bath vulcanisation the iron case in which the sheets are packed should be large enough for the water to circulate freely round the sheets. A thick cast-iron plate, planed smooth, serves as a base on which the separate sheets of foil-covered rubber of equal size are laid, care being always taken to avoid creases; it is not advisable to vulcanise more than fifteen to eighteen sheets each 3 mm. thick, in a single case. To prevent the sheets from being displaced, a cast-iron plate, planed smooth, and of the same size as the sheets, is laid on top of them. After vulcanisation—which, as stated at

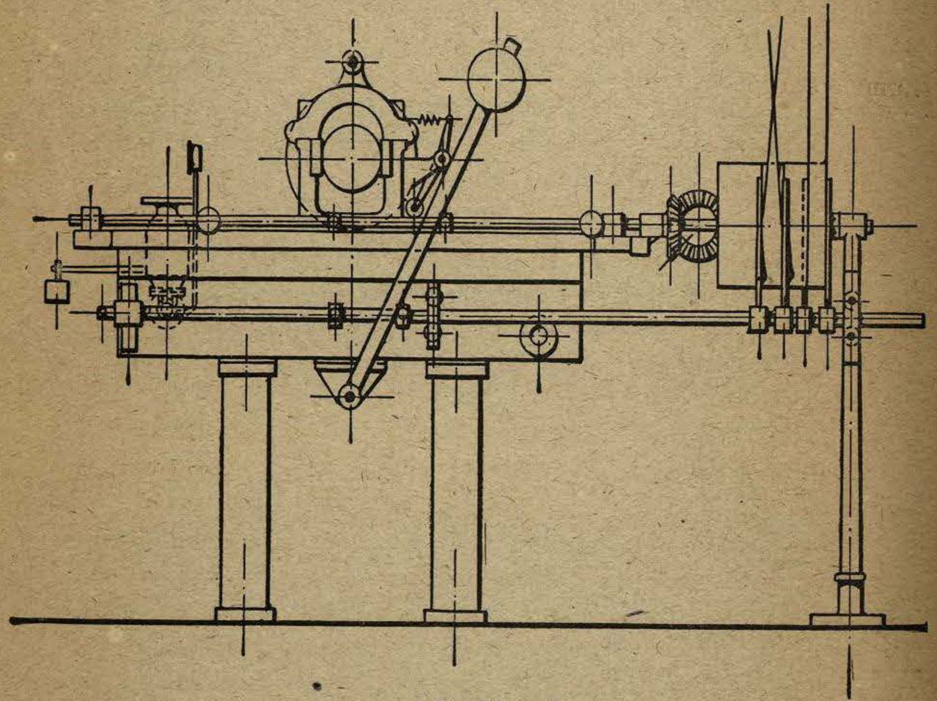

FIG. 96.

the outset, is regulated according to the quality and thickness of the sheet—the sheets are allowed to cool, and the tinfoil is then taken off and melted down again. In the process of doing this indications are obtained as to the correctness or otherwise of the vulcanisation. If the sheets are under-cured the tinfoil adheres tightly to them, and the sheets themselves are of a dull, dirty greenish-black colour, and leathery in texture; this mistake may be partly rectified by re-vulcanising the sheet. If, on the other hand, the sheets have been over-cured they are as hard as glass, and more often still are porous and carbonised.

Sheets more than 15 mm. thick are covered on the hot-bench with tinfoil; this is not, however, pressed down at the edges, but

cut with the sheet itself to the right size for the frame mould which is going to be used, and the sheet is then partly vulcanised in the press, under hydraulic pressure. The size of the frames used is determined by the thickness of the sheet, and the temperature at which the partial cure is effected is at first a low one, but is gradually raised until the sheet is about three-quarters cured. The cure of the sheets is then completed in the water-bath for from three to four hours, at a temperature not exceeding 130° C.; in this way the productive capacity of a plant is increased.

After vulcanisation the sheets are either worked up further, that is, cut up into other articles, for which purpose special saws are used, or they are sold as they are. In the latter case the sheet has still to be finely polished.

2. **Manufacture of Tinfoil.**—The consumption of tinfoil in a hard-rubber factory being exceedingly great, and since the foil can sometimes only be used once, its preparation is usually provided for in the factory itself. The foil is rolled from pure block tin.

The manufacturing process may be divided into three parts:—

1. Melting down and casting.
2. Preliminary drawing out.
3. Rolling and glazing.

The tin is melted down in a special oven, and the scale must be very carefully removed so that only a perfectly clean melt is poured; the metal should not be overheated. It is cast in iron Register moulds, 30 cm. square. Each mould is formed of a cast-iron plate in which a cavity has been planed out, surrounded by a rim 15 mm. thick. The back of one plate forms the cover of the next. On one side of each plate the rim is missing, the edge being slightly bevelled off. The plates are all built up together to form a mould. This is inclined at an angle of about 75°, the mould is closed by a clamp, and after it has been warmed up is ready for use. The casting is done in the ordinary way, the metal being slowly poured into the moulds from a ladle, while the moulds are cooled with water. The plates of metal obtained, which measure $300 \times 300 \times 15$ mm., are now drawn out on the mill illustrated in fig. 97, and are then rolled out on the tin-calenders,—which are similar in construction to the ordinary two-roll calenders (fig. 25), except that they must have rolls ground and case-hardened across their whole breadth,—to thin doubled foil of 120 cm.; soapy water is used as a lubricant. For comb manufacture the foil is calendered into narrow sheets about 15 metres long. This calendering process is carried out in several stages, the sheet of foil being run thinner and thinner by gradually closing up the rolls, using soapy water as a lubricant. Finally, in order to improve the gloss and smoothness, the sheet is glazed and is then ready for use.

3. **Ebonite Rods and Tubes.**—The manufacture of these articles is in many respects distinct from that of sheet. Whereas sheet was covered with tinfoil and vulcanised in the water-bath, it was formerly the practice to vulcanise rods and tubing wrapped in cotton binders, the tubing being of course first placed on mandrels.

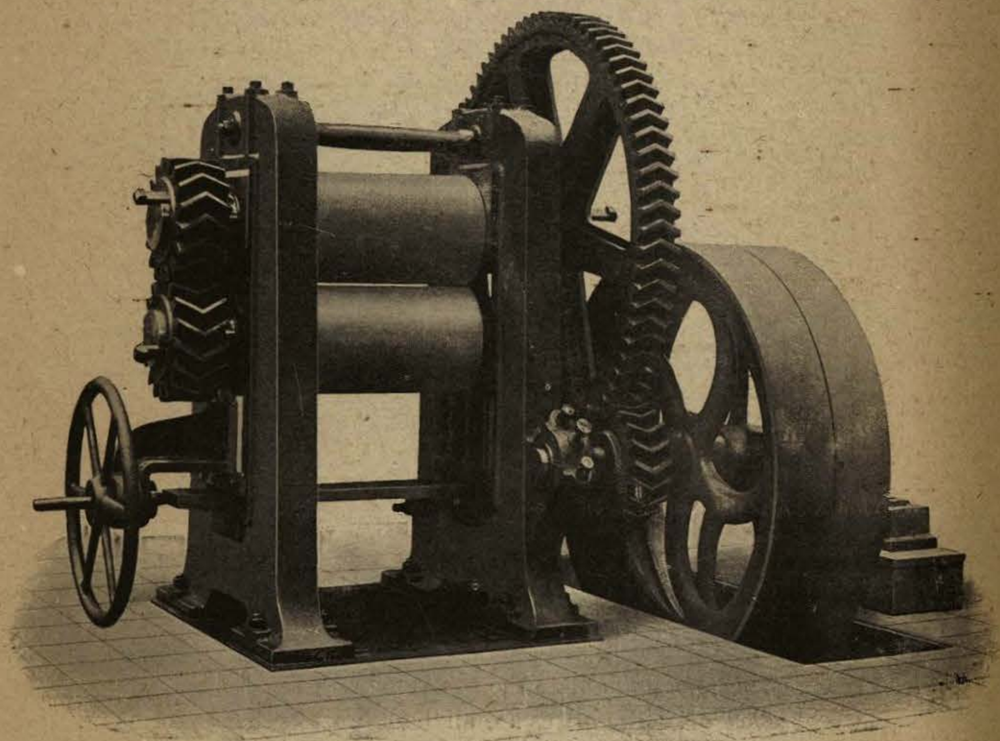

FIG. 97.

It is customary now to cure both these classes of goods in chalk in the open, or, as in cases where one is concerned with the production of an absolutely true and smooth-surfaced article, in glass or metal moulds, the inside walls of which are smooth. In carrying out this process care must be taken that both the moulding tubes and the machined ebonite cord or tube are evenly heated, so that the rubber may distribute itself evenly in the mould and fit closely against the walls. Some experience is, however, necessary here, in order to prevent air-markings on the outer surface of the rubber rod or tube. With the increasing use of magnesia usta this method of vulcanisation has come into more general use, the results obtained

being quite equal to those produced according to the older method. As a rule, the tube or rod is prepared on the tube machine already described, the particular article required being run to the desired dimensions. By working with the tube machine one obtains a much more uniform product, and the troublesome wrapping process is done away with. Moreover, no defects can arise in such tubing from faulty seams, whereas such defects are very likely to occur in the case of common, dry qualities with thin walls, made up by the wrapping method; on the machined rod, again, there is no seam-like marking showing where the edge of the rubber sheet came when the rod was rolled up. The mixings should be of such a composition that they do not tend to run out of shape during vulcanisation; they should therefore set rapidly, and this is generally ensured by the use of magnesia usta and ebonite dust as ingredients. The finest possible dust should be used so as to ensure getting very smooth surfaces straight away, and make subsequent burnishing unnecessary. Furthermore, the magnesia should be as free as possible from hydrate and carbonate, or porous goods may be obtained as a result of the evolution of gas on heating. In very highly polished tubes and rod the magnesia is omitted, the time of vulcanisation being correspondingly increased.

Tubing up to 15 mm. in diameter may also be vulcanised in the open without mandrels, according to the thickness of wall, whilst larger sizes for very accurate goods of smaller diameters, which must measure correctly to a hair's-breadth, are either run on the tube machine and then slipped on to mandrels, or run direct on to the latter in the proper machines, and vulcanised in moulding tubes. Rods more than 25 mm. in diameter after being run on the tube machine must be cured in tubes, and larger sizes still in moulds, since these larger sizes are very apt to swell and burst open. After being suitably vulcanised the rods and tubing are either further worked up, that is to say, turned, or they are regarded as finished products, in which case they are in part polished or burnished, processes which are dealt with later. Vulcanisation is carried out either in the water-bath or in hot-air chambers.

The rods and tubes made in this way are quite smooth and exact in dimensions.

4. **Insulation Tubes.**—Insulation tubes for electric conductors form one of the chief objects of attention in the tube machine department of an ebonite factory. The point to which greatest importance has to be attached is the production of a good insulator with as thin a wall as possible, and in this connection it is impor-

tant to put together the right mixing, so as to be able to make a tube which is tough without being excessively hard, and which can still be bent. The lengths of tubing should not be run from the tube machine on to trays, but in lengths of from 1 to 3 metres on to belt conveyors, passing through water, if necessary, as they leave the die of the machine, so as to cool them down rapidly and keep them in shape.

The following is a suitable mixing:—

Batanga	1,500 gms.	Sulphur	5,000 gms.
Balata	500 ,,	Brown rape oil substitute	8,000 ,,
Dust	6,000 ,,	China-clay (free from mica)	15,000 ,,
Almeidina	3,000 ,,	Whiting	6,000 ,,
Reclaimed	12,000 ,,	Palm- or castor-oil	2,000 ,,
Pontianac mixture	6,000 ,,	Magnesia usta	1,000 ,,
Talite, Atmido or Atmoid	15,000 ,,	Tar	2,500 ,,
Carbon-black	2,000 ,,		

Time of vulcanisation, about one hour at 145° C.

5. **Ebonite Accumulator Cases.**—The method of manufacture of these articles is not quite equal to the great demands put upon them, and very unpleasant consequences have frequently resulted from cases being badly made, or made from unsuitable mixings. Ebonite cases have to fulfil the following conditions, and should be made with this in view:—

1. They must withstand the action of sulphuric acid of 66° Baumé.
2. They should not soften at a temperature of 65° C., and must not be brittle at 10° C.
3. They must be reasonably tough to be able to withstand shocks without breaking.
4. They must be absolutely watertight.
5. They must not break down under a high-tension test at 30,000 volts.

The composition of the mixing will determine whether the first of these conditions is fulfilled or not. The following mixings are extensively used:—

A. Congo	10,000 gms.	B. Congo	10,000 gms.
Sulphur	4,000 ,,	Sulphur	4,000 ,,
Ebonite dust	2,500 ,,	Magnesia	250 ,,
Powdered pumice	5,000 ,,	Ebonite dust	4,000 ,,
Linseed oil	600 ,,	Powdered pumice	7,000 ,,
		Linseed oil	800 ,,

Pure silica, produced in the manufacture of sodium silicofluoride, may also be recommended as possessing advantages over pumice in this connection.

In order to produce a good serviceable case the course of

manufacture described below must be followed; attempts to economise by the use of light sheet-iron moulds instead of the heavier castings are doubtful policy. Cast-iron moulds should, without question, be chosen as the cores on which to make up, and as moulds on which to vulcanise, the cases, which vary in size from the smallest up to 70 cm. deep; the moulds should have a slight taper of about 1 mm. so that the finished cases can be easily taken off. The surface of the mould is brushed over with a thin solution of Para, in order that the rubber sheets may make intimate contact with it. The sheet of the requisite thickness is placed on the mould and rolled down with a rubber roller, starting from the top and working downwards. That portion of the sheet of rubber which projects beyond the corners of the mould is cut off square with the face of the mould by means of a thin sharp knife, and the adjacent surfaces are then applied. Finally, the bottom is placed on the mould, rolled down firmly and cut round the edges, and the case is now ready for vulcanisation. It is not necessary to enclose the case in an outer mould, since the surfaces are securely and firmly united, and the case cannot get out of shape on the solid mould. The case is vulcanised in chalk, the moulds being firmly embedded in it and covered with a good thick layer. Vulcanisation is complete in eight hours at 145° C. with the proportion of sulphur given above, and this composition and time of cure have been shown by a series of experiments to form an advantageous combination.

While the cases are still warm they are loosened from the mould in a small press, and are then taken right off and smoothed down by means of a sand-blast. By this means the faces are made quite even, and at the same time a considerable saving in wages is effected as compared with the process of buffing by means of emery-wheels; these are only employed to grind down the cases to the right height.

The cases should now be tested as follows:—

1. In a special apparatus under a water pressure of 1 atmosphere, to make sure that the seams are perfectly tight; and
2. as regards their behaviour towards high electric tension, the test being applied by means of a spark inductor.

The tested cases are varnished with an asphalt varnish, and are then ready for use.

6. **Moulded Ebonite Goods.**—A large proportion of the articles made in ebonite are vulcanised in moulds. The process is carried out in cases where metallic fabrics are pressed into the rubber, in

the same way as described for moulded soft-rubber goods. But, on the other hand, in order to economise in moulds and at the same time to produce smooth surfaces, certain articles may be given a preliminary pressing in steel moulds and the vulcanisation completed in hot-air ovens, or in compo-moulds which, amongst other things, may be dressed with collodion solution to prevent sticking to the mould. This process has found employment especially in the case of surgical goods; such articles as enema fittings, taps, screw-unions, cannulæ and cigar holders are made in this way, and it is not necessary to turn them up on the lathe

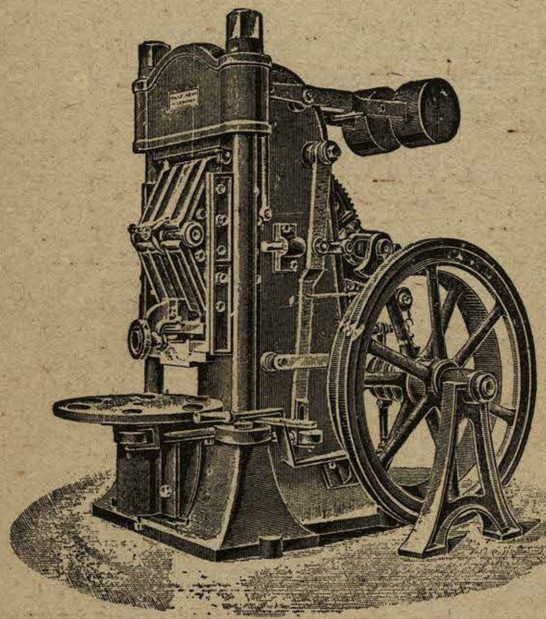

Fig. 98.

afterwards, since they come from the moulds with a perfectly smooth surface. All articles which are mounted on mandrels can be cured with comparative ease by means of hot air. Naturally they are not very smooth after vulcanisation, and have to be turned up before a polish can be put on. On the other hand, in the case of certain articles which are covered in tinfoil and vulcanised, or which are cured in moulds dressed with a special solution, a brilliant gloss can be produced, which gives the article a peculiar enamelled appearance, and does away with the necessity of subsequent polishing. Combs are made in the same way. The sheet rubber is pressed into the comb moulds, between sheets of tinfoil, by means of heavy bent-lever presses (fig. 98), so as to form a flat piece of the shape of the comb, but without the teeth.

The teeth are cut out after vulcanisation by means of automatic saws, the ingeniously-constructed machine working in such a way that the slot in which the comb is fixed, according to the number of teeth, moves towards the revolving saw, and is automatically thrown out as soon as all the teeth of the comb are cut; the comb has then only to receive the final polish. By a special arrangement of the mould the teeth can also be first of all pressed out.

7. Buffing and Polishing Ebonite.—The buffing of ebonite sheet

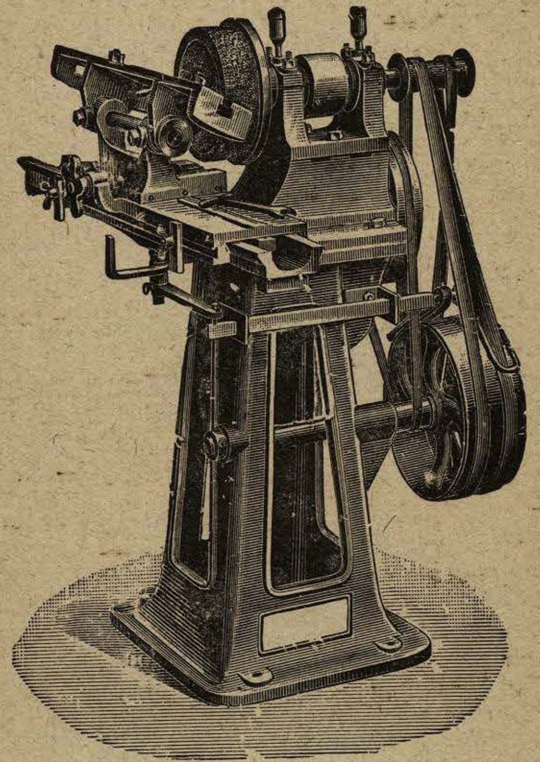

Fig. 99.

and surfaces of other ebonite goods must be done in a continuous stream of cooling water, and the articles being buffed should be pressed as lightly as possible on to the buffing wheel, in order that the ebonite may not become too strongly heated. For sheet ebonite an automatic buffing machine is used, in which emery-wheels are moved evenly over the whole surface, rubbing down the sheet, which is immersed in water, with fine Tripoli or pumice powder. No cracks or streaks should show themselves; if they do, the sheet should be at once cooled down. In fig. 99 is illustrated a special machine for buffing ebonite. Smaller articles are either tubbed, or buffed with powdered pumice on emery buffs or maizeleaf wheels working wet. After buffing, the articles are scrubbed with brushes in order to remove all the fine Tripoli dust or pumice powder still adhering to them, before being oiled, dried, and polished. If the article should remain dull in appearance it is rubbed down with a little linseed oil; on the other hand, in order to produce a polish the ebonite must be worked on rapidly revolving flannel buffs with fine Tripoli powder and a little linseed oil until a deep gloss is produced. In carrying out this operation the ebonite should not be rubbed too hard, or it will become overheated and lose its capability of taking a polish.

Should spots and greenish-coloured patches show themselves on the surface—defects which are due to the action of moisture during the process of vulcanisation—they may be easily removed by repeatedly rubbing them over with carbon disulphide.

8. **Ebonite "Mechanicals."**—Amongst the most important of these goods are the coverings for the machinery and boilers used in chemical works; they constitute a branch of ebonite manufacture which demands much experience and knowledge; the difficulties are increased by the circumstance that the articles have to be made without moulds. In covering heaters (Montejus) the following are the points most worthy of note:—The surface to be covered must be roughened as thoroughly as possible, after which it is carefully warmed up and cleaned, and then dressed with a suitable solution. When this is dry a layer of unvulcanised ebonite is rolled down on to the iron; this layer of ebonite must fulfil the following conditions:—

1. It must make good contact with the iron.
2. It must be tough and as hard as possible without being too brittle.
3. It must not contract to a greater degree than the iron, or it may break away from it.

On the top of this layer a suitable hard quality is rolled down; this also should show very little contraction; finally, the actual insulating quality is put on, and this must be absolutely stable towards acids. If a partition is to be made in the heater only such a quality can be used for it as shrinks very little, and this may, with advantage, be partly vulcanised first of all by itself.

When covered, the heater is allowed to stand for some time, in order that any blisters which make their appearance may be pricked or pressed out. The inside of the heater is filled with chalk, tightly packed, and vulcanisation is then carried out at 130° C. with a gradual rise. Coverings for centrifugal machines are put on in

exactly the same way. The small holes which have to be covered round, are filled with tubing of the right outside diameter, through the inside of which passes a short nickel rod of the diameter of the finished hole. The whole centrifugal basket is packed in chalk and cured. Vulcanisation may take anything up to fifteen hours at 135° C. according to the size of the basket. The chalk should only be removed when the article has slowly cooled down. Taps, curves, bends, and shaped pieces, of different inside measurements, can be most conveniently dealt with on thin, stiffened, hollow, sheet zinc cores; it is important to see that the individual parts will all cure in the same length of time, for one cannot cure pieces of over 30 cm. in diameter with a wall 8–10 cm. thick, of one quality. They would be porous in the centre, and would blow, and cause the article to burst. In order to remove the zinc core it may be dissolved away in hydrochloric acid. By this means a much better mould can be produced inside than if a corresponding plaster mould were used. Plaster cores are, on the one hand, difficult to remove, and, on the other hand, produce a very rough inside surface.

Quite recently it has become the practice to insulate ship's screws and their bearings with ebonite, in order to stop the corrosion due to local currents, which have been known to eat out even 25 per cent. nickel steel from the propeller shaft. Traun's protected process for covering propellers, used on ships of the German Navy, may here be referred to. These qualities should be perfectly homogeneous and durable, and, on the other hand, should adhere firmly to the steel. Vulcanisation is carried out, in heaters of their own construction, by means of hot air, in the docks, in order to save the very considerable costs of transport.

9. **Imitation Ebonite.**—The various resinous compositions put on the market under different names can be quite advantageously used for the preparation of solid articles, used for insulating purposes in the electrical industry, for surrounding and insulating all kinds of metal parts, which are made in large quantities.

The insulating material occurring in commerce under the names "Ambroin," "Ebolite," etc., consists of an intimate mixture of resins, fibre, and fillers, and is prepared by the method explained below.

The basis of the composition is resin. Lac resin (*resina lacca*) or shellac is used by preference. Gum-lac comes from the branches of several trees and shrubs, such as *Ficus religiosa*, L.; *Ficus bengalensis*, *Ficus indica*, *Butea frondosa*, Rb.; *Croton aromaticus*, *Croton lacciferum*, L.; *Ziziphus Jujuba*, Lam. The first-named of these is a strong East Indian tree of considerable size, with pointed, oval, somewhat heart-shaped leaves. The "fruits" are rounded and elongated, and are actually none other than the enlarged receptacles, to the inner walls of which the extremely small flowers and fruits proper are attached. Gum-lac results from the perforations made by a species of coccus, *Coccus lacca*, in the young branches of the tree. These insects, with their brood, become surrounded by the glutinous liquid which exudes,[1] later on boring their way out through the outer shell, leaving behind the mass of resin still adhering to the branches; this is collected with the fragments of wood attached to it, and is called stick-lac. The pieces are taken off the branches, and when freed from pigmenting material by treatment with sodium carbonate, are known as button-lac. This button-lac is heated, forced through linen bags, and pressed between Pisang leaves into sheets of varying degrees of thinness; this forms true shellac. It is a yellowish-brown to brownish-red, hard, glossy, transparent substance, which clings together in large pieces. Shellac is an article of commerce in Bengal, Assam, Siam, Annam, Sumatra, and China; that which comes from Bengal is, however, accounted the least valuable.

The more transparent a shellac, the greater is its value. Shellac is only partially soluble in cold alcohol, leaving undissolved a sticky mass, the so-called "wax."

The other resin used in the preparation of imitation ebonite is copal (*resina copal*).

There are various kinds of copal on the market, the chief sorts being the following:—West Indian copal, obtained from *Amyris copallifera*, Sprengel, a member of the Terebinthaceæ. In October and November the resin exudes from the bark of the trees in drops, and is collected and melted together. The fracture is highly vitreous, the colour varying from light to dark.

Brazilian copal is derived chiefly from *Hymenæa Courbaril*, Linn., and is of two kinds. The first kind oozes out of the bark and forms tear-shaped, somewhat angular pieces of a yellowish to yellowish-red colour, transparent, with a vitreous fracture; while the other kind is found in the earth beneath the roots, and forms egg-sized lumps, with a wrinkled surface.

Copal being cheaper than shellac, it is of advantage to use the former in the preparation of imitation ebonite. Proceeding now to the actual manufacture of the mass, the following details should be noted.

The resin is dissolved in solution mills (Pfleiderer's system), in

[1] The now generally accepted statement of the case is that the lac is mainly, if not entirely, a secretionary product of the coccus, elaborated by it from the sap of the tree.—See Tschirch, *Die Harze und Harzbehälter*, 1906, pp. 812, 813.

125 per cent. of its own weight of absolute alcohol; the process of solution is completed more rapidly if the resin be first of all powdered in an Excelsior mill. The liquid is filtered, and the residue on the filter is warmed up and treated with a further quantity of solvent, this solution being afterwards added to the main portion. In addition to the resin, the mass contains asbestos fibre, jute fibre, and the various fillers, such as china-clay, magnesium carbonate, zinc oxide, barytes, and lithopone. The colouring matters used are Frankfort black, nigrosin, carbon-black, the last-named only in small quantity, since it is a good conductor, and iron oxide or *caput mortuum*. The various materials are weighed off and put into a large Pfleiderer machine; the latter is set in motion and the resin solution slowly added, the extra spirit necessary being added later. When the mass has been worked up for about an hour, and the ingredients are intimately mixed together, the asbestos and jute fibre, which must be thoroughly disintegrated, are scattered in gradually in the form of a very light fluff. It may here be noted that the asbestos fibre should be teased out as thoroughly as possible on the fur carder; the finer the fluff, the better the properties of the finished mass. The mixing-machine must be kept going for one and a half to two hours longer, until the dough is ready for use. The latter is then spread out on sheet-iron racks to a depth of 2 cm. and put into the vacuum drier. The alcohol is distilled off and recovered for further use. The drying is completed at 140° C. with a vacuum of 65 cm. in about 2½ hours.

In order to work up the mass still further, it is crushed on the "Kaiser" mill (fig. 92), and finally ground in the Excelsior mill. The powder thus obtained is compressed in moulds and made into articles of various shapes.

The following mixings may be recommended as suitable for different purposes:—

	gms.	gms.	
Resin solution	30,000	12,500	
Alcohol	8,000	3,000	
Ambroin waste (powdered)	15,000	2,500	
China-clay	5,000	1,500	
Magnesia	10,000	3,000	
Talite or atmoid	5,000	1,000	
Frankfort black	4,500	1,750	Iron oxide or
or Nigrosin	500	250	fuchsin
Asbestos fibre	5,000	4,000	
,, ,, waste	2,500	1,250	
Jute fibre	2,250	800	
Linseed oil	750	550	
Ozokerite	250	200	
Burgundy pitch	7,000	750	
Colophony	2 000	...	

For glossy imitation ebonite:—

Resin solution	12,000 gms.	Zinc white	2,000 gms.
Alcohol	3,000 ,,	Carbon black	750 ,,
Magnesia	1,200 ,,	Asbestos fibre, fine, short	5,000 ,,
China clay	2,500 ,,		

10. **Moulding and Pressing Imitation Ebonite Goods.**—Every article is made by compression in steel moulds, made up in three portions:—

1. The outer casing.
2. The matrix or mould proper.
3. The plunger.

The outer casing encloses the matrix, and must be designed with very thick walls. It is also designed, as far as practicable, to take as many different moulds as possible, so that the one casing will serve for all moulds of a similar type. The plunger serves to compress the mass, and should be an exact fit to the matrix.

The method of procedure is as follows:—

The powdered mass already described is accurately weighed out, filled into the mould, and compressed by means of the plunger under small hydraulic presses at a pressure varying from 75 to 300 atmospheres. The moulds are put into hot-air ovens for about ten minutes, then slightly cooled, and the matrix and plunger forced out of the jacket in the same way as they were put in, when the finished article drops out of the matrix. The manufacture can be carried through very rapidly, and an experienced hand can mould as many as 400 pieces of simple construction—*e.g.*, handles—per day.

The final process consists in buffing on emery-wheels and varnishing.

Imitation ebonite which is to have a good polish after coming from the press must, on the other hand, remain for about ten minutes under the press at 75 atmospheres pressure.

Naturally the material cannot be worked, drilled, or turned very well, since it breaks very easily, but where moulding is possible it constitutes a cheap electric insulating material, with a high resistance amounting to as much as 80,000 megohms, and can easily be applied to the insulation of metal parts of the most varied shapes.

APPENDIX I.

THE REGENERATION OR RECLAIMING OF RUBBER WASTE AS CARRIED OUT IN RUBBER GOODS FACTORIES.

NEARLY all waste rubber is used over again in some form or other. The factories which have been established for the express purpose of reclaiming waste rubber have latterly advanced beyond the stage when old rubber shoes constituted the chief form of rubber waste worked up by them, although such old shoes are the basis of a very considerable proportion of the reclaimed rubber used in rubber factories. But, except in a few instances, the reclaiming of old rubber shoes is not, as a rule, carried out in the rubber factory, but in special factories. This statement holds good, also, for old bicycle tyres. The typical reclaimed rubber factories of Theilgaard in Copenhagen have been already so clearly described in the *Gummi-Zeitung*[1] that it is only necessary here to refer the reader acquainted with German to the articles in question.

The following short account is therefore concerned only with the reclaiming process as carried out in the rubber factory itself.

The fact that by no one of the reclaiming processes at present in use is it possible from vulcanised waste to reproduce *unvulcanised* (devulcanised) rubber, must be assumed to be well known. The sole result of reclaiming processes as now applied is to render the rubber plastic again. If in any given instance the vulcanisation coefficient is reduced as a result of the reclaiming process, the reduction is only slight, and indicates that the rubber substance has undergone some decomposition. The only case in which this is not absolutely true is that of cut-sheet (or other cold-cured) waste, but the reduction is in this case due to the removal from combination with the rubber, not of sulphur, but of chlorine, a result which is achieved with comparative ease by heating the waste with solutions of the alkalis or alkaline earths.

[1] 1904, xix. pp. 87–93.