eccentric so that the materials passing through the cylindrical sieve are passed through the second sieve on to the rubber. A celluloid cover is fitted over the whole sifting apparatus in such a way that it can be adjusted to the height of the front mixing roll; the edge of the cover presses lightly on the front roll so that it readily adjusts itself to inequalities in the thickness of the material surrounding the roll. The back part of the cover is carried about half-way across the top of the back roll, and is also adjustable. So that the cover may be transparent, only pale-coloured celluloid should be used. This cover prevents the

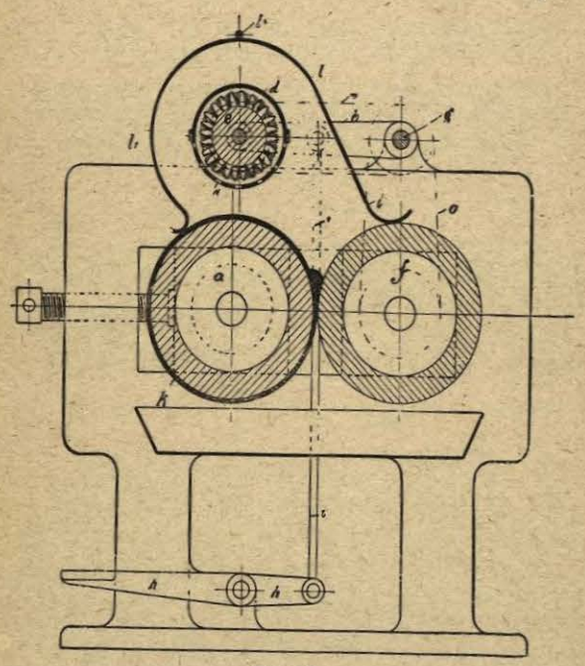

FIG. 21.

inhalation of the fine magnesia dust produced when the sieve is working; any dust which tends to settle on the smooth surface of the celluloid is at once shaken off on to the rolls by the vibratory motion.

The Calenders.—We have seen in the last few paragraphs how the mixings are prepared on the mixing rolls, and we have now to follow the mixed rubber through its further manipulation until it arrives at the stage of hard- or soft-rubber goods.

Before anything more can be done with it, the mass of mixed rubber has now to be run into the form of sheets, the thickness of which, together with the greater or less degree of smoothness of their surface, depends upon the details of the manufacture of the article

for which the rubber is to be used. The strange notion which was very widely prevalent outside the industry for a long time, and which is still in existence here and there, that indiarubber articles such as tubes, balls, syringes, etc., are made by simply casting liquid rubber in suitable moulds, in the manner in which metallic castings are made, is, of course, quite an erroneous one. With only a few exceptions, all rubber goods are prepared from *plastic* material, partly by hand, partly by special machinery. But even so it is the calendered sheet which has to be used for the purpose. The calenders must therefore be looked upon as the centre of the manufacture and of the machinery, and must accordingly be dealt with fully.

As already stated, the calenders are used to run the sheets of rubber, which are then worked up into the most diverse articles, according to the kind of rubber. In whatever manner the sheets are afterwards to be used, uniform thickness throughout the sheet is the first essential to the achievement of good results. Considerable experience is necessary in order to be able to produce such uniformity in thickness, and there would appear to be very few men who really understand the proper working of the calenders. It most cases it is found that a three-roll calender has only two of its rolls in use while the third is running empty; so in "frictioning" insertions it is no uncommon thing to find only two of the rolls in use. Taken as a class, the calender-hand knows very little, or at any rate insufficient, about the principles which underlie that method of working which involves the use of all the rolls. The winding apparatus, which is a most important feature, is in most cases left unused, or even thrown aside as worthless, because the value attaching to the apparatus is not known, and in most instances the fitter charged with the erection of the machine is not clear himself as to the use of it. In order to be able to understand things more clearly, the reader may first of all be made acquainted with the constructive details of the calenders.

In all calenders, whether with two, three, or four rolls, the following points must be specially observed, if the rolls are to work perfectly, and accuracy in running the sheet of rubber is to be secured: the rolls should be of sufficient strength not to spring, and must in every instance be ground true. It is most convenient to have cast-iron rolls 1250 mm. long and 500 mm. in diameter, which have been ground on a Poole's grinding-machine. Three- and four-roll calenders may be driven by a special motor to ensure a uniform speed to the calenders, and to avoid the irregularities

brought about by driving the mixing rolls from the same main shafting. Fig. 21A shows a modern set of three-roll calenders, electrically driven, and provided with a friction-clutch.

In laying down new plant all the gear-wheels should have double-helical, or at any rate helical teeth, the preference being always given to the former, however, for when they are used the motion of the calender rolls is absolutely uniform, as is most markedly noticeable in calendering very thin sheet. Ordinary

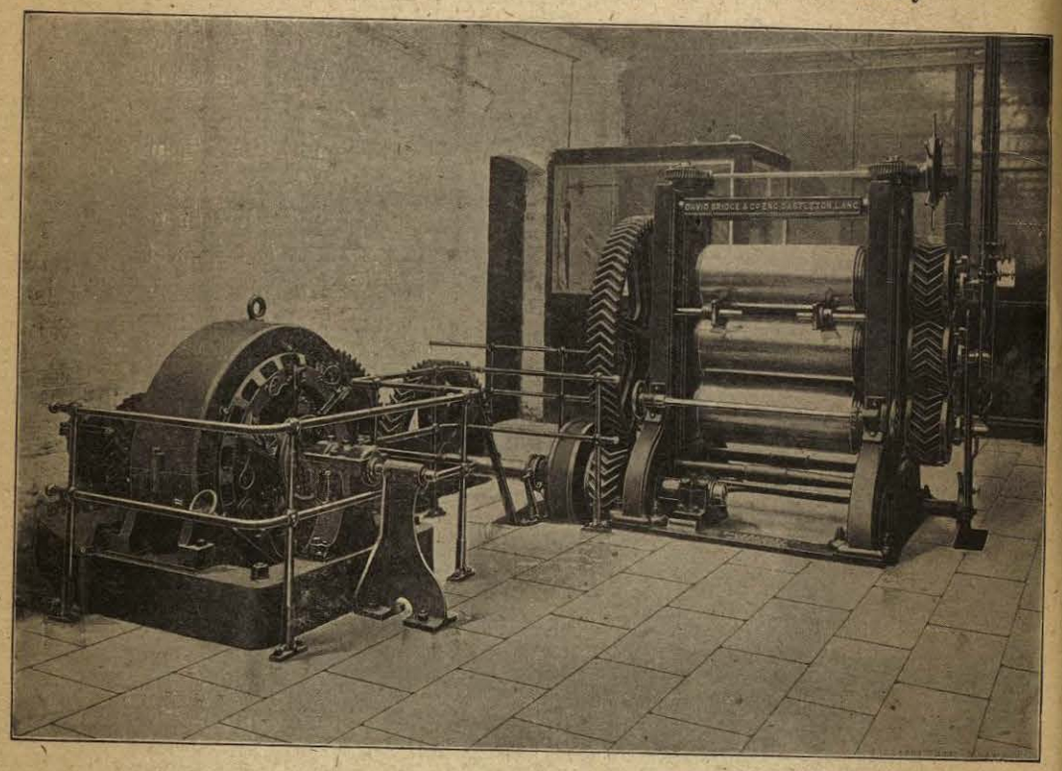

FIG 21A.

teeth always give rise to a certain amount of back-lash, which makes itself evident in the form of striped markings right across the calendered sheet, where the rubber runs thin.

The arrangement for adjusting the top and bottom rolls should be fixed in a convenient position about half-way up the machine, and it should be possible to adjust either top or bottom roll by manipulating a single wheel. The bearings of the middle roll are fixed. The gearing, as also the worm-wheels for the spindles, and the spindles themselves, cannot be chosen large enough to allow of a certain and easy raising and lowering of the rolls. Chain-drive should be altogether avoided, and the vertical shaft with bevel-

wheel gearing should be selected as the best arrangement. The normal speed of the rolls is 4 revs. per minute, but for friction-ing the lower rolls should be geared up so as to work with a

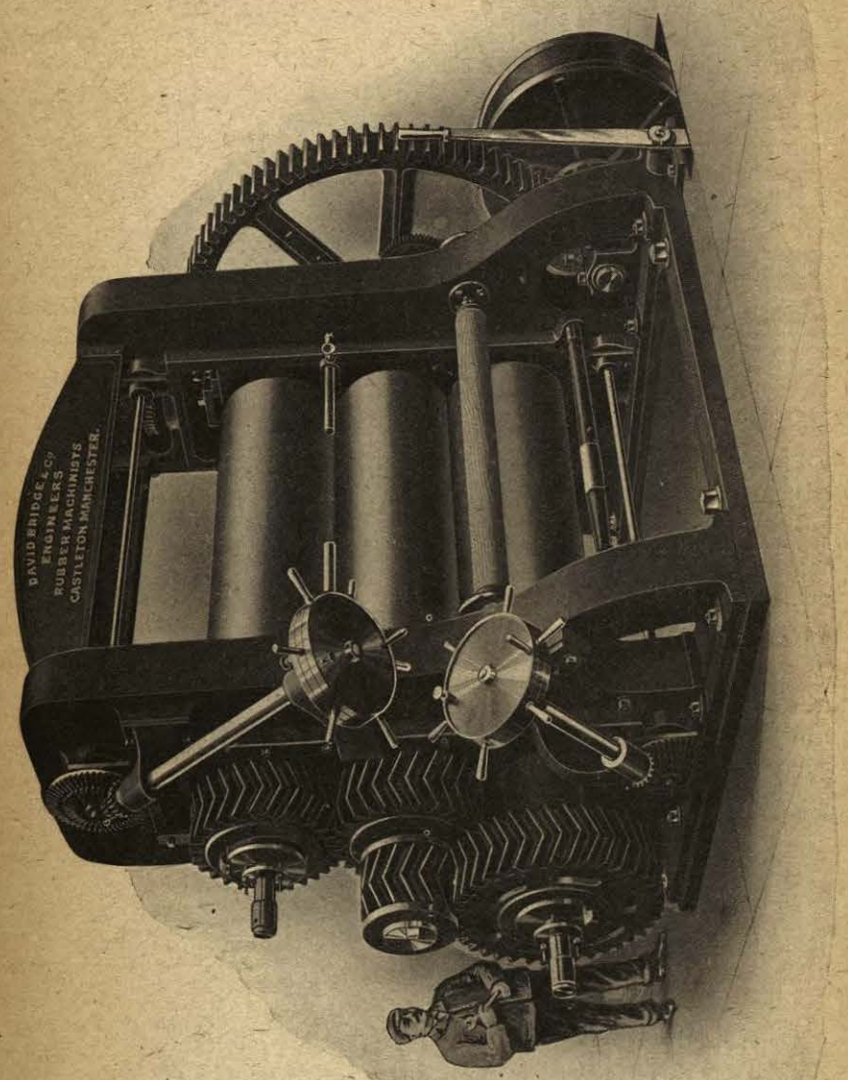

FIG 22.

maximum speed-ratio of 1 : 3. In large factories it is, however, always better to use, for proofing purposes, special calenders constructed for the purpose, as illustrated in fig. 22, and to use the ordinary calenders only for running sheet. It is of fundamental

importance that every set of calenders should be provided with reliable apparatus for heating and cooling the rolls, and that the controlling valves should be placed in a convenient position. Finally, attention must be paid to apparatus for reeling and unreeling, which should always accompany a set of calenders. The method still frequently employed for effecting these two purposes, consisting in the use of a simple wooden roller, on to which the rubber sheet is still more simply wound by several workmen, is quite irrational. On a closer consideration of the process of running a sheet of rubber, it will be found that in the case of the three-roll calenders the upper and middle rolls do the work, and that the distance from the point where the sheet leaves the rolls to the trestle, where it is taken up by the running cloth, is about $1\frac{1}{2}$ to $1\frac{3}{4}$ metres. The faults of such a sheet, and the damage that may be caused to the finished goods by them, are instructive. In particular, the sheet draws up more or less, according to its quality, very considerably and very unevenly; whilst hanging free between the calenders and the winding trestle the sheet gets stretched, and the uneven tension of the winding which follows suffices to produce great variations of thickness in the sheet, quite apart from the creases and folds that are formed. If, however, every workman understood the art of winding calendered sheet on the calenders, and if the apparatus were always in position, these faults would be remedied. Moreover, the use of the apparatus necessitates the attention of only one man in addition to the foreman, whereas in the older method at least two others besides these are necessary to look after the winding, or to hold the cloth and the sheet of rubber apart. The entire arrangement of the apparatus on the calenders is extremely simple, but the bearings must be accurately centred, and the friction-brake must work properly.

On the opposite side from where the rubber is fed in, the unwinding apparatus is fixed to the calender frames, on a level with the axis of the lower roll. The square iron axle, 35 mm. thick, which carries the wooden roller 120 mm. in diameter, rests in two bearings; that on the right-hand side is closed on the upper side by a hinged piece, with a fly-nut, so that it can easily be opened, while that on the left-hand side is a closed bearing in which runs the box which carries the axle. The box is provided with a fixed friction-brake on the other side of the bearing, and by adjusting this the roller is allowed to run free or is kept in check to a greater or less extent. On the other side of the machine—that is to say, on the feeding side, and at the same height as the apparatus

just described—is that for winding up the emergent sheet. One bearing of this can also be opened, whilst the other takes the box with the friction-drive. The roller is best driven from the middle roll by means of toothed-wheel gearing to the friction coupling. If a chain-drive is employed great care should be exercised in getting a chain which is of an even make. Belt driving is quite unsatisfactory, for as the roll of rubber sheet increases in diameter the belt slips, destroying the even tension on the sheet.

When the wooden roller and axle have been put in position in the bearings, the running cloth from the feeding roller is drawn through between the middle and lower calender rolls, stretched tightly over the receiving roller and wound round it a few times. Care must be taken that the cloth lies smoothly on the roller, and rolls up evenly. The calendering of the sheet may now be started.

The mixed rubber is warmed up to a uniform temperature on the warming-up rolls situated close to the calenders; these rolls are quite similar in their construction to mixing rolls, but their use is restricted to warming-up. Care must be taken that the rubber does not become too doughy, and that it is not put into the calenders in large masses, but that strips about 20 mm. ($\frac{3}{4}$ inch) thick and 200 mm. (8 inches) wide, cut from the warming-up rolls, are fed in. In this way one ensures keeping the rubber at a uniform temperature, and the pressure against the bearings of the upper roll remains more constant than if the calenders were fed with large masses of rubber; for while the large mass is still warm, it exerts little upward pressure, but as it cools its pressure increases, causing the roll to lift; on the other hand, as the rubber gets used up the upward pressure again becomes less and the roll drops, the net result being considerable unevenness in the thickness of the rubber sheet. Assuming now that the rolls have been set to the right distance apart, the rubber passes between the upper and middle rolls, round the middle roll, to which it adheres closely until it has gone half-way round, when it is taken up by the running-cloth, which, as has been mentioned, passes between the second and third rolls. Immediately the rubber comes in contact with the cloth the winding apparatus is started: that is to say, the friction rim is drawn into the shell, and the roller begins to turn. The speed of the roller is accurately regulated, so that when the brake is on fairly hard it takes up exactly as much sheet as the calenders pay out. As the diameter of the roll, with its alternate layers of cloth and rubber, increases, the brake is slackened and the friction pulley allowed to slip round, so that the speed of rotation of the

roll decreases as its circumference increases. After a little practice the calender-man can adjust the brake to a nicety, so that the sheet is rolled up without being stretched or creased. In this way the thinnest Para sheet (0·2 mm. thick) can be calendered, and a uniform thickness will be maintained, since the sheets are not stretched, and cannot draw up unevenly. To entirely do away with drawing up, the sheet should be left in the running cloth until it is quite cold, and only then unrolled and made up.

It should be mentioned that the bottom roll should be so adjusted

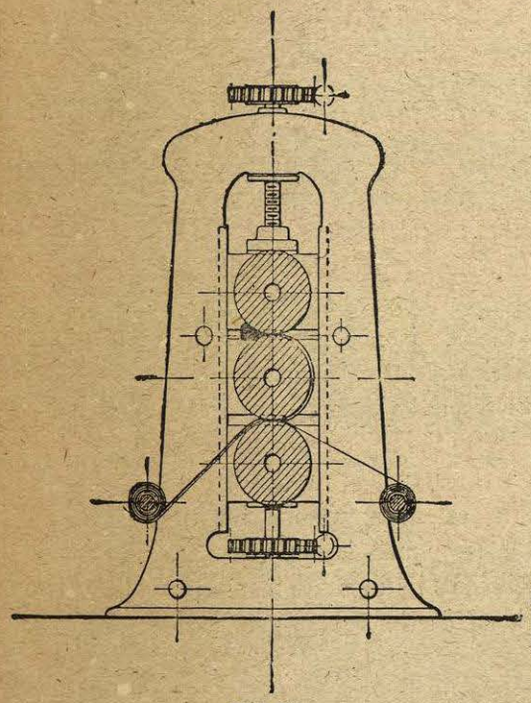

FIG. 23.

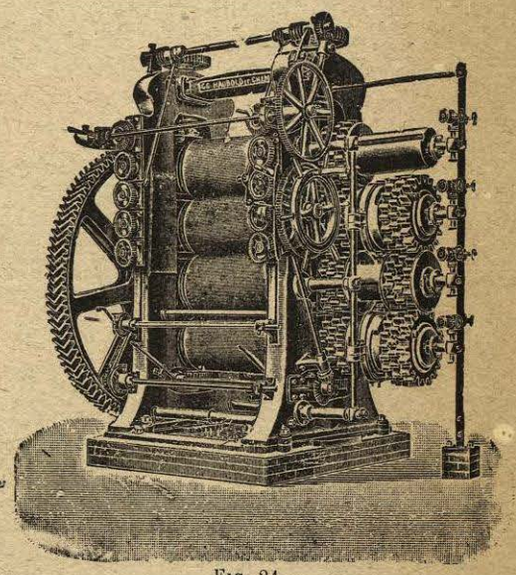

FIG. 24.

as to gently press the rubber against the face of the running cloth. Fig. 23 illustrates the principle of a modern set of three-roll calenders. Such three-roll calenders are chiefly used for running rubber sheet of the better qualities, which must be as free from air-bubbles as possible. But they also come in for doubling the sheets on the calenders, since it is only with great difficulty that, for example, a sheet in a pure rubber quality, $\frac{3}{4}$ mm. thick, can be obtained in long lengths quite free from air-blisters. In that case the calendering takes the following course: in order, for example, to produce a sheet 1 mm. thick, a sheet $\frac{1}{2}$ mm. thick is first run as described, and wound on to the wooden roller. This is then mounted on the axle of the feeding roller (unwinding apparatus),

and the running-cloth, with the sheet of rubber upon it, is passed between the two lower rolls and taken up by the winding-up apparatus; the bottom roll is now closed up towards the second, until the second $\frac{1}{2}$ mm. sheet, now to be run, is pressed tightly on the first, so as not, however, to form blisters or streaks. The whole is then wound up again, as already described, and yields

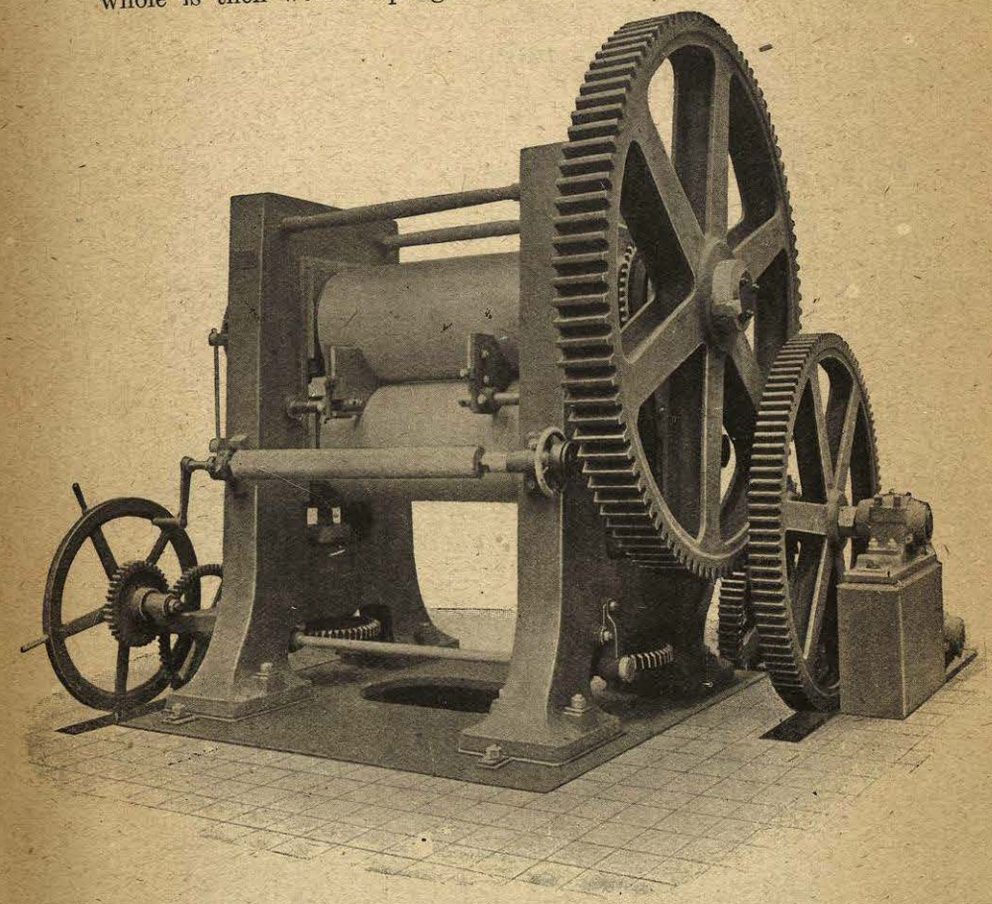

FIG. 25.

a sheet, built up of two layers which cannot be separated from one another again. In this way the various thicknesses of sheet can be built up of different numbers of layers according to the use to which the sheet is to be put. For still thinner sheet, down to 0·15 mm., the four-roll calenders shown in fig. 24 have to be used. The method of using them is similar to that described for the three-roll calenders, only that one actually works with three rolls and uses the fourth to cool the sheet as it is run out.

The two-roll calenders depicted in fig. 25 are chiefly used for

running sheet which is to be cut up for solution, or where uniform thickness is not of importance. If, however, it be required to produce on the two-roll calenders, sheet as even in thickness as possible, for mechanical work, an automatic winding apparatus must be provided, as shown in fig. 22, for the three-roll calenders.

The two-roll calenders (fig. 26) are also often used to run thicker sheet free from blisters, to be used for surgical work, and which must therefore have a smooth surface. The method of doing

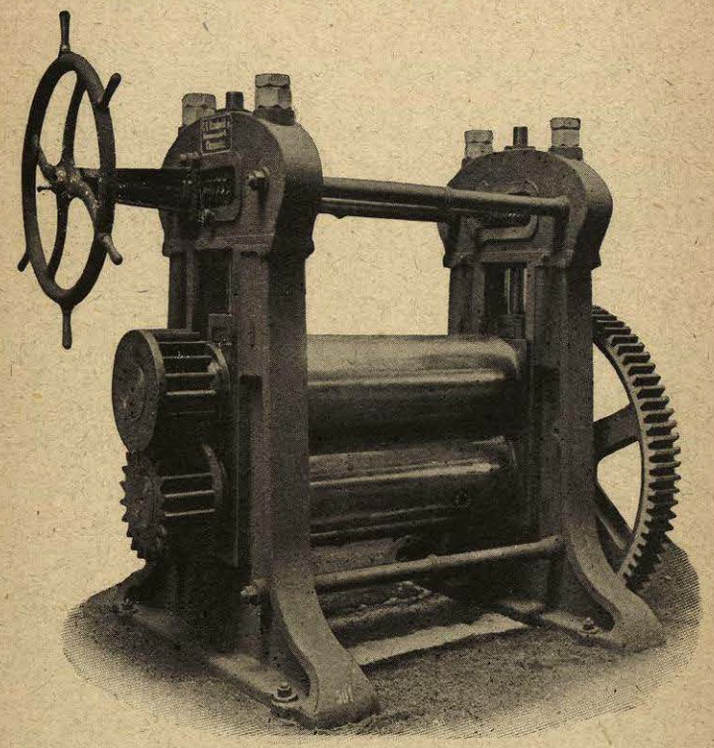

FIG. 26.

this is not to run the sheet out in long lengths, but to allow it to run right round the roll; a sheet equal in length to the circumference of the roll is thus obtained, that is, about 120 cm. long. It is advisable to rub a little vaseline over the roll round which the sheet runs; this helps to give the rubber a smoother surface and allows the air which collects between the rubber and the roll to get away at the sides.

It is also necessary to have a second set of two-roll calenders, of similar construction to that shown in figs. 27 and 27A. This set is chiefly used for running sheet, for ebonite manufacture and also for moulded goods, which is required in thicknesses of from 3 to

10 mm., and which must be doubled absolutely free from air-bubbles. These calenders are used in particular in the manufacture

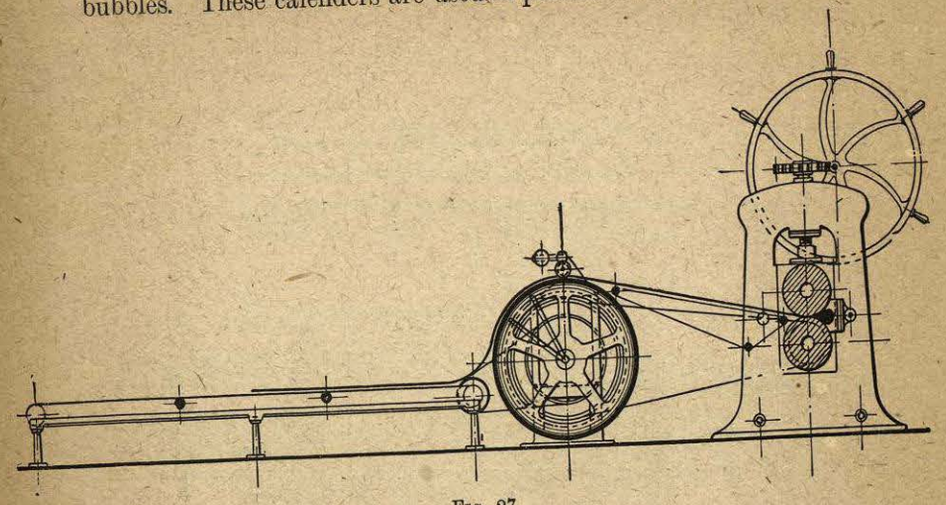

FIG. 27.

of accumulator cases. The separate lengths are only 4½ metres long, but this is quite enough for the purpose. As indicated in the illustration, the machine consists of a two-roll calender with a

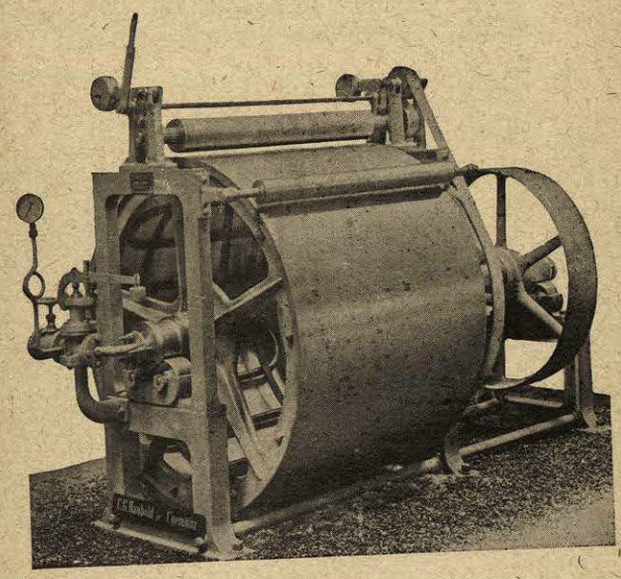

FIG. 27A.

doubler in front of it. The calender rolls are 450 mm. in diameter and 1200 mm. long. The doubling drum is 1300 mm. in diameter, and the conveying-cloth 5 metres long. The pressure-roll is rubber-covered, and its distance above the drum can be adjusted by means

of movable bearings. Pressure is applied by means of weighted levers. The drum is driven from the calenders, and the travelling table derives its motive power from the same source. The rubber mixing, which is run out between the rolls into the form of sheet, passes over the cloth conveyor on to the drum, round which it is wound until the correct thickness is reached, when it is cut off and passed on to the table, by which it is carried away.

It may be mentioned that the rubber sheets can be cut into

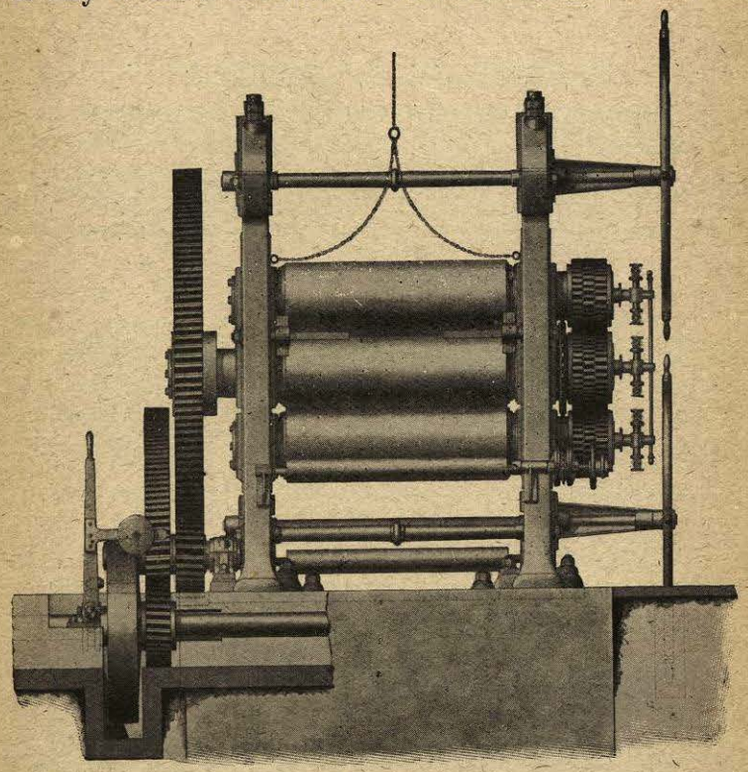

Fig. 28.

strips on the calenders themselves, before being rolled up in the running-cloth. To effect this a cutting apparatus is fixed between the two vertical frames of the machine, about 18 cm. below the level of the middle of the second roll. The knives, fitted in boxes provided with grooves, are fixed upon the spindle between the wheels, can be set to any desired width of strip, are kept in position by means of set-screws and are pressed against the sheet by means of a spring, the strength of which can be regulated; this arrangement results in the sheet being cut through clean.

The spreading calenders shown in figs. 28 and 29 are now generally used for impregnating insertions and fabrics with rubber,

since by the use of these a considerable saving of benzine as well as of time is effected as compared with the spreading machine. As already mentioned, where the plant is a large one it is better to use a machine exclusively for "frictioning." The use of three rolls is nowadays substituted for the American method, in which two rolls only were employed, and which may easily lead to the cloth getting torn. The uppermost and lowest rolls are driven slowly at equal speeds, while the middle roll makes the ordinary four revolu-

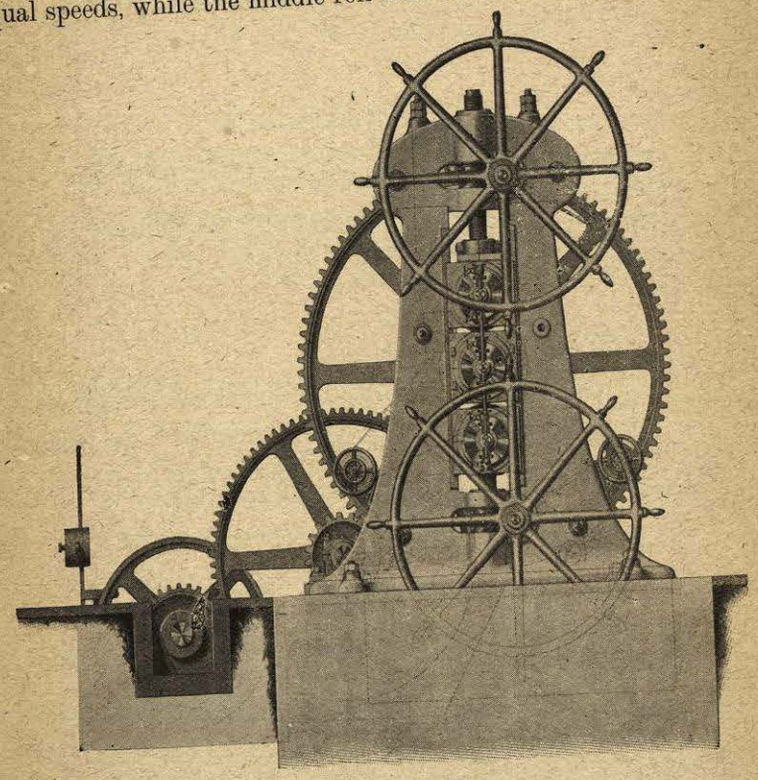

Fig. 29.

tions per minute. The material on which the rubber is to be spread passes, like the running-cloth mentioned above, between the second and third rolls, when it is wound up. The process consists essentially in feeding the rubber into the calenders between the top and second rolls, allowing it to run round the much hotter middle roll in a very thin sheet, the thickness of which is determined by the substance of the cloth to be coated, and by means of this pressing it into the cloth. The third roll, revolving slowly, rubs the thin sheet of rubber deep into the meshes of the fabric, and completely covers it over, filling up and penetrating all the interstices with an even mass of rubber. In carrying out this process,

care must be taken to have the rubber mixing worked up and warmed uniformly, so that it may lie evenly round the roll, and not in too soft or sticky a condition, so that the friction roll can remove it without difficulty. Sticking to the middle roll must in all cases be avoided; it indicates that the particular mixing is not suitable for calendering. With few exceptions the fault lies in having the middle roll too hot. One of the chief aims should always be to keep feeding in fresh quantities of rubber regularly, and not too much should be fed in at a time. It is also essential to success to have the cloth rolled up evenly and tightly on the wooden roller before passing it through the calenders, so that no creases are formed as the cloth is unrolled, and to see that the fabric does not run crooked, which would lead to its getting torn. In rolling up the cloth, as also in dealing with the ordinary running-cloths, it is best to make use of a machine which should always be provided with a calendering plant. This machine has a large heating drum over which the cloth or fabric is carried in order to dry it thoroughly, moisture being capable of great mischief under these circumstances. Behind the drum is a mechanical brush enclosed in a box, by means of which the fabric is freed from loose fibres and dust. Into this the fabric passes as it comes from the heating drum, emerging on the other side, and after passing over the stretcher is tightly wound on the interchangeable rollers. In this way one is always sure of getting clean, dry fabrics.

Having now shown how the mixed rubber is worked up into the form of sheet, we propose to deal in the two following chapters with the important subjects of Vulcanisation and Mixings, and shall then proceed to consider in detail the various stages in the manufacture of a number of different articles.

CHAPTER II.

THE VULCANISATION OF RUBBER.

THE discovery of the process of vulcanisation by Charles Goodyear, an American, in 1839, was not, as one often reads, an accidental occurrence, but came about as the result of investigations which had been carried on by him for years. Goodyear, like many other men of an inventive turn of mind, kept on dabbling with rubber in spite of his numerous failures, and studied the effect of mixing all sorts of substances with it. Through this he was, undoubtedly of set purpose, led to his discovery, and as a result of the experience he had gained in the course of his investigations he recognised, on observing the effect of heat upon a mixture of rubber and sulphur, that the heating was essential to the process. It is a remarkable thing how this hard-pressed man, overwhelmed with debts, succeeded in working out his invention. That he did work it out is clearly demonstrated by the fact that in the description first published by him of his method for the "metallisation" of rubber he gave sufficient instructions for the technical preparation of perfect rubber goods, and that these instructions have even up to the present time lost no essential part of their technical importance; in every instance they are still in the main far superior to any of the processes devised by Goodyear's imitators. Thomas Hancock can only be regarded, in relation to the vulcanisation of soft rubber, as having confirmed Goodyear's results, though Hancock was actually ahead of Goodyear in his application for a patent for his alternative method. Without doubt he must be looked upon merely as the inventor of another way of carrying out Goodyear's invention (in a strictly chemical sense), but, on the other hand, he has undoubted rights to priority in the discovery of ebonite.

The discovery made by Alexander Parkes of Birmingham, in 1846, that soft rubber could be vulcanised by means of a solution of chloride of sulphur in carbon bisulphide, is also, from the chemical