cured or open-cured the heating is carried out in vulcanisers. These consist as a rule of long cylindrical boilers (Fig. 3) connected with a supply pipe for live steam obtained from a steam-generating boiler, and also with a waste pipe for blowing off. The steam supply pipe runs along on the bottom inside the vulcaniser and has several outlets, and in addition to which there is a stage or platform immediately over the supply pipe and running the whole length of the vulcaniser, so that the steam is well distributed on entering and uniform heating is obtained. One end of the vulcaniser is detachable and is arranged to swing open on a hinge and the articles to be vulcanised are wheeled in on a cage which runs on a pair of rails right along inside the vulcaniser on the platform already mentioned. The door is then shut to and made fast with a number of swing bolts. The vulcaniser is also provided with a

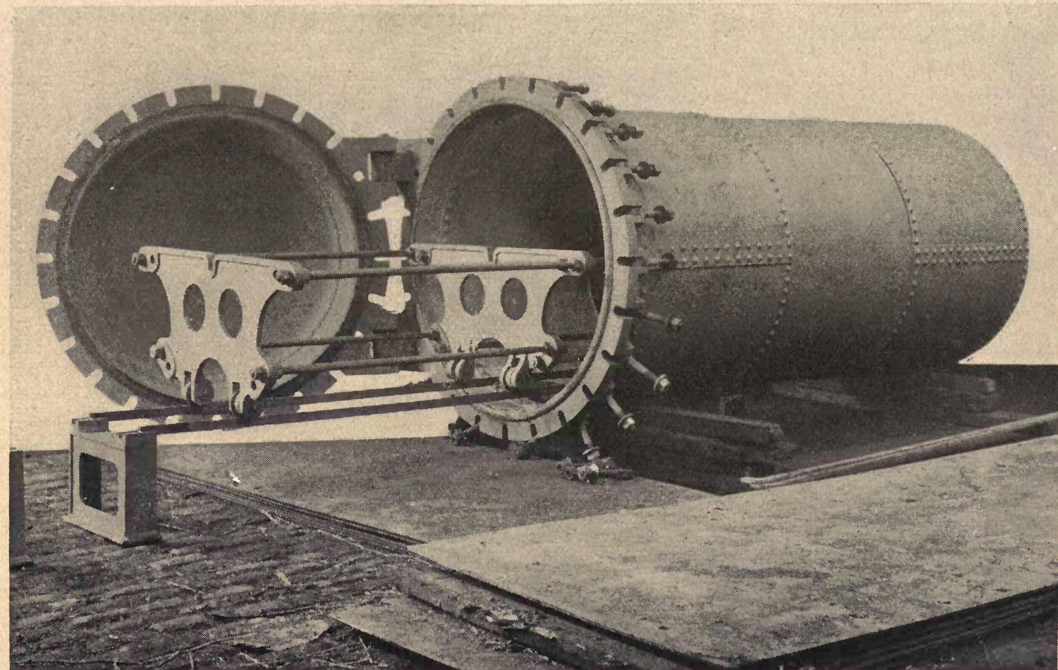


FIG. 3.—VULCANISER
(*Joseph Robinson & Co.*)

safety-valve and pressure-gauge. The progress of the cure is followed by means of a thermometer, the bulb of which lies inside the vulcaniser and is protected by a metal tube. In many factories self-recording instruments are installed which register the steam pressure during the cure on a sheet of squared paper round a cylinder driven by clock-work, such as is used for self-recording barometers and similar instruments.

The works manager has therefore an unalterable record of each cure, which can be filed and referred to in case anything goes wrong and the goods are subsequently found to be under or over-cured. Vulcanisers are built in a variety of sizes to suit the type of goods, and may be three to twelve feet in diameter, and anything from three to sixty feet in length or even longer for vulcanising hose. Some vulcanisers are built with a steam jacket where the steam is kept permanently at a pressure and let into the interior only when the articles to be vulcanised are in place and the lid screwed down. This has the advantage of more rapid working, as the vulcaniser is not allowed to cool down and has not therefore to be heated up again with the fresh charge. The heating is also more uniform, a great essential in successful working. It can easily be understood that with condensation on the walls taking place all the time there is a liability to currents, and, therefore, uneven heating in the interior. Steam-jacketed vulcanisers are not suitable for working with hot air for the same reason. In the case, say of a number of layers of rubber being cured between cloth, the outer and inner layers get heated but the hot air cannot penetrate between them, and the middle layers get only gradually heated by conduction from the outer ones and are consequently under-cured. In some vulcanisers there is a contrivance to keep the articles to be vulcanised in motion so as to secure even heating.

In addition to the ordinary pan vulcanisers there is the vulcanising press (Fig. 4), which functions not only as means of heating but at the same time as a mould. The simplest form of press consists of two steel boxes with smooth even surfaces facing one another. The boxes are heated by steam the pressure or temperature being controlled exactly as in the vulcanisers above described. The sheet to be vulcanised is placed between the surfaces and pressed down while steam is let in and the rubber cured. Presses are often built up of several of these steam boxes superimposed and worked by an hydraulic ram so that several articles can be cured at the same time. They are also made in very large sizes for curing such articles as belting or heavy waterproof sheeting. Reference must also be made to hot-air vulcanising, suitable for waterproofing materials where moisture and heat combined would spoil the colours in the fabric. The proofed material is hung in festoons and the hot air blast driven through so as to secure uniform heating throughout.

We have explained that it is necessary to take more sulphur for vulcanisation than actually enters into combination with the rubber, so that there is always some free sulphur in the vulcanised product. When the percentage of free sulphur exceeds a certain figure the sulphur crystallises out on the surface of the vulcanised article as a white dust or powder. This is also largely dependant on the ingredients of the mixing and the method of curing. This phenomenon is termed blooming and is common with all types of rubber goods, especially where a large percentage of sulphur has been used to facilitate rapid curing. In some cases it gives a finish to the appearance of the rubber, which is desired,

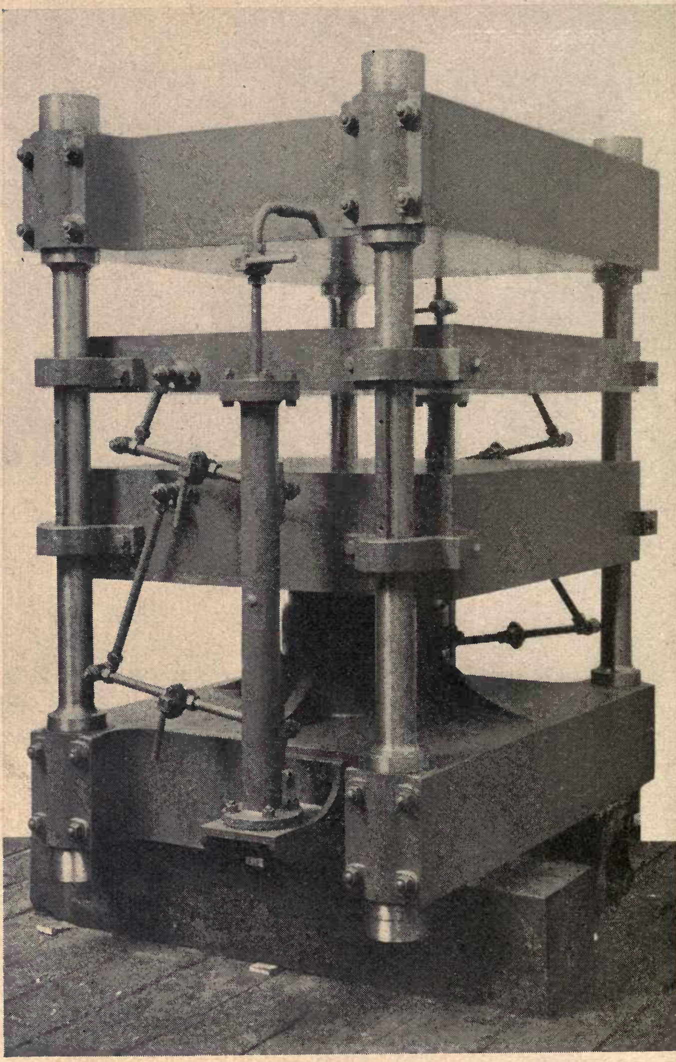


FIG. 4.—VULCANISING PRESS
(Joseph Robinson & Co.)

but in other cases the blooming is regarded by the manufacturer as an unwelcome feature. Especially is this the case where the rubber is compounded without minerals. The matter is, however, of a sentimental rather than practical nature, as blooming does not affect the quality of the goods in a real sense, that is, it does not detract from the strength or resistance to wear and tear. As a general rule, bloom on the surface should be regarded as a good sign, as there is probably less danger from over-curing when an ample proportion of sulphur has been used in the mixing and the goods bloom freely. We are ignorant of the exact cause of blooming, although allied phenomena are frequently met with, the discussion of which would be of too technical a nature for our purpose. The formation of the powdery sulphur layer is, however, gradual, and no traces are to be found on the freshly-cured goods. On standing, the sulphur begins to appear either in the course of a few minutes or after a few hours or days. Where not required, it can be removed by washing in a bath of weak soda which dissolves the sulphur.

CHAPTER VIII

Solid Tyres and Rubber Tubing

Having now explained the process of vulcanisation by heat, we will pass on to a short description of the methods employed in the manufacture of some of the commoner rubber goods. There is a large class known in the trade as "mechanicals," which include such rubber goods as are

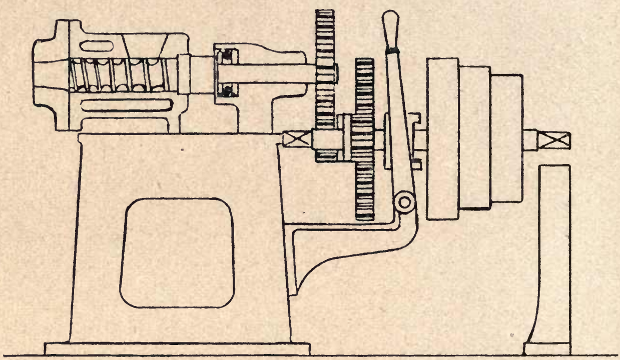


Fig. *g*.—Forcing Machine
(*J. Robinson & Co.*)

used for mechanical purposes, such as buffers, hose, tyres, etc. We will take, to begin with, the manufacture of solid rubber tyres and rubber tubing, both of which articles are open-cured.

As moulds are not used, the goods are shaped to the required form by other means. In this case, a spewing or forcing machine is employed, constructed on the same lines as machines for making lead tubing, or to take a homelier parallel, they bear some resemblance to a sausage machine. The machine, shown in outline in Fig. *g*, consists essentially of a very strongly-constructed cylinder in horizontal position, within which a powerful screw or worm revolves. This is driven by a belt and pulley at one end, while the other end of the cylinder tapers and is fitted with a die of the required shape, that is, corresponding to the section of the tyre to be made. The nozzle is arranged so that the dies are interchangeable. At the other end at the top of the cylinder is a rectangular opening through which the rubber compound is fed into the cylinder. In some machines a pair of small rolls are fixed over the openings with axes parallel with the axis of the cylinder for forcing the rubber compound into the cylinder. These are not shown in the illustration. The rubber, as required, is cut off from a batch kept hot on a pair of smooth rolls close by and the cylinder of the forcing machine is also heated by means of a steam jacket. The shape of the die does not correspond exactly with the cross section of the tyre but is made rather different in outline and somewhat smaller, as the rubber compound expands as it leaves the nozzle owing to the enormous compression exerted on it in the interior of the cylinder. The expansion is not, of course, a true expansion of the material in the ordinary sense of the term, as rubber compound is not appreciably compressible. The expansion in this case is rather of the nature of a flow due to the irregular strains and stresses than to the compression of the material.

When making rubber tubing, the principle is the same, except that the die has a projecting piece in the centre which forms the cavity in the tubing. The spewing machine was at one time used for small sized tubing only, large sized hose being built up from calendered sheet in quite a different manner, but a modified machine is now frequently used for large hose. As the tyre or tubing comes away from the nozzle, it is led on to a large circular tray on which a thick layer of French chalk has been spread. This tray is pivoted so that it turns easily, and the continuous length of trye is wound in a flat spiral on the surface of the tray. When full, the end is broken off and another tray started on. Further quantities of French chalk are dusted over the rubber and the trays taken to the vulcaniser for curing. As we have explained, care must be taken to so compound the rubber that it does not sag appreciably at the temperature of the cure. In cases where this has not been sufficiently taken into consideration, tubing is found to come out of the vulcaniser with an oval instead of a circular section. Of course, curing in the open is cheaper than the use of moulds. There is the saving in the capital expenditure on the moulds and in the time and labour taken for filling the moulds and emptying them. Moulds are, however, used for some forms of solid tyres and always in cases where they are built up in sections. This type of tyre is used for heavy work, such as for motor lorries and consists of a series of rubber pads on which the wheel rests. These pads are held together in a specially constructed framework. Other heavy solid tyres are cured in moulds in one piece after shaping roughly in a forcing machine. Sometimes they are vulcanised on to a steel rim which is then fixed direct to the wheel. In order to get the rubber to adhere firmly, it is necessary to insert between it and the steel rim a layer of rubber compound termed a " junction." This consists really of a vulcanite mixing with the addition of such materials and other ingredients as may be necessary to make it cure hard in the same time as is required for curing the body of the tyre. The production of a vulcanite layer entails the use of a large proportion of sulphur in the compound, and when the composition is correctly adjusted a very firm joint results. Cab tyres, for horse vehicles, of course, are either wired on or held gripped by flanges on either side. The former method of attachment although more expensive is more satisfactory and better for the rubber. Where the tyre is held by flanges it requires a lot of hammering or jamming with a powerful lever to get it into position, which sometimes results in the rubber splitting when in use. Often, too, the grip is very uneven, the flange pressing more tightly on one side than the other.

Even when the compound is intended for curing in moulds the forcing machine comes in useful for roughly shaping the rubber which is subsequently cut up into compact blocks and the method can be adapted to the manufacture of a number of other articles.

Washers, Valves and Railway Buffers

Many goods are built up out of the calender rubber sheet. It would take too long to explain the exact method of procedure in each case, but rubber washers and valves may be taken as examples. Calendered and unvulcanised sheet is taken of the required thickness, or a sheet of the required thickness is built up in plies by rolling two or more sheets together. The article is then cut out or stamped out of the required shape, or perhaps a trifle on the large side. It is then vulcanised between plates or in the press, a flat ring of the correct shape being used to confine the rubber. The cuttings go back to the machine and are worked up again. In a machine for cutting washers the sheet is laid on a table and cut by knives attached to a revolving arm. Railway buffers consist of thick cylindrical pads. They are vulcanised in moulds. Sometimes metal plates or rings are vulcanised on to them in the same manner as in the case of the solid tyres with steel rims already referred to. The surface of the metal must be clean, and to ensure good adhesion it is usually painted with some of the "junction" compound dissolved in coal-tar naphtha. When the latter evaporates it leaves a thin layer of the compound in close contact with the metal.

Rubber Hose

Large size rubber hose is built up from long strips of compound in sheet form, these are wrapped round a mandrel with special forms of support on a bench stretching the whole length of a large room. The hose is built up with alternate layers of rubber and canvas, The canvas used is sometimes subjected to a previous treatment by which it is coated with a thin layer of rubber which penetrates the interstices between the cotton fibres. The rubber compound adheres more firmly to canvas that has been treated in this manner. The method of coating the canvas will be explained later. The hose can be built of one strip with a central join along its whole length or it can be spirally wrapped. The latter method is, of course, preferred. The mandrel is of iron and must be well rubbed over with chalk to prevent the rubber sheet from adhering to it. The sheet itself has, of course, to be well chalked to enable it to be handled, and it is necessary to get rid of this chalk where the join has to be made, which is done by washing with naphtha. The clean washed surfaces are then pressed together to cause them to unite. It is here that defects may arise and the method of spewing has the advantage, the tube being formed whole without a seam. The Americans were the first to design spewing machines for the manufacture of hose of large size with canvas between. The machine is built on the lines of that already described for the manufacture of solid tyres or small tubing, except that the forcing screw has a hole through its axis through which the iron mandrel passes and the rubber compound is squirted on to the mandrel as it passes along forming an even layer over it. A mechanical contrivance pushes the mandrel forward at a speed corresponding to the rate at which the rubber is forced out. When the mandrel is coated from end to end, it is removed and wrapped with one or more layers of canvas as required. It is then taken back to the spewing machine and a layer of rubber is spread on to the surface of the canvas just as in the previous case when it was spread on to the mandrel itself. To bring the various layers of which the hose is built up into thorough contact it is wrapped spirally with cotton cloth before vulcanising. The cloth is taken in strips and must be tightly and evenly bound along the whole length. If this is not done, the hose will not be uniform and air may be retained between the several layers. Of course, what we have said with regard to wrapping applies equally to hose that is not squirted but lapped and joined. After vulcanising, the cotton cloth is stripped off and leaves an impress in the form of fine cross markings on the rubber. Instead of wrapping a layer of cloth or fabric between the layers of rubber, the fabric can be woven on to the first layer of rubber in the form of a seamless sleeve which is then coated with a solution of rubber in naphtha. In this way, if required, several layers of fibrous material can be woven in to the rubber. Hose made in this manner will stand much greater pressures than that made by lapping cloth in the ordinary manner. For some purposes hose has to stand not only a considerable pressure but also a high temperature, as for instance, for coupling the steam-heating appliances in railway carriages. The steam may be at several pounds pressure which means a temperature considerably above the boiling point of water, in addition to which there is a good deal of ordinary wear on the hose in the coupling and uncoupling of the carriages. As might be expected, the life of such hose is short, but nothing more economical has been found to satisfactorily replace it. Armoured hose may be employed for purposes of withstanding a high pressure, as in connection with vacuum brakes or for water under pressure. In this a spiral steel wire is wound either inside or outside the rubber and canvas layers, according as to whether it has to withstand a pressure from the outside or inside. The wire may also be actually imbedded between layers of canvas in the walls of the hose.

Deodorisation of Rubber Goods

With the exception of the best grades all raw rubbers have a distinctive smell which is often strong and unpleasant. No objection can be taken to the smoky odour of hard cure Para or the very faint odour of best washed plantation rubbers, although even good class plantation rubbers may have a very unpleasant smell if produced by spontaneous coagulation or where fermentation has set in before the rubber has been washed and dried. Some of the lower grade African brands are notoriously evil smelling, so much so that the smell in the washing department of the factory where they are treated is a drawback to their use. Even medium grades have frequently a distinctly unpleasant odour. The smell would not matter so much for manufacturing purposes were it not that it clings tenaciously to the rubber and is often very pronounced after vulcanisation. This is a serious drawback for rubber in certain classes of goods, particularly some sorts of hose such as brewers' hose. Here the rubber comes in contact with the beer which may become tainted. The exclusive use of Para or other high-grade rubber is generally ruled out of account on the question of price, so that various means are employed for deodorising the vulcanised rubber. These may consist of washing with solutions of oxidising agents or stoving, that is heating for some time to a temperature which, of course, must not be too high. In the latter case the use of charcoal is recommended as helping to absorb the evil-smelling substances driven out on heating the rubber. It is difficult to effect a permanent deodorisation, as these methods remove the noxious substances from the surface layers only of the rubber, so that after a time contamination sets in again from the inner layers. Rubber manufacturers make a special line of "sweetened" hose for brewers' use which sells at a higher figure than similar hose unsweetened.

CHAPTER IX

Motor Tyres

Of all types of rubber goods, the motor tyre, perhaps, comes more often before the notice of the general public than any other class of rubber article. If a discussion should arise as to the future supply and demand for rubber or the probable outlet for the vast quantities of the plantation product that the East is expected to produce, the rubber tyre is generally instanced as likely to absorb any increase in production. Although the manufacture of motor tyres is undoubtedly on a very large and increasing scale, it is doubtful whether this article accounts for as large a proportion of the raw rubber used, as is generally supposed. Until quite recently, for example, the rubber shoe trade in the United States absorbed more rubber than any other class of goods in that country. It must not be forgotten that the pneumatic tyre is not wholly built up of rubber, but that canvas duck plays an important part in its construction and that the rubber compound used is prettily heavily mineralised. A tyre, costing say £8, would require not more than about ten pounds of rubber compound, costing say, five or six shillings a pound for the ingredients. This is allowing for raw rubber at the present high price. It will be seen then that the motorist pays a good deal more for his tyres than the cost of the rubber plus that of compounding, mixing and vulcanising.

As a matter of fact, the manufacture of a motor tyre is a difficult and expensive operation. Great care and skill are required in building up the different layers of rubber and canvas. The canvas duck itself is an

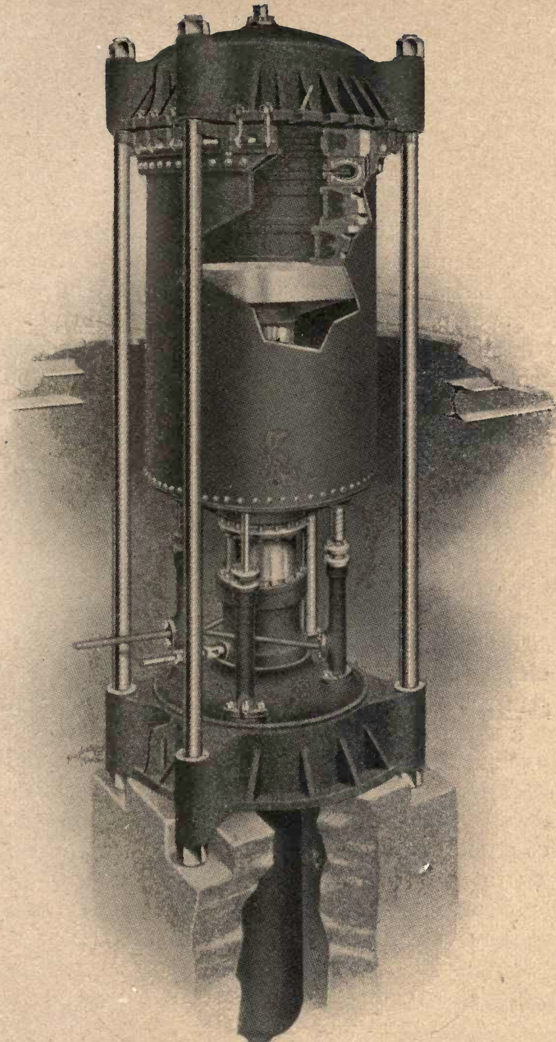


FIG. 5.—HYDRAULIC TYRE VULCANISING PRESS
(*John Shaw & Sons*)

expensive material. The layers of rubber and canvas are laid over a core and built up in the same way as rubber hose with canvas insertion. The tyres are then vulcanised in moulds and the capital expenditure on these is a heavy item in the cost of the tyre. Every variation in size and form of tread necessitates a new mould. Fig. 5 represents a modern type of the vulcaniser and press combined. The tyre moulds are seen in section in the upper part of the pan and are held in position by hydraulic arms, obviating the necessity of screwing up each mould separately. Of the four tyre moulds shown in section the second from the top is a pneumatic, the others being solid tyres. Considered as an outlet for rubber a solid tyre is better than a pneumatic one. The London Omnibus Companies must pay away several thousand pounds a week for the upkeep of their solid motor bus tyres.

Tyre Repair

While on the subject of tyres reference may be made to the repair by vulcanisation. With the inner tube of a bicycle tyre a thin patch on the outer side of the tube cemented with a little solution of rubber in naphtha makes a satisfactory joint. The pressure of the inner tube against the inner lining of the outer cover holding the patch in place. Such a method does not, however, produce a satisfactory repair with a motor tyre, possibly on account of the heat developed which causes the rubber solution to flow and the patch does not hold in place. The only satisfactory method of repair for a motor tyre is repair by vulcanisation, that is to say, the patch is vulcanised in place. For this purpose special compounds are sold. These compounds consist merely of unvulcanised mixing in the form of thin sheet between two layers of cloth to prevent adhesion. It would not be permissible to dust the sheet with chalk. The compound should be soft and plastic so that it readily takes the shape of the space into which it is pressed. In order to have a clean surface it is necessary to cut away the rubber around the slit or puncture and to wash this with a little naphtha, a clean surface is absolutely necessary if a good union between the old and new rubber is to be obtained. The compound when in place is vulcanised by fixing a hot plate against it and the plate may be heated either by steam or by the direct application of a flame or electrically. From what has been said on the subject of vulcanisation it is apparent that whatever means of heating be adopted for curing the compound, the temperature to which the plate is heated and the time during which it is heated must be adjusted to the rate at which the compound cures. Otherwise the compound will be over-cured, which from the authors' experience is more often than not the case. A recently cured rubber article always tends to be soft and does not acquire its full strength for a week or two. The repair after vulcanising should still be a little soft and on the under-cured side, it will then last much better than if cured quite hard. If cured hard it really means that the rubber is over-cured, and the original tyre also damaged for the following reason. When heating the patch of unvulcanised compound it is impossible to avoid heating the adjoining portions of the vulcanised tyre, and this is equivalent to giving these portions of the tyre rubber an additional cure, with consequent deterioration of the rubber. For this reason, too, a quick-curing compound is better than a slow-curing one, as a compound is required curing in the shortest time and at the lowest possible temperature. Some compounds on the market are sufficiently cured in a steam-heated vulcaniser in ten minutes to a quarter of an hour at thirty to forty pounds pressure. Inner tubes as delivered by the makers are usually under rather than fully cured as the tyres get very hot after a long run. What has been said in regard to the repair of inner tubes applies equally to the outer covers, but except in the case of small patches, this is best left in the hands of the tyre manufacturers, or of the firms who make a special business of repairing and retreading tyres.

Rubber compound for retreading should be quick-curing to avoid heating the canvas and other parts of the tyre more than necessary. The layer of rubber is applied to the cover after the remains of the old rubber has been stripped off. After cleaning the cover is painted with a solution of some of the compound in naphtha, the naphtha is allowed to evaporate and the compound is applied in layers, each layer being pressed down well with a hand roller. When a sufficient thickness of rubber compound has been built up to serve as the new tread the tyre is tightly wrapped with long strips of cloth just as in the manufacture of hose, a stiff coil of wire being placed inside the tyre to prevent it collapsing. The tyre is then vulcanised in a steam vulcaniser in the usual manner. If the canvas of the tyre be sound and the retreading properly carried out with suitable compound the result should be satisfactory. Tyre treads are sometimes semi-vulcanised before attaching to save the canvas ; this has the advantage that they can be made of the most suitable composition, not necessarily quick-curing, the quick-curing portion being confined to a thin layer lying between the tread and the body of the tyre.

Rubber Rings and Bands

India-rubber rings and elastic bands are made in a similar manner to rubber tubing, that is either by means of a spewing machine or by wrapping layers of calendered unvulcanised rubber sheet round an iron mandrel, until the required thickness is obtained. The rubber is then vulcanised after wrapping in cloth in the same way as rubber hose. It is then taken to a lathe where the length of tubing is cut up into rings. The rubber compound used must be of good quality containing but little mineral matter, so that the ring can be stretched to many times its original diameter without breaking, and great care is needed to see that it is neither under or over vulcanised. Besides elastic bands large numbers of rubber rings, the so-called Codd's rings, are used for closing aerated water bottles with an air-tight joint. These are made usually of red rubber, and antimony sulphide is a constituent of the mixing, if not replaced to a large extent by cheaper colouring matters. A good deal was heard some few years ago about the possibility of antimony poisoning through the use of these rings, particularly worn and frayed ones. It was suggested that the vegetable acids in lemonade and similar beverages dissolved the antimony out of the rings. The matter was raised by a Dr. Pond, of Liverpool, but his statements were adversely criticised, particularly in Germany, and if there is anything in the views he put forward the matter has been dropped and mostly forgotten about. Similar statements have been made with regard to lead compounds in rubber tubing of the kind used by brewers. It has been argued that the tubing can be made perfectly well without the use of lead compounds and this is doubtless correct, but whether lead, even in minute quantities, is actually dissolved out of vulcanised rubber is doubtful.

Dental Rubbers

To take one more instance, we may call to mind the use of the sulphides of antimony and mercury in dental rubbers. The possibility of some of the compound being dissolved can be understood, as the rubbers are used for making the orange or red vulcanite plates to be worn constantly in the mouth. The rubber is always subjected to the action of the saliva, besides being exposed to a good deal of wear. It is doubtful, however, if any properly authenticated case of mercury or antimony poisoning has ever been brought forward. The coloured vulcanite can only be produced with the aid of these poisonous metallic salts. The colours obtained can hardly be regarded as matching that of the gums or palate by any stretch of the imagination.

The ordinary black vulcanite serves equally well and is even preferable, as it can be compounded of rubber and sulphur without the addition of minerals which results in a lighter and stronger product. People, however, seem to prefer any shade of red or orange rather than black, at any rate black is seldom used. The pink colour of some plates which is a really good match to the colour of the gums is obtained by a veneer of material on the front of the plate which is hardly rubber at all.

For those who are not familiar with mechanical dental work it may be explained that the dental plate is prepared by moulding the soft rubber against a plaster of Paris mould of the palate, confining this with a metal plate to form a box or mould and vulcanising in a small boiler under pressure. Dental rubber compounds are made of the very best materials procurable and the prices paid for them are relatively high.

Elastic Thread

Elastic webbing and braid consists of elastic threads running parallel and woven in with cotton or silk. In recent years mercerised cotton and artificial silk have been largely used when a good appearance is required at a price which would not justify the use of real silk.

The elastic thread itself represents one of the highest classes of rubber goods, and only the best Para rubber is capable of giving the particular physical properties termed "tension" demanded by the manufacturers of webbing. The mixing is compounded of rubber and sulphur only softened with naphtha and is calendered to a thin and very regular sheet on to cloth. This is then tightly wrapped in layers of cloth and vulcanised in steam in the form of a roll. When cured the sheet is unrolled from the cloth and re-rolled on a drum. Some shellac or similar substance dissolved in spirit is spread between the layers of rubber, so that when dry the whole mass is stuck together to a firm cylindrical block. It is then taken to a lathe, and accurately cut so that the sheet is reduced to long strips of square section and of the original length of the sheet. The shellac is then dissolved out in a bath and the thread boiled in a weak solution of caustic soda which removes the excess of sulphur that has come to the surface in the form of bloom. The thread is made in a variety of sizes or counts reckoned by the number of threads required to be laid side by side to measure one inch. They must be free from mineral matter and translucent or almost transparent. They must stretch neither too much nor too little under a given weight. All these requirements necessitate the greatest care in vulcanising; if under-cured the thread is soft and stretches too easily, and if the right cure be overstepped ever so little the thread will gradually lose strength and go rotten. This is not apparent when first made and the thread may keep all right for months when suddenly the rubber begins to get weak, and is easily broken, finally becoming thoroughly rotten and perished.

CHAPTER X

RUBBER SOLUTION AND ITS APPLICATIONS

Rubber Solvent

Many goods are manufactured with the aid of a rubber solvent. The solvent most commonly used is coal-tar naphtha; a volatile inflammable liquid obtained from the first portions which pass over when coal-tar is distilled. Mineral naphthas find employment to some extent, although less suitable for the purpose; disadvantages attaching to their use being counterbalanced to some extent by a lower price. Chemically considered they differ entirely from coal-tar naphtha, but have the same qualities of volatility and inflammability. They are obtained from the lower boiling constituents of petroleum or from shale oils and are known respectively as benzine and shale naphtha. There are many other liquids which dissolve unvulcanised rubber, such as ether, chloroform and carbon disulphide, but the only other solvents of technical importance are carbon tetrachloride, and some similarly constituted bodies which have been recently introduced to manufacturers. They have the advantage that they are not inflammable, but they are too costly for most purposes, at any rate, wherever the solvent is not recovered in the manufacturing processes.

India-rubber Solution

In the ordinary way rubber when vulcanised does not dissolve in the ordinary rubber solvents, although it swells and takes up some of the liquid, especially if the rubber be under-vulcanised. It can, however, in some cases be got into solution if subjected to sufficient mechanical treatment, or if heated with the solvent. In the latter case the rubber is partly decomposed. By long grinding of some kinds of vulcanised or semi-vulcanised rubber with a solvent a strongly adhesive but slow-drying solution is obtained.

If a piece of raw rubber be placed in a bottle of naphtha the rubber gradually swells absorbing the solvent, and eventually loses its tenacity, so that the mass if vigorously stirred or the bottle shaken at a certain stage and this treatment repeated from time to time, an apparently homogenous solution is finally obtained. The solution is very sticky and tenacious. If poured on to a glass plate or other smooth surface and allowed to dry down it forms a thick skin of rubber which can be pealed off. If spread on cloth it forms a thin coating and the solution having penetrated more or less between the fibres of the cloth the skin of rubber adheres firmly and cannot be torn off. A test often applied to rubber solutions consists in spreading an even layer on a strip of cotton canvas to within a few inches of either end and then folding the canvas in the middle so that the coated surfaces are brought in contact and pressed firmly together with a roller. The force required to tear the two surfaces apart after they have had time to dry thoroughly is a measure of the quality of the solution. There is a great difference in the appearance and properties of solutions made from dried raw rubber and similar rubber which has been masticated. It would appear that when rubber latex coagulates and the globules coalesce the other constituents of the latex are also precipitated, in particular certain substances containing nitrogen and termed "protein." These substances form the so-called insoluble constituent of india-rubber. It was for a long time supposed that this insoluble substance consisted of the elements of carbon and hydrogen with perhaps some oxygen, the former in the same proportion as in the remainder of the rubber, until Spence discovered that the insoluble constituent contained nitrogen and consisted wholly, or at any rate, to a large extent of "protein." The source of the "protein" is the original latex in which it is present in soluble form.

The protein is distributed throughout the rubber in the form of strings or films and is probably impermeable or with difficulty permeable to naphtha. As the particles of rubber are enclosed in the protein films as in a mesh the solution takes place with difficulty unless well stirred. The solution is also very viscous on account of these protein films and we have found that the difference in viscosity of solutions of raw rubbers of the same strength is largely accounted for by the mode of distribution and amount of protein present in the rubber.

On masticating the raw rubber these films are broken up and consequently the masticated rubber dissolves more readily in naphtha and the solution is less viscous than that from the untreated rubber. On allowing to stand the protein films separate and form a deposit at the bottom of the solution. For purposes of clarification on a manufacturing scale the solution is forced through fine gauze filters.

There is a great difference in the way various raw rubbers are dissolved by naphtha. Strips cut from a loaf of fine Para and dried are only slowly dissolved, and some of the plantation sheet and biscuit is even more difficult to get into solution, while the solution is more viscous. On the other hand, well washed plantation crêpe is easier to dissolve, no doubt owing to the breaking up of the protein films in the washing process. These considerations would appear to prove the futility of attempting to judge the quality of rubbers by the viscosity of a fresh solution as has been suggested.

Some plantation rubbers without preliminary treatment are so readily dissolved or " let down " in naphtha that they have mostly displaced the sale of masticated Para for this purpose. Owing to the inflammable nature of rubber solutions, brought about, of course, by the naphtha used as the solvent, great restrictions are placed on the carriage and storage of this material and users as a rule purchase the rubber and make their own solutions in small quantities at a time as they require it.

Spread Sheet

Rubber solution is used in some quantity by the cycle and motor tyre repairer and also in various trades as a waterproof varnish. The original mackintosh was prepared by treating the cloth with a solution of rubber, but owing to the inconvenience attaching to a surface which became sticky in hot weather the manufacture would have been abandoned had it not been for the discovery of the means of vulcanising the layer of rubber attached to the cloth. The chief consumption of naphtha in the rubber trade is for the production of a rubber solution for further manipulation, and the naphtha is removed by evaporation before the goods are finished. The fact that rubber can be dissolved and the rubber obtained again on evaporation of the solvent affords the rubber manufacturer an invaluable means of manipulation. This can be illustrated by reference to the production of " spread sheet." We have seen how raw rubber can be calendered to form a sheet and that for certain purposes the rubber is softened with naphtha before calendering and the naphtha subsequently removed

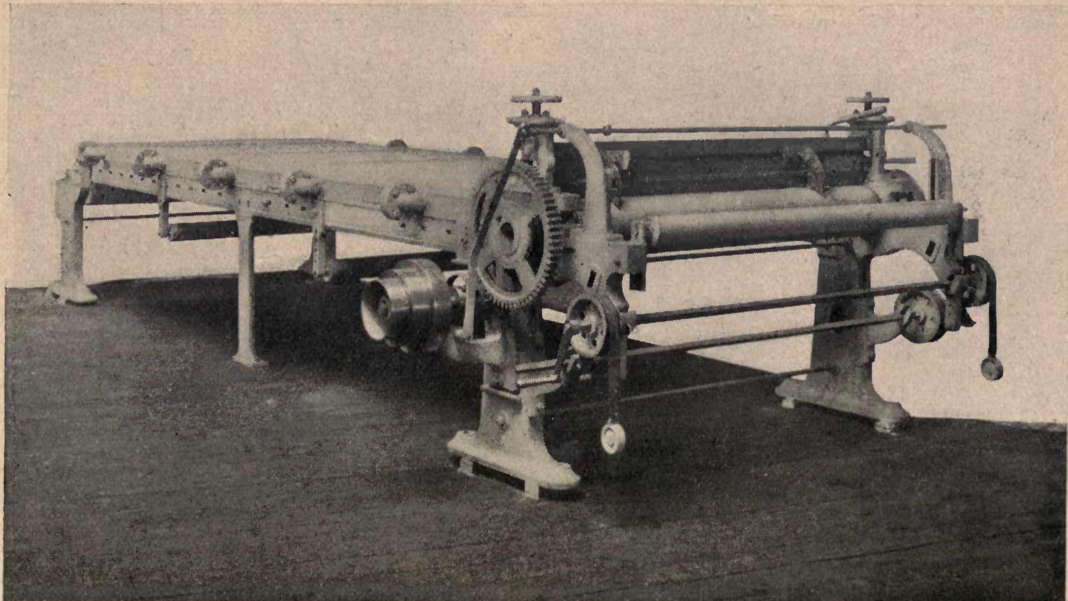


FIG. 6.—SPREADING MACHINE
(*Joseph Robinson & Co.*)

by evaporation. Spread sheet is made by dissolving the rubber in naphtha and spreading the solution on to the surface of specially-prepared cloth. Heavy calender rolls are not required, rubber solution being soft, and they need not be used when the solution is thin enough. The cloth carrying the layer of rubber solution passes over a large shallow box or "chest" which is steam-heated to evaporate the naphtha. When one layer has been deposited and dried another can be deposited on

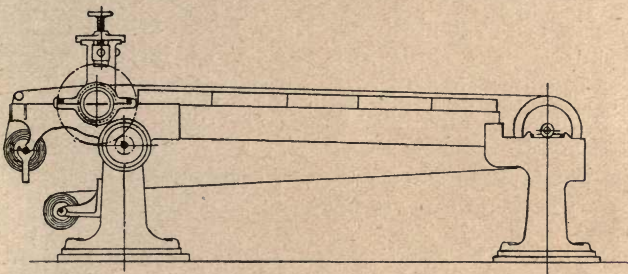


FIG. *h*.—SPREADING MACHINE
(*J. Robinson & Co.*)

the first and so on till a sufficiently thick sheet has been built up. This is then well chalked and separated from the cloth.

The spreading machine or spreader (Figs. 6 and *h*) consists of a roll fixed at one end of a large steam chest or table. Over the roll is an adjustable knife with a blunt edge and the cloth to be coated passes from an auxiliary roll over the first-mentioned roll and under the knife The rubber compound which has been thinned down with naphtha to suitable consistency in a pug mill, is spread on the surface of the cloth on the top of the roll and the knife edge is adjusted at such a distance from the surface of the cloth that a layer of the required thickness passes along on the cloth, the remainder being held back by the knife. The two wheels on the top of the machine on either side are for the purpose of adjusting the height of the knife, and there are two cheeks also adjustable which confine the dough and prevent it wandering over the ends of the roll on to the bearings. As the rubber-coated cloth passes along, the heat from the steam chest underneath evaporates off the naphtha. In this way one thin layer or coat is deposited on the cloth. The process is repeated until a sufficient number of coats have been deposited so as to give a coating or layer of the required thickness. The cloth with the coated surface passes over a roll at the end of the chest, and almost hidden from view in the illustration, and then back again underneath the chest where there are two guiding rolls, and is finally wound on to a roll slipped on to one of the square shafts in front of the machine.

CHAPTER XI

Cut Sheet

There is a third method for the manufacture of sheet more costly than either of the two preceding ones. This is known as "cut sheet," and had its origin in this country, although it is now made in many parts of the Continent as well. In principle it consists in slicing thin layers of rubber from off a block with a knife having a rapid to and fro motion. The rubber is frozen to a hard block to give it the necessary rigidity. It must, of course, be absolutely homogeneous and free from air-bells, or flaws of any kind, as otherwise corresponding defects would occur in the sheet. For some of the purposes for which it is used, in particular electric insulation, flaws or pinholes would be fatal defects. The raw rubber which at one time consisted exclusively of fine hard Para is carefully and thoroughly washed. Nowadays, lower grade rubbers are used in admixture with the Para rubber for second grade sheet—particularly on the Continent, and cases have been reported of the presence of oil substitute. Special pale cut sheet is now made from plantation rubber and the authors have found some of this to be stronger than that of first quality made exclusively from fine hard Para. In making this statement they have the support of a manufacturer who had come to the same conclusion. Plantation rubber for cut sheet is generally washed before using in spite of the fact that it had already been carefully washed on the plantation, and many manufacturers state that they will always rewash the rubber themselves when required for high-class goods. The washed and dried rubber is next masticated in a special machine (Fig. *i*) which is intended to reduce it to the necessary

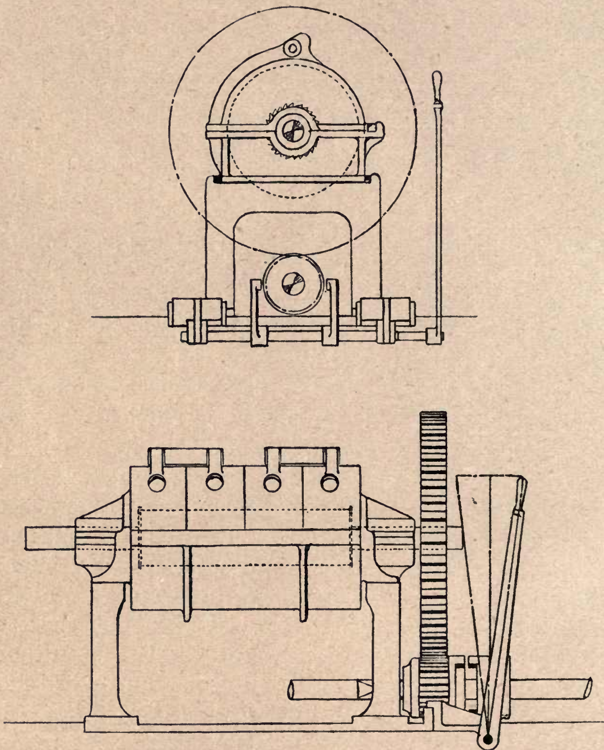


FIG. *i.*—RUBBER MASTICATOR
(*J. Robinson & Co.*)

degree of plasticity without working it so much as the ordinary mixing-rolls. This machine consists of a hollow iron cylinder with openings in the top and a roll with a ribbed surface which revolves on the rubber. The illustration shows the machine in section and the general external view when casing is closed. The machine is arranged for steam heating. The rubber is taken out of this machine after mastication in a bolster-shaped block which is then placed in a steel cylinder and subjected to hydraulic pressure by means of a plunger. The rubber is then frozen, which at one time used to take many months, but with modern refrigerating machinery is accomplished in a few weeks. Time, however, must be given for the block to freeze through right to the centre which must always be a slow process owing to the fact that rubber is a bad conductor of heat. In the older process the sheet was sliced off the end of the block, that is to say, in a plane at right angles to the direction in which the pressure was applied, and it is stated that the best results were obtained in this way. For the production of a continuous sheet the block, which is cylindrical in form, is in the first place compressed in the steel cylinder and a steel spindle is then forced down along the centre line of the block. After freezing the spindle is forced out again leaving a hole along the axis of the cylinder on which the block is mounted. It is then made to revolve against a very rapidly oscillating blade which slices the rubber in a continuous length spiral fashion. The knife is kept well lubricated with water and leaves its mark on the sheet in the form of a number of very fine lines parallel with one another. This marking is so characteristic of cut sheet that it has been imitated abroad by the use of an engraved calender roll. The surface of machine-planed steel will mould a very similar appearance on a sheet of rubber.

Insulation Tape

Most of the pure rubber sheet is vulcanised at some stage or another, either by the cold-curing process or by immersion in a sulphur bath. Part of it, however, finds employment as rubber tape for electrical purposes. Rubber tape consists of long strips about half-an-inch wide used for winding round the copper conductors of cables. Copper is a dangerous metal to bring in contact with vulcanised rubber, as after a time the copper would be liable to be corroded by the excess of sulphur in the rubber and this would cause the rubber itself to perish, and consequently the insulation of the cable to break down. It is usual, in the first place, to tin the surface of the copper and then to wrap a layer of unvulcanised rubber next to the metal to be followed with vulcanised rubber outside this again. The best tape is, of course, that made from cut sheet, the strips being cut at right angles to the knife marks. Spread sheet is, however, very generally employed for insulating purposes and also gutta-percha compositions.

CHAPTER XII

Cold Curing of India-rubber

This process, discovered by Parkes in 1846, consists in treating the raw rubber with sulphur chloride (disulphur dichloride $S_2 Cl_2$), which reacts with it in the cold. The reaction is a vigorous one and a diluent is required, as otherwise the surface of the rubber would be attacked and over-cured while the centre of the sheet would be unaffected. For a diluent a liquid is required which will mix with the sulphur chloride without decomposing it and which will also have a solvent or swelling action on the rubber. The first effect of a solvent is to penetrate the sheet causing it to swell. Of numerous substances which have been tried for this purpose, nothing has been found to work so well as carbon disulphide. Consequently it is generally used for this purpose in spite of its inherent drawbacks which include inflammability, volatility and poisonous nature. The solution of sulphur chloride required is a very weak one, containing somewhere about two or three per cent. of the chemical. This solution can be brushed or spread over the surface of the rubber by a suitable mechanical contrivance. Another method by which the sulphur chloride may be applied consists in allowing the vapour to act on the surface of the rubber in a closed chamber. In this case, however, the rubber is not penetrated to the extent it would have been if a solvent had been used, and although the action of the vapour is under control, the surface primarily is acted upon, while the inner portions remain unvulcanised. If an excess of sulphur chloride has been used, this may be removed after treatment by washing the vulcanised articles in a weak solution of soda which decomposes the residues of sulphur chloride and neutralises the hydrochloric acid formed in the reaction. As an alternative, the article may be well dusted with magnesia. The cold cure is the usual method of vulcanising waterproof textures but not the only means. The method is also used for articles such as tobacco pouches and some surgical goods. From what has been said as to the penetration of the rubber by the sulphur chloride with the aid of a rubber solvent, it can readily be understood that the cold cure is only applicable to rubber in the form of thin sheets and preferably containing little or no loading. Some of the minerals used in rubber-mixings are inert but a great number of them, particularly those of basic character, as magnesia, litharge, etc., are inadmissable for compounding rubber intended for cold curing, as these minerals react with the sulphur chloride and decompose it.

Sulphur chloride is prepared by bringing the two elements together, dry chlorine being passed over heated sulphur. It is an amber-coloured liquid which fumes in the air and gives off vapours which irritate the eyes and nose. It is decomposed by water and hence in working the cold cure process moisture must be carefully excluded. In the manufacture of tobacco pouches, india-rubber gloves and similar articles, the vulcanised sheet rubber is cut to shape and the article built up from these on wooden moulds. The edges are joined up by making them overlap and gently pressing them together, or the edges may be brought up flush and the joint strengthened, if thought necessary by laying a narrow strip over it.

Unvulcanised rubber can easily be made to adhere if the surfaces are clean, and an inspection of any rubber tobacco pouch will illustrate the way these articles are made. In this connection, mention should be made of some of the best black india-rubber tubing, the joint along the tube is easily detected and if made from cut sheet the strip is taken at right angles to the marks of the knife cuts, the latter forming circles round the tube.

Cold curing is largely used for waterproof cloth. We refer here to light cloth such as is used for the manufacture of the ordinary mackintosh, and which has been spread with a thin layer of rubber. The rubber is generally adulterated with substitutes, often with a large proportion of the latter, and the general low level of quality produced by competition and demand by the public for a low priced article, has considerably restricted the output of the industry in recent years.

Reference has been made to a suitable mechanical contrivance for cold curing the cloth on which the rubber has been spread. This consists essentially of a wooden trough and roll dipping into it. The trough takes the solution of sulphur chloride in carbon disulphide and is built shallow, coming close up to the roll so as to expose as little surface of the solution to the air as possible, so as to minimise both evaporation of carbon disulphide and decomposition of sulphur chloride. The cloth is led with the rubber face downwards on to the surface of the wooden roll, which spreads an even layer on the rubber. The rubber is kept in contact with the wooden roll by guiding rolls and then passes over a heated table or drum to remove the remainder of the chemicals and is finally re-rolled. Cold cure has the great advantage over vulcanisation by heat in that the colours are better preserved. Many of the coal-tar dyes can be used when the cloth is cold cured. Some of the lustre effects on these cloths are got by the use of starch which is dusted on before treatment with the sulphur chloride solution.

India-rubber Teats

The use of rubber solution for the manufacture of spread sheet has been explained. There are other articles, such as teats for babies' bottles, which are made on the same principle. The reader may smile, but the number of these india-rubber teats manufactured in the course of a twelvemonth is enormous. The visitor to the rubber factory may find a big department devoted to this purpose. Rows of narrow benches are arranged down a long room on which are trays containing rubber solution. Over the trays are suspended square boards from the underside of which project a great number of glass moulds. These are dipped into the rubber solution and the naphtha evaporating leaves a thin layer of rubber on the surface of the glass. On dipping a second time a second layer is deposited on the first until a sufficient thickness of rubber is obtained. The board with the moulds now covered with a layer of rubber are next lowered over a tray containing a solution of sulphur chloride in carbon disulphide, so that the rubber is vulcanised, and after washing the finished teat is slipped off the glass moulds, which are ready for making a fresh batch. With the introduction of plantation rubber teats may now be obtained pale yellow and almost transparent.

While on the subject of goods made from rubber solutions, a few remarks may be made on the question of recovery of solvent. It is obviously an undesirable thing to breathe in an atmosphere containing much naphtha vapour, quite apart from the waste of solvent when this evaporates and is lost in the air. Various suggestions have been made and plant erected for collecting the vapours given off from the spreading machine. A hood is provided over the table and a fan to draw the vapours up into the hood which then pass into a condensing arrangement consisting of tubes artificially cooled where the naphtha vapours are condensed. No great success has up to now attended the efforts of engineers in this direction chiefly owing to the difficulty caused by the admixture of air with the naphtha vapours. This makes it much more difficult to condense the vapours, and it is found impossible in practice to fit a hood and construct the spreading machine in such a manner that air is not drawn into the hood along with the naphtha vapours.

CHAPTER XIII

INDIA-RUBBER BALLS, FOOTBALL BLADDERS, AND CHILDREN'S TOYS

THE method of making india-rubber balls, hollow rubber dolls, and similar toys, is a very ingenious one. It is obvious that they cannot be built round a mandrel or mould, as there would be no means of withdrawing the latter. They have also to be filled with air. To begin with, calendered sheet is provided of suitable composition and generally heavily mineralised. By cutting four segments out of the sheet of a suitable size and shape, and joining these along the edges a hollow article can be built up more or less resembling a ball. The shape of the segments will correspond to the four pieces of peel obtained by cutting up an orange into four quarters. Before joining up the edges two things must be done. Firstly, a small piece of rubber compound containing no sulphur and which will not, therefore, vulcanise with the rest of the rubber, is stuck on the inside of one of the segments. A mark is made on the outside to correspond, so that when the ball is vulcanised the position inside of this piece of unvulcanised rubber may be easily found. And secondly, a pinch of carbonate of ammonia is placed inside before joining up the edges. The ball is then sealed up, placed in an iron mould and vulcanised in the ordinary manner. The moulds are simple in construction, consisting of two hollow plates with a large number of hemispherical depressions corresponding with one another in the two plates. When the mould gets hot it causes the carbonate of ammonia to vaporise and the pressure of this vapour inside the ball keeps the rubber pressed against the metal of the mould while the rubber is being vulcanised. When taken out the ball is found to be perfectly shaped on the outside. It is, however, quite soft and collapses as the carbonate of ammonia in the inside condenses to a solid again on cooling. To fill the ball with air, the operator takes a hollow needle, connected with a small bellows or air reservoir, and pushes the needle into the ball at the spot where the piece of unvulcanised rubber is fixed on the inner side. Air is then forced into the ball through the hollow needle and as the needle is withdrawn, the unvulcanised rubber closes over the hole so that the ball remains full of air under pressure. The same principles are applied in the manufacture of india-rubber dolls. Football bladders are put together out of sheet. Hot-water bottles are built up in a similar manner, but cloth insertion is used, as the function of the rubber in this case is to keep the bottle watertight and the walls are not required to expand, but merely to be flexible. Surgical goods, such as enemas and the like, are built of sheet and vulcanised in moulds in the same manner as india-rubber balls.

India-rubber Shoes

The manufacture of india-rubber overshoes or goloshes is a very large industry, particularly in the United States, Germany, Russia, and Scandinavia, where there is a considerable demand for this particular article. In this country rubber shoes are used to a much smaller extent and are principally worn by women and children who wear a lighter boot than men. The home demand is supplied largely by import from the United States, although there are some firms in this country who have taken up this branch of manufacture. Rubber shoes, like leather ones, are made on lasts, and we can also distinguish between the "soles" and the "uppers" which are made of different classes of compound. As in leather shoes, the soles must be made of a tough material to stand wear and tear, while the uppers require to be strong and elastic, but can be built much thinner. There is also the lining to consider which is made of some sort of rubber-proofed cloth to suit requirements. The soles are made of calendered sheet. A special form of calender is employed having an engraved roll which stamps or impresses on the rubber the common diamond pattern such as is usually seen on the underside of the sole. The roll in front at the top is engraved for embossing in this case for the uppers of shoes, a smaller calender being used for the soles. The sole piece is generally cut from the sheet by hand. The shoes are built up by hand on an iron or wooden last. The various pieces that go to form the shoe are supplied, already cut to shape, to the operator who joins them up on the last with the aid of a solution of rubber in naphtha. To vulcanise black the rubber must be compounded with litharge and lamp black, but to give the shoes a bright gloss, presumably in imitation of polished shoe leather, the rubber is painted with a special varnish before vulcanising, the main constituents of which are boiled oil, turpentine and lamp black. Much of the time and expense involved in the manufacture of rubber shoes is necessitated by the demand for an attractive looking article. The shoes must be neatly put together with a good glossy surface and of good appearance generally if they are to sell readily. They are usually so neatly made that they look like mould-cured goods. A dozen or more pieces are required to build up a single shoe, and when the lasts are covered they are placed on a frame and cured in hot air chambers.

Besides goloshes there are various military boots and similar articles of rubber which are made in the same way.

STATIONERS' RUBBER

Ink erasers and rubber for removing pencil marks as at present manufactured are much better adapted for the purposes for which they are required than the hard lump of raw rubber that was at one time used. For erasing purposes either the paper itself or the rubber must be worn away. For erasing pencil marks the rubber should be soft enough to crumble down without wearing the surface of the paper, and therefore for this class of article no harm is done in compounding with a liberal proportion of oil substitute. On the other hand, for erasing ink marks a hard rubber is required, into the composition of which some gritty mineral enters such as ground pumice or glass, the object of the ink eraser being to wear away the surface of the paper to a depth to which the ink has penetrated, as ink does not lie on the surface of the paper like a pencil mark.

RUBBER SPONGES

The process for the manufacture of rubber sponges does not appear to be understood in this country, and these articles are imported from abroad. There are a number of sufficiently obvious means for producing air-bells in a mass of vulcanised rubber, for instance, one might apply the principle employed in the manufacture of rubber balls incorporating ammonium carbonate in granular form with the rubber compound, so that at the temperature of vulcanisation each particle of the chemical forms an air-hole. However, this may be it would appear to be a difficult matter to obtain an even and regular distribution of large air-bells throughout the mass.

Asbestos Washers

Rubber of low grade is often used as a binding material as in the manufacture of asbestos washers. For such a purpose Jelutong, Pontianac or dead Borneo is suitable. Pontianac is a port on the West Coast of the Island of Borneo from which the rubber derives its name. The material contains a small proportion of a rubber-like substance which is left behind if the resin be extracted with acetone. The price of the raw material is low, but a few pence per pound. This, by the by, has encouraged research, and a process has been worked out in the United States for extracting the resins, no doubt by means of suitable solvents. A company has been formed and a large plant has been erected in Borneo, while another is in course of erection on Karimon Island, near Singapore; the supply of raw material is almost inexhaustible, single trees we are told yielding fifty to one hundred pounds. In the rubber factory there is some difficulty in cleansing Pontianac, as owing to its large content of resin the crude gum is sticky and adhesive. For this purpose it is sometimes dissolved in oil by heating and straining the mixture by forcing it through layers of fine gauze. The mixture of oil and rubber can then be used straight away in rubber mixings.

For making asbestos washers, the rubber is softened with benzine so that the mixing can be carried out in a Werner-Pfleiderer machine instead of the ordinary mixing-rolls which would break up the asbestos fibres too much. The aim is to keep these fibres as long as possible consistent with a thorough mixture with the rubber and other ingredients, mostly fillers. The Werner-Pfleiderer machine is an extremely effective type of mixing machine and finds useful employment in many industries. Although built modified in different ways for different purposes the general type consists in principle of an oblong trough; two shafts parallel with one another and carrying curved arms pass through the sides of the trough, and these shafts are driven at different speeds by suitable gearing. The curve and shape of the arms have been carefully designed, and to this the success of the machine must be largely attributed. The mixture complete, the material is sheeted and after removal of the solvent forms a very tough sheet, especially where a good class of long-fibred asbestos has been used.

Washers made in this way where the rubber is used merely as a binding material, will stand a much higher temperature and steam pressures than the older type of rubber washer in which both a larger proportion of rubber was used and a rubber of better quality. As Klingerite and under other names very large quantities have been put on the market and have found a ready sale. This is especially owing to the greater demands put upon this class of article since the use of superheaters for steam raising has become general.

CHAPTER XIV

VULCANITE

VULCANITE or ebonite (German *Hartgummi*) is made, speaking broadly, in the same manner as the ordinary soft rubber goods, except that larger proportions of sulphur are employed and the vulcanisation takes longer, while the temperature is generally higher. Reference to vulcanite has been made when speaking of dental rubbers. The best vulcanite is made from Para rubber and sulphur only in proportions somewhere in the neighbourhood of ten to three, usually, however, a very small quantity of wax and linseed oil are added. Inferior rubbers usually take more sulphur partly on account of the resins they contain and in cases where much fatty oil is incorporated in the mixing allowance must be made for the sulphur which will combine with it forming an oil substituted in place.

The effect of increasing the proportion of sulphur and the time and temperature of vulcanisation on the physical properties of vulcanite may be noted. When under-cured the tendency of the vulcanite is to be soft and leathery, it is tough but easily bent and shows little inclination to return to its original position. These properties are less marked as the time of curing is lengthened, and at the right stage a thin sheet of vulcanite is no longer soft but full of "spring," and returns at once when bent out of shape, although it is so tough that it can be bent double without breaking. If the cure be carried further the vulcanite gets harder, offers more resistance to bending but tends towards brittleness.

Vulcanite is easily softened by heat as, for instance, boiling water, when it can be shaped as required, or will take an impress becoming hard and resistant again on cooling. If of good quality without mineral admixture it will take an excellent polish and has been used for ornaments. Perhaps the most familiar article for which it is now used is the fountain pen. Vulcanite can not only be moulded but can be cut and turned, and is also very resistant to strong acids and other chemicals, so that it is a most suitable material for making troughs, pipes, joints and cocks, for chemical manufacturing purposes; also photographic developing trays and electric accumulators. In the latter articles its high specific resistance as an electric insulator is of great value.

The mixing of the compound intended for vulcanite is made in the same way as for soft rubber. When intended for polished articles care must be taken to exclude all grit, but for technical articles this does not matter so much. In place of ground waste, vulcanite waste is used which is finely ground. A tough substance like vulcanite takes a good deal of grinding which is done in easy stages; one machine, like a stone breaker, breaks the waste down to large lumps, a second machine reduces this to coarse powder, which is reduced to fine dust on powerful rollers built like a mixing machine. The dust is sifted from coarser particles which go back to the rolls again. Besides vulcanite dust ground pumice and precipitated silica are used and as a mineral magnesia (oxide of magnesium). Where the object is to produce an article which is to be finely polished, these gritty substances must, of course, be avoided, and to get a fine smooth surface in the case of sheets the calendered unvulcanised compound is laid on a table and covered with a large sheet of tinfoil, which is made to adhere closely by the application of a heavy roll. The sheets thus coated are placed in an iron frame and vulcanised in water with steam under pressure. When cured properly the tinfoil comes away easily from the surface but if under-cured it tends to stick just as when curing soft rubber in cloth.

CHAPTER XV

Direct Utilisation of Rubber Latex

Attention has been drawn in the early part of this book to the disadvantages attaching to the mechanical working of india-rubber in the processes of washing, masticating, and mixing. Washing rolls, unless carefully handled, may do a lot of damage to raw rubber, especially in the freshly coagulated state, and mention has been made of the Universal Washing Machine of Werner-Pfleiderer and Perkins, designed to wash rubber effectively with less working than the ordinary washing-rolls; whether or not this machine can be adapted for plantation rubber remains to be seen. In the ordinary manufacturing processes mastication of the rubber is necessary in order to reduce it to a condition in which it can be brought into intimate admixture with sulphur and other ingredients or in the case of articles intended to be cold cured, the rubber must be obtained in a condition in which it can be sheeted. Even for spread sheets and other cases where the rubber is applied in the form of a solution in naphtha mastication is necessary in order to break down the insoluble constituent which would hinder the swelling and ultimate solution of the rubber in the naphtha; as exceptions may be mentioned, some of the plantation rubbers which have been washed in the freshly coagulated state, the tearing and crushing action of the rolls having broken up the insoluble constituents so that the rubber dissolves without further treatment.

To obviate the need of mastication suggestions have been made for the manufacture of rubber goods direct from the latex. The first proposal was to partially manufacture rubber goods in Ceylon and other parts of the East, by mixing sulphur and minerals with the latex before coagulation. The coagulated latex was then to be dried in the form of sheet or pressed into blocks. It has also been suggested that the latex be treated with a solution of sulphur, presumably an alkaline sulphide from which sulphur will be precipitated in a finely divided form, at the same time as the rubber is coagulated by the addition of acid. The general idea in working these processes was to ship the dry rubber containing the sulphur and mineral so as to effect a saving in time and labour in a subsequent manufacturing stage. It may be safely asserted that such suggestions would never have appeared in print had the authors possessed an elementary knowledge of the rubber manufacturing industry.

Somewhat more rational is the proposal of Morisse who would export latex to Europe with the addition of preservatives. The latex on arriving at the rubber factory is, according to the patent specification, to be poured into moulds and coagulated with a solution of creosote, guaiacol, and alcohol. This coagulant is described as a coagulating, antiseptic and vulcanising solution. In the patent claim we are further told the caoutchouc is to be vulcanised by a weak solution of commercial sulphuric acid. Probably sulphur chloride not sulphuric acid is intended; as the former substance is commonly known as "acid" in the factory. Morisse took out his English patents in 1905, but as far as we are aware, nothing has been done either in this country or on the Continent to exploit the patents on a manufacturing scale.

APPENDIX

The Quality of Plantation Rubber

The position of plantation rubber with its rapidly increasing output naturally leads us to ask how will it stand in competition with the old standard brands collected from trees growing wild in the forests and cured in a more or less primitive manner. The only method in vogue that gives satisfactory results with wild rubber is the tedious process of smoking as applied in the case of the hard and soft cured Para.

There is not much doubt what will happen in the future with regard to the low grade native prepared brands. These are already suffering in competition with the various scrap rubbers from the plantations. Even the lowest grade rubber from the latter source, namely the scrap derived from the bark shavings, produced when tapping the trees, is superior to much of the low grade African sorts, especially if properly treated in the washing machine and dried. It is here the Werner-Pfleiderer Universal machine is likely to be useful.

As a rule, when a comparison is made, plantation rubber of the best quality is measured against fine hard Para. At first sight the conclusion to be drawn would appear obviously in favour of fine hard Para. Apart from the statements of varying nature made by some rubber manufacturers, we have the usually unanswerable argument of market value. For the last year or two, that is to say since plantation rubber was obtainable in quantities such as a manufacturer could use, the price of the best plantation brands has been below that of fine hard Para in spite of the fact that the latter is very moist when marketed and loses 15 to 20 per cent. of its weight on washing. To be of equal market value plantation rubber which is dry should sell at 15 to 20 per cent. more than fine hard Para, whereas it has never reached a premium of more than a few pence. At the present moment plantation rubber is quoted at 6s. 2d. to 6s. 8d., while fine hard Para is 6s. 3d. spot, and the difference in favour of plantation is now greater than it has been for many months.

The difference in quality has been attributed to (1) some difference in the nature of latex owing to difference in climate, locality, etc. ; (2) a difference in the age of the trees ; (3) the superiority of the smoke cure as employed in the preparation of fine Para.

As regards (1) we have but little evidence ; (2) is strongly supported in various quarters but less so than at one time. We are of opinion that whereas the latex from very young trees may yield rubber showing some deficiency as compared with fully-matured trees the difference is very slight, and often no greater than would be found between different samples of fine hard Para. (3) This is perhaps the most generally accepted theory. Planters have gone so far as to dry their rubber in smoke, and such smoked rubber has fetched better prices than similar material unsmoked. Smoking in this manner, however, differs essentially from the smoking on the Amazon, but drying in smoke is now largely practised as it has other advantages which appeal to the planter.

We come back, however, to the question whether the difference in price in favour of fine hard Para as against plantation rubber is justified ; whether, in effect, the best plantation rubber is inferior to fine hard Para. We are of opinion that some of the best plantation rubber is quite as good as fine hard Para, at any rate, for a great variety of purposes, and there is no reason why plantation rubber, if suitably prepared, should not be capable of replacing fine Para for all purposes. This opinion is based on a large number of tests on plantation rubbers vulcanised on manufacturing lines, and is in accordance with views of some prominent rubber manufacturers. If this is so some explanation is required as to the discrepancy in prices, and we quote from an article of Dr. Stevens in the Quarter Century Issue of the *India Rubber Journal* published in November of 1909.

" The price of hard cure Para, for some time to come, at any rate, must, in my opinion, stand at a higher level, quite apart from the relative merits of the rubber substance or caoutchouc itself, and for the following reasons :—

" (*a*) Fine hard is the specified quality in a number of War Office, Admiralty, and other contracts, and must, therefore, be used for many goods quite apart from the question of merit.

" (*b*) Fine hard is to be had in very large quantities in fairly uniform quality, so that it can be depended on to produce uniform results, while plantation rubber is put on the market in almost every imaginable variety of shape, form and quality. Even when an Estate is shipping a product of uniform quality, the quantity in most cases is relatively small. If a manufacturer could depend on getting the greater part of every consignment of the same rubber from a given plantation, the amount would not be more than he would require to keep him going on one or two special lines.

" (*c*) Plantation rubber has not yet stood the test of time. If it is to be capable of replacing ' fine hard ' it must be used by manufacturers who produce the highest class of rubber goods, and these are just the people who will be most cautious and whose goods are required to last the longest whether stored or in use. I am acquainted with more than one of the leading rubber manufacturers, who have made, or who are making experimental batches of high-class goods from plantation rubber, but who have not as yet used a single pound of plantation for their ordinary manufacture.

" It is obvious that while all these factors keep down the price of plantation rubber, they are none of them permanent, and will gradually tend to disappear in the course of time. Plantation rubber must, however, for the present fetch a relatively lower price than fine Para, quite apart from the actual quality of the caoutchouc substance itself."

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