pression takes place, and the excess of rubber is cut off at the edges by the pressure of the sharp edges of the roller. On leaving the first pair of rollers the wires pass on to the second pair, where the second coating of rubber is put on, and so on for further coats of rubber. The wires run through fine steel combs, which separate the cut edges from one another, and from these to the drums, on which they are wound evenly and without tension by means of the winding apparatus.

For ordinary insulations, machines similar to tube machines may be employed. Dr Baur's assertion that only inferior qualities can be run on such machines is not accurate; the better qualities can also be dealt with if the rubber mixing is properly treated and suitable additions of ceresine and vaseline are made. Thin wires are wound in layers on slightly tapered wrapping-drums and then vulcanised, but the stouter sizes must first be lapped round with tape, proofed on one side, on a special machine, so that the insulation may not get pressed out of shape and become one-sided.

Vulcanisation is best carried out in the autoclave (fig. 32), for it is of great importance that the steam throughout the heater should be dry, and should circulate uniformly round about the wires wound on the drum; that this result cannot be attained in the ordinary heaters must be known by everyone who has had to deal with them, and is easily shown to be the case by determining coefficients of vulcanisation. The drum being mounted at a sharp angle to the horizontal, and kept in motion, prevents the formation of steam banks in the heater, and in consequence the wires do not come into contact with wet steam in the lower part of the heater. For this reason the insulation absorbs a comparatively small amount of water, and the insulation resistance of the conductor is higher than in the other case. In addition to this, vulcanisation is completed more quickly on account of the more thorough circulation of the steam in the heater, and immediately the cure is completed the wire can be dried *in vacuo* in the same heater. To obtain a uniformly good insulation resistance it is most important that the rubber be correctly vulcanised; in no case should it be left too soft.

Mixings for cable insulation should contain rather a large percentage of pitch which has been heated at 225° C. For high-tension cable this is strictly necessary, the rubber being rendered more homogeneous thereby. The addition of pitch to the mixing has the effect of enabling it to be run out into a firm, very dense sheet, of low porosity, even if it contain a considerable percentage of brown substitute (white substitute must not be used in cable

mixings). Brown substitute should not be despised as an ingredient of such mixings, more particularly if it be made from high-grade blown oils. In cable mixings, differences in insulating power result from uneven distribution of the compounds in a mixing, and the aim in preparing such mixings should be to make the "breaking-down" and the insulation resistance in different parts of the cable equally good. The results obtained by these two methods of testing should not greatly differ from one another. For this reason care should be taken to produce a homogeneous mixing by the addition of pitch, and to carry out the mixing process in such a way that an almost air-free admixture of the ingredients is brought about; the attainment of this end is assisted by the addition of pitch which displaces the air contained in the pores of the rubber.

17. **Compositions of Asbestos and Rubber.** (a) *Vulcanised Asbestos.*—This insulating material consists of asbestos fibre felted together with rubber and mixed with pigment and other fillers. By intimate subdivision of the asbestos fibre a felted sheet is formed which answers the highest requirements of electrotechnics.

This sheet can be made in the following way:—The washed rubber indicated in the mixing given below is dissolved in a Werner-Pfleiderer machine in 35 kilos. of light benzine. The other ingredients named in the mixing are then gradually added to the rubber solution, and the whole mass is worked until a homogeneous solution is produced, a process which may occupy about two hours. When that is complete, and not till then, the finely frayed-out asbestos fibre is slowly added in the form of fluff, and the whole mass is again worked for about an hour on the machine. When the mass is thoroughly mixed it is spread out in large frames, the benzine evaporated off in the vacuum chamber, and the sheet dried. The sheets are then put between zinc plates in a hydraulic press, where they are subjected to a pressure of 40 kilograms per square centimetre. Finally the sheets are passed through the glazing calenders, and are ready to be used for making magnet bobbins, rollers, and sounding-boards. The articles are afterwards vulcanised; the sheets may also be vulcanised as such in the press, under hydraulic pressure.

Specimen Mixing.

Massai	2,500	gms.	Barytes	4,000	gms.
Columbian	2,500	,,	Japan red	4,500	,,
Substitute (free from smell)	2,000	,,	Zinc oxide	4,500	,,
Waste	2,000	,,	Linseed oil	1,000	,,
Sulphur	2,500	,,	Magnesia usta	500	,,
Golden sulphide	4,000	,,	Asbestos fibre	16,000	,,
China-clay	4,500	,,	Burgundy pitch	1,000	,,

A second process is based on the use of papermaking machinery, the "solution" being dried off on the steam-heated drums, and the mixture cut off in the form of a cylinder when it is thick enough.

(b) *"-Ite" Compositions.*—The demand for ordinary rubber packing-sheet for steam-packings has fallen off, as the practice of using superheated steam and high pressures has grown amongst engineers. At steam pressures of twelve atmospheres and at temperatures of 180° to 186° C. ordinary rubber packing-sheet cannot be used, since it is no longer able to meet the demands made upon it.

In recognition of this change, in consequence of which a more resistant packing material became a necessity, attention was turned to new compositions, and the result was the "-ite" sheets, which satisfied all requirements. The sheets as a class were given this name in consequence of the number of names ending in "-ite" given to different makes by the firms which made them, *e.g.*, Klingerite, Moorite, Metzelerite, Cooperite, etc. (The name "Itplatte" itself has recently been protected by the firm of Gustav Adolph, Biebrich-a.-Rh.). Indeed, blind competition has in this instance, as in others, brought this composition, in principle a good one, to the very limits of possibility within a very short time, and converted the quondam speciality into a staple article of rubber manufacture, a state of affairs which is of no more benefit to the consumer than to the producer. The "-ite" compositions consist essentially of a thoroughly felted mass, in which asbestos is used by preference as the fibrous material. But it is not a matter of indifference what kind of asbestos fibre is used. Blue Cape asbestos has proved to be the most resistant towards high temperatures. Next on the list comes Siberian asbestos, and this is to be preferred to the Canadian product. The staple of the fibre is also an important point to be considered, and only samples with long fibres should be used. Waste fibre from spinning, which is in part richly mixed with cotton, is not to be recommended for the production of a good sheet, the fibre being too short, on account of the frequent carding and willowing to which it has been subjected, and so giving rise to an imperfect felting. The composition is the better the more intimately the fibre is mixed and bound together. For similar reasons hand-picked asbestos sheet is to be preferred to machine-made sheet. As regards other ingredients, "-ite" sheets generally contain quantities of mineral fillers, such as china-clay, barytes, talite, iron oxide, etc., according to quality. On the other hand, the

rubber content is rather low, the rubber acting mainly as a cement. Hydrocellulose is a particularly suitable ingredient.

It is clearly and easily conceivable that packing of this description must be able to withstand not only high temperatures but also the high steam pressures which are now usual everywhere: because, indeed, the packing actually consists merely of an intimately felted mineral mass, to which a somewhat elastic, leathery grip is imparted by the rubber cement, and so it cannot be forced out between the flanges. A further advantage is the mechanical stability of this kind of packing. It has already been rolled out and firmly compressed in the course of manufacture, and therefore cannot alter very much afterwards in tightening up the flange bolts; these bolts, therefore, do not require continually tightening up. The composition vulcanises in a few minutes between the flanges, and so forms a safe packing which can only be damaged by blows.

Why the most inconceivable additions should be made to such a simple composition passes comprehension, and reminds one of the early days of rubber manufacture. Why, in fact, employ purposeless additions, only to add mystery to the subject?

Two different methods are available for the manufacture of these sheets, but a preliminary mixing in the dough mill is common to both. The masticated rubber which is to be used is, first of all, dissolved in benzine, and the thin solution obtained is mixed in two lots with the mineral ingredients, a homogeneous paste being formed. Into this the loose, carded asbestos fibre is introduced, and the whole mass is worked until it is thoroughly felted together. The more thoroughly the mixing is done the more homogeneous will be the resulting composition. We consider it very advisable to first card the fibre before adding it to the mixture, and recommend the use in connection with the mixing-machine of a small special opener with a belt conveyor to carry away the carded fibre. By this means the fibre can be mechanically added to the mass in a uniform way in the form of a light fluff and not balled up together; this leads to more efficient felting.

The methods of working up the mixed compound into sheets are as follows:—The sheet can with advantage be either rolled round the rolls in single layers, the ends of the length being then brought together and the sheet "doubled" up to the desired thickness, or the special "-ite-sheet" rolls made by Haubold, and shown in fig. 89, may be used. On these rolls sheet up to 3 metres in length can be made. On the rolls shown in fig. 89A, on the other hand, it is possible to work sheets as much as 5 metres in length, one after another, without having to build up from a number of thin layers.

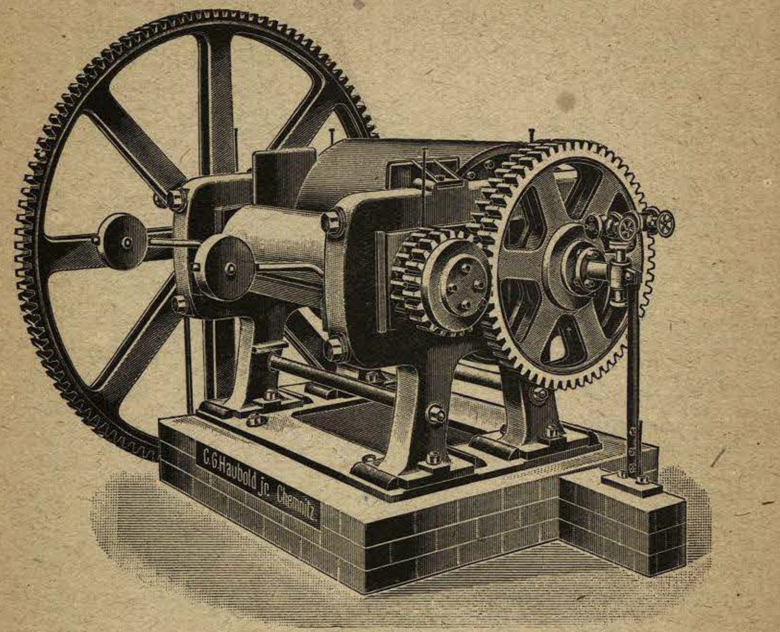

Fig. 89.

In principle the manufacture is similar to that of asbestos sheet. The stiff pulp on leaving the mixing-machine is rolled out into

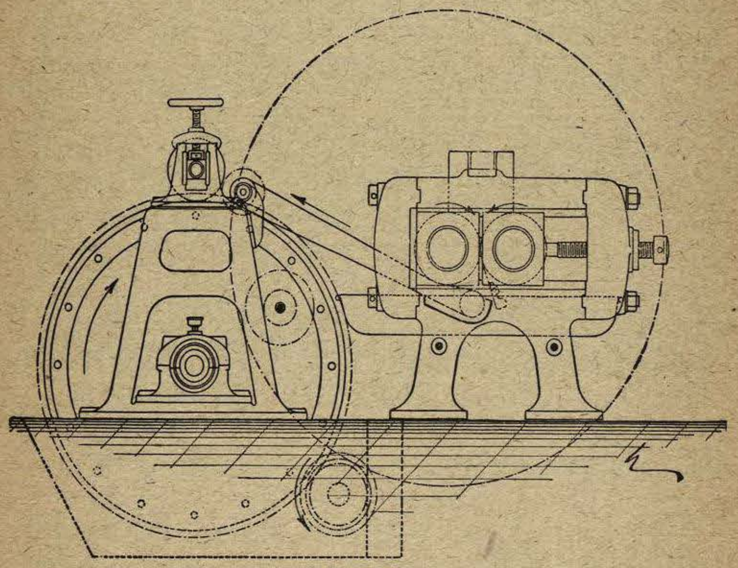

Fig. 89a.

wide sheet between the cylinders, taken up by the conveyor, and carried forward to the large cast-iron roll. Here the thin sheet is

firmly pressed by the press-roll on top. As soon as the correct thickness is reached the sheet is cut off and removed. The rolls are provided with arrangements for heating and cooling them, and also with a spreading-knife and carrier rollers; the metallic conveyor passes through a containing vessel where, if necessary, it can be kept moistened. By this means a solid "-ite" sheet is obtained, consisting of thin separate layers intimately felted together. In both cases the sheets are afterwards subjected to pressure in large hydraulic cold presses, in order to produce a hard sheet.

18. **Eraser Rubber.**—The manufacture of this article is carried out in the following way:—Mixings of suitable composition, containing as fillers chiefly pumice powder, glass powder, whiting and barytes in large quantities, are calendered into sheet and doubled up to the requisite thickness as described on pp. 54–56.

The sheet, which should be free from blisters, is compressed in metal moulds measuring 60 × 60 cm., which are provided with the various impressions which it is desired to reproduce on the rubber. A cold press is all that is necessary for this purpose, and in it as many as twenty moulds or more can be dealt with at a time, the pressure being maintained for about three hours. The compressed sheets of rubber obtained in this way are cut up and vulcanised in chalk at a low temperature. Another method is to vulcanise the roughly-calendered sheet in the moulds in a multiple press. Qualities containing much waste give better results when treated by the latter process, for in the first method of production the impressions on the rubber turn out indistinct and not so sharp as is desirable, this defect being enhanced during vulcanisation by the shrinkage which then takes place.

Union rubber—that is, rubber consisting of two different qualities (one for rubbing out pencil and the other ink marks)—is prepared in the following way:—The sheet, pressed smooth, is cut up on the lathe into strips of suitable width, attention being mainly directed towards getting a clean cut. The cut edges are allowed to dry, and are then given two coats of a good vulcanising solution. This is allowed to dry off, and the strips of the two kinds of rubber are then stuck together alternately, compressed, and vulcanised in suitable frames under the press.

These various kinds of eraser-rubber are cut up in automatic cutting presses with smooth- or saw-edged knives, it being unnecessary in these machines to mark out the separate sizes.

Another kind of eraser-rubber comprises the polished varieties, such as "Velvet" and "Diamond" American rubber, pointed rubbers, etc. "Velvet" rubber is cut from sheet, and the pieces are rubbed down in a revolving drum, which is best made with a hexagonal section, and contains powdered pumice. The shaped, so-called, "Diamond" rubbers have first to be buffed on an emery-wheel, each piece being separately pressed into a wooden holder and held down on the wheel. In this way all the pieces are obtained of exactly the same shape and size. Pointed rubbers may be cured in moulds and then tubbed, or they may be cut out of sheet and smoothed down and pointed on special machinery.

Grease rubber consists of a mixing containing considerable quantities of dry white substitute and vaseline. Marbled rubber is prepared by the non-homogeneous mixing and calendering of mixings of different colours. *Radifix* is essentially only a chloro-sulphide substitute containing magnesia, and has nothing in common with rubber.

It was formerly the practice to use ordinary rubber stamps for branding the pieces of rubber, but the whole sheet is now printed in a press or by means of a roller.

19. **The Manufacture of Para Sheet and Elastic Thread.** — The oldest method of making these goods, and the one still the most widely used in the special factories which deal with them, consists in spreading them on the spreading-machine (as opposed to calendering the sheet). Both methods are equally difficult to carry out, and good results are only possible after long experience and with the help of a well-trained *personnel*. It is also essential that only first-class raw material, consisting of selected "old Para" of the highest quality, should be used. It is by no means a matter of indifference what kind of Para is used, as is often incorrectly assumed even by specialists. The Para used should contain less than 2·8 per cent. of resin, a figure which would indicate that the latex was obtained from very old trees, and which would ensure a high degree of elasticity. The protein content should not be higher than 2·6 per cent. A good quality for sheet and thread should stand the following test:—A piece of the rubber 0·2 mm. thick and 50 mm. long by 10 mm. wide, should be capable of extension to 570 mm., and should recover its original length, on releasing the tension, to within from 3 to 8 mm. When the raw material has been selected it is washed and dried, as described in an earlier chapter, but obviously vacuum-drying is excluded in this instance, for well-known reasons which have been already discussed in Chapter II., p. 34. When dry, the sheet of rubber is run through a cleansing machine as a safeguard against the possible presence of any particles of dust and other impurities, and only when the process is completed is the rubber subjected to mastication and mixing on the rolls with sulphur. The rolls should not be worked too hot at first, or the finely-powdered sulphur may melt on the rolls and form granules or crystals. The addition of sulphur being completed, the rubber is rapidly worked between hot rolls, so that the process may be completed as quickly as possible. The mixing and working on the rolls necessitate great watchfulness on the part of the workman.

When the mixing is completed the actual preparation of the calendered or spread Para sheet commences.

(a) *Calendered Sheet.*—The calendering of this sheet requires, in the first place, a carefully selected, capable *personnel*, and, secondly, a set of four-roll calenders of the best construction, which alone can find use here. This machine should in particular run quietly and smoothly; the rolls should be highly polished and as smooth as glass. The central adjustment for the rolls is so arranged that the third and fourth rolls (the two uppermost) can be adjusted, not only individually, but also both at once from the middle roll (the second), which is mounted in fixed bearings and serves as the driving-roll. The fourth (bottom) roll is also capable of being moved downwards. In connection with the third roll the necessary double-wedge adjustment, which serves as an arrest, and prevents the vibration of the rolls, should be looked for. In that way the bank of rubber between the second and third rolls is kept equal; otherwise the third roll would be lifted by the rubber against the fourth roll above it, a state of affairs which would be very detrimental to the uniform solidity of the sheet. The spindle of the roll-adjusting apparatus should not be in front of the rolls, but above the lower end of the frame top, since the rolls must be easily accessible. In front of the calender-rolls, which should always be regulated to a constant temperature with the aid of thermometers, are small, easy-running rollers over which the sheet can be drawn away. The four-roll calenders illustrated in the chapter on calendering (p. 52, fig. 24) are, up to the present, the most perfectly constructed set which it is possible to get for the purposes of this branch of manufacture.

In making this sheet it is not at all a matter of no importance at what temperature the rubber is introduced into the calender-rolls, and variations in the different batches among themselves should also be avoided. The temperatures of the rolls, too, should not differ, since apart from the so-called star-markings and blisterformation, the rubber molecule also suffers, and this again reacts upon the vulcanisation, and shows itself in the extensibility and the tensile strength. The sheets, which show unequal constants in other respects, would then be very liable to undergo partial premature decomposition. The temperature to be employed must be regulated according to the kind of Para used, the kind of treatment it has already received, and the thickness of the sheet.

Sheets from which thread is to be cut are made from doubled-sheet run on cloths such as are used in the spread-sheet manufacture, and which will be described more fully later. The sheet is doubled in the way described on p. 52, and is afterwards dealt with and vulcanised, as described in the next sub-section.

(b) *Spread-Sheet.*—As mentioned at the beginning of this section, spread-sheet is that most commonly made in Germany. This kind of sheet has admittedly its advantages, but is a good deal more costly to produce, on account of the enormous consumption of benzine by which it is attended, and the greater amount of labour involved. The homogeneity and purity of the sheet made by this process can hardly be attained by any other method. The statement made by Baur on p. 270 of his book *Elektrische Kabel,* that spread-sheet may be recognised by its lack of cleanliness, is quite incorrect. In the manufacture of spread-sheet the place of the calenders is taken by the spreading-machine shown in fig. 72. For a daily output of 120 kilos. of sheet four spreading-machines are generally considered necessary, and in addition to these, and the washing- and mixing-rolls, a three-chambered masticator 720 mm. long and 750 mm. in diameter is required, together with two solution-mills.

The process of manufacture is in this case as follows:—The masticated rubber is dissolved in benzine in large tins, and then worked up on the solution-rolls or mills until a clear solution, free from lumps, is obtained. This solution is diluted with benzine to a degree dependent on the quality and thickness of the sheet.[1]

The rubber is spread on specially prepared cloths. The closely-woven fabric used for this purpose is impregnated in a special machine with shellac, and the rubber is then spread on the smooth coat of shellac exactly as described in section 12. When the sheet is finished it is stripped off the cloth on a stripping apparatus, and is chalked and vulcanised. The shellac-coated fabric must be washed out as soon as it has been used, and impregnated anew with shellac.

[1] *Cf.* also the exhaustive article "Gummilösungen" in *Gummi-Zeitung*, 1906, xx. p. 1204.

Spread-sheet is cured in the same way as calendered sheet.

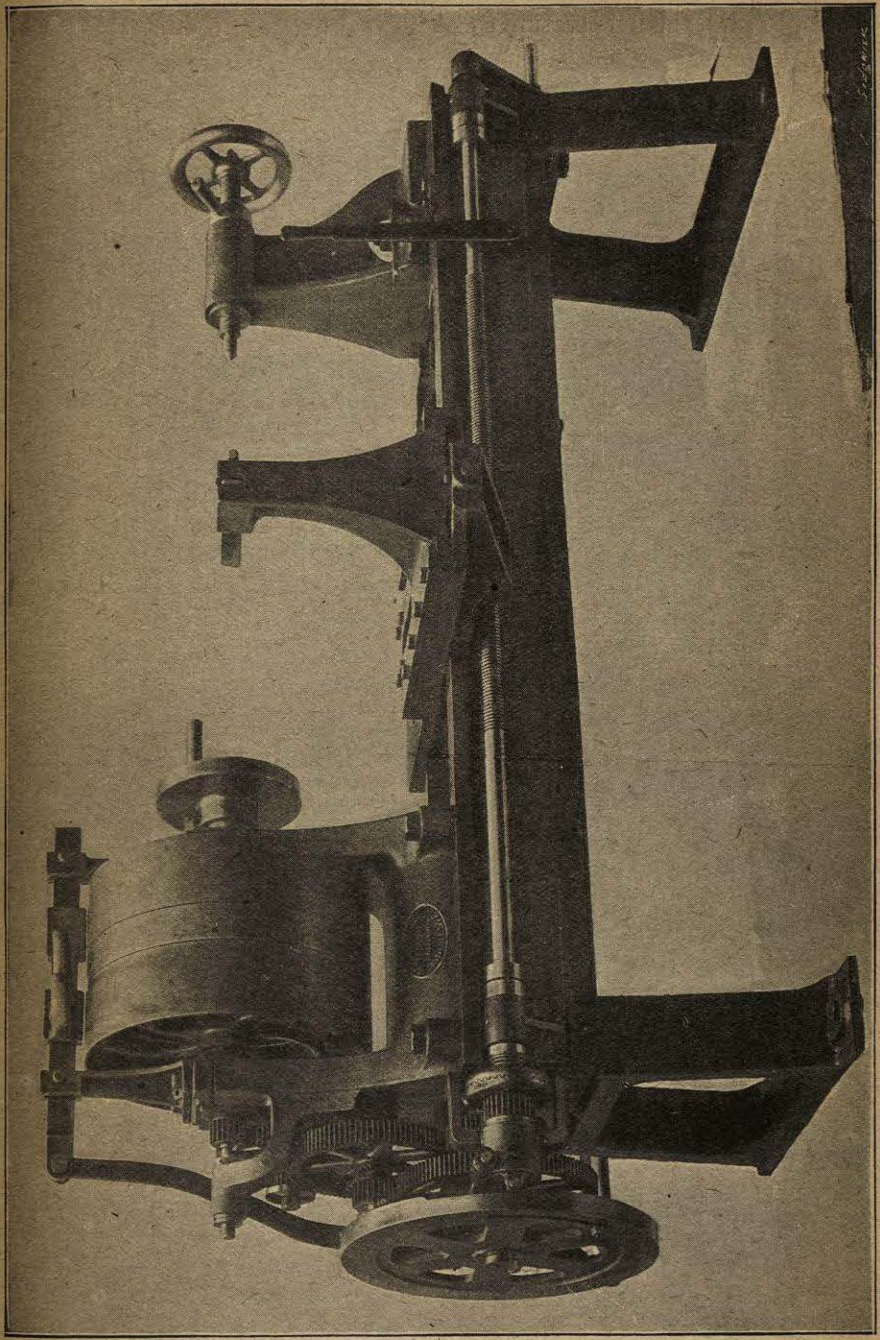

Fig. 90.

Para-proofed twill is used as a wrapping-cloth for this material, though, of course, it can only be used two or three times, after which it is sold as waterproof cloth. The vulcanisation is carried out in a water-bath at $2\frac{1}{4}$ to $2\frac{1}{2}$ atmospheres pressure, care being taken to keep the temperature constant.

After vulcanisation the sheet is unwrapped and washed.

For thread-cutting the automatic cutting-machine shown in fig. 90 is employed, with drums 450 mm. in diameter and 700 mm. long, on which the sheet, lightly coated with shellac, is rolled. On an average six such machines are required to cut 120 kilos. of thread per day, and three men are required to attend them. The cutting is followed by boiling-out (to remove free sulphur), drying, sorting, and tying into bundles, special care being taken with the boiling-out process. The drying-room should be kept well ventilated and dark.

CHAPTER V.

MANUFACTURE OF EBONITE.

HANCOCK is generally looked upon as the originator of the *manufacture* of ebonite. He patented his process for the vulcanisation of rubber by means of sulphur towards the beginning of the year 1843 without prejudice to the fact that Goodyear had already obtained the substance "hard-rubber"; Goodyear, however, had not gone so far as to prepare useful articles from it on a manufacturing scale.

For a long time, however, nothing more was heard of the process, since the various experiments made did not turn out favourably enough when they came to be put into practice. It was in 1851 that Goodyear, realising the importance of ebonite, took up his experiments again and succeeded in preparing a substance which was very suitable for articles in which, in addition to elasticity, the qualities of durability, ease of working, and chemical stability are essential. Goodyear's ebonite of that date consisted of a mixture of Para, magnesia, whiting, shellac, lead or zinc salts, and sulphur, these ingredients being intimately mixed together and run out into strips which were vulcanised at a fairly high temperature. The product obtained was dark in colour and hard, similar to jet or horn, and lent itself to being worked quite well. Gradually Goodyear omitted from his composition all the fillers except sulphur, his mixing now consisting of rubber and sulphur only; at the same time he raised the temperature of vulcanisation to about 165° C., and so arrived at a perfect ebonite. The problem still remained of finding a material with which to cover the plastic hard-rubber composition before vulcanisation, and with the discovery by L. Otto P. Meyer in 1854 that tinfoil was eminently suitable for this purpose, ebonite manufacture took its place amongst the industries in which manufacture in bulk can be successfully carried out, and, advancing steadily, soon won for itself a large market.