March 19, 1940. D. J. CROWLEY 2,193,861

METHOD OF AND APPARATUS FOR IMPREGNATING FIBROUS MATERIALS

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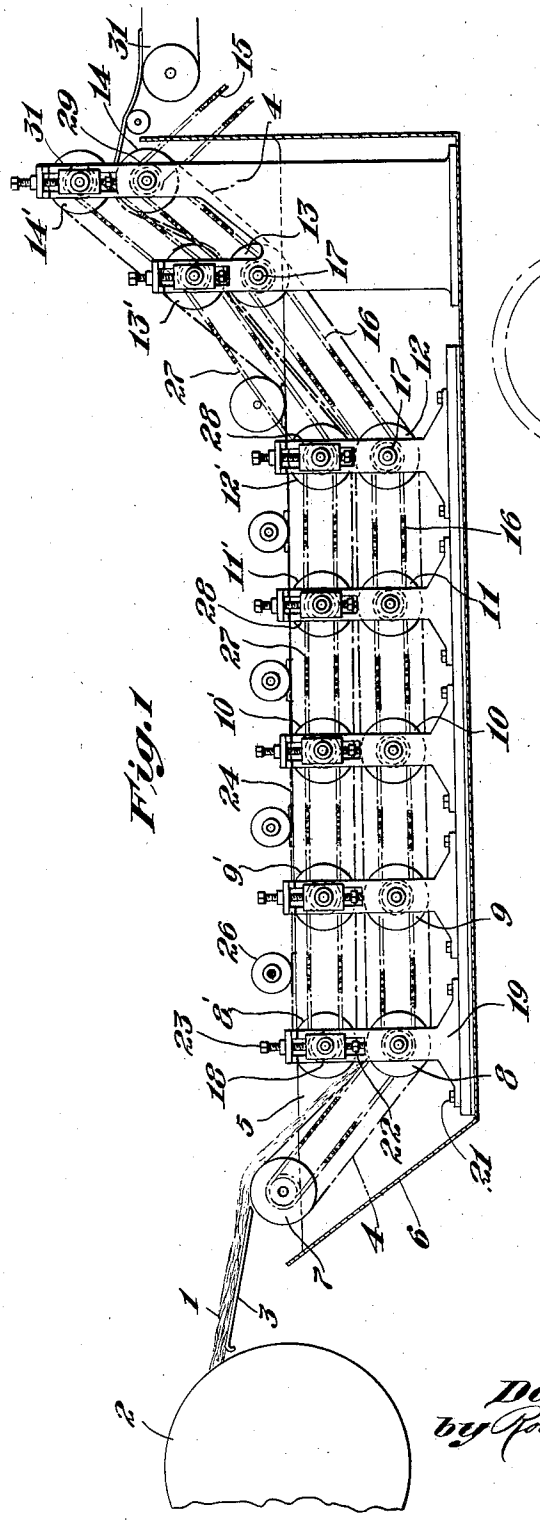

Fig. 1

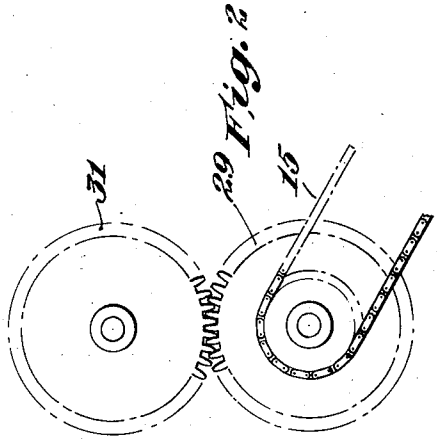

Fig. 2

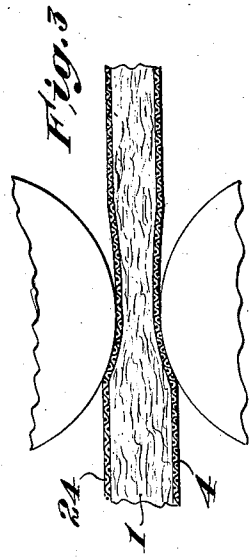

Fig. 3

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METHOD OF AND APPARATUS FOR IMPREGNATING FIBROUS MATERIALS

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7 Claims. (Cl. 91—46)

This invention relates to a method and apparatus for impregnating fibrous materials, such as wood pulp fibers or cotton fibers, with viscous liquids, such as rubber latex and to the resulting product thus obtained.

It is an inherent problem, in the treatment of finely divided materials, and especially fibrous materials, with impregnating liquids, that the liquid which wets the exterior surface of the fibrous mass under treatment constitutes a barrier to the further progress of that liquid into the mass and hence retards and soon completely prevents the penetration of further liquid. The result is that the interior of the mass does not receive the liquid which is intended.

A further impediment to the penetration of liquids into fibrous materials is the occluded air already contained in such masses. When the outer surface or surfaces of the mass are covered with the impregnant liquid, this occluded air is confined and offers appreciable resistance to any further penetration. It also makes such penetration as is effected irregular.

Another tendency, in such operations, is for the wetted surface fibers to draw together, under the forces of surface tension of the liquid, and thus to make the wetted surface or surfaces more dense in respect of their fiber structure.

It has been proposed to pass such materials between pressure rolls to effect the double purpose of squeezing the liquid impregnant into the fibrous mass and to expel the occluded air out of the mass. It has also been proposed to compress the fibrous mass to expel the air and then to permit the mass to expand and draw the fluid into the interfibrous void spaces and then to compress the mass again and force the outer layers of wetted fibers more closely together to effect the further penetration of the fluid and improved adherence between the external, fluid saturated layers of fibers. But these procedures do not provide for nor permit the complete expulsion of air from the inner portion of the mass, unless the mass is reduced to a thickness of only a few fibers—and such thin sheets, although completely impregnated, are not practically useful.

Accordingly, it is an object of this invention to provide a method and apparatus for treating substantial or even thick masses or sheets of fibrous materials, whereby the liquid impregnant may penetrate uniformly through the sheet, displace occluded air therein, and form a continuous impregnating matrix throughout the fibrous mass. It is a further object to provide for the handling of very open, fibrous sheets or webs which, while the substantial thickness may not be possessed of appreciable mechanical strength, especially when wet. It is also an object to effect the positive control of the ultimate thickness of the impregnated sheet and to provide a smooth finished surface thereon. Other objects will appear from the following disclosure.

In the present invention the material to be impregnated may be composed of wood pulp fibers or cotton fibers, or both, and is preferably assembled in the shape of sheets. The wood pulp fibers may be in the form of laps but are in any event preferably dry. They may also be advantageously (though not necessarily) dispersed in the form of light fluffy, widely separated fibers, laid down in the form of more or less uniform sheets of fibers, of open formation. The fibers are preferably free from fillers and other materials, including water. Cotton fibers, or mixtures of cotton and wood fibers or various other vegetable fibers may be used, after similar preparation and purification and finally drying in the form of a sheet of the desired thickness and openness.

The sheet, as thus prepared, which may be effected by various processes and machines known to the arts of paper and cotton fabrication, is conducted or laid between a pair of metallic screens, preferably characterized by being made of fine wire and also of relatively small mesh. The screens are commensurate with or overlap the margins of the sheet. As the sheet is introduced between the screens, or shortly thereafter, as the case may be, it is immersed on one or both sides or completely in the impregnating bath of liquid with which it is to be saturated. The sheet and screens, as thus assembled, are then passed between directly opposed pressure rolls which exert a light pressure thereon. Thereafter it is released and then passed between succeeding pairs of similar opposed pressure rolls, preferably while keeping the sheet and screen continuously submerged in the impregnating bath. The succeeding compression rolls are set at progressively closer spacing adjustments, thereby gradually to reduce the thickness of the sheet by each pair of rolls, while permitting the sheet and screens to expand slightly in their span between the rolls.

The initial penetration of the liquid into the sheet will uniformly wet the surface layer of fibers, especially if the sheet is subject to the impregnating liquid before passing between the screens. But if it is first placed between the

screens and then wetted with the impregnating liquid, the latter will pass through the meshes of the screen and into the sheet in such areas while the portions of the surface contacting with the wires will not be wetted thereby. Each of these modes of procedure has certain advantages as will appear hereinafter.

As the sheet and screens pass between the first pair of compression rolls, the thickness of the sheet (because the screen is substantially incompressible) is thereby slightly reduced. In such reduction a corresponding amount of air in the sheet is expelled, passing outwardly through the screen or possibly rearwardly through the oncoming porous sheet. In the nip of the compression rolls, the sheet will of course reach its minimum thickness in that pass and at this stage the portion of the sheet underlying the wires of the screen will be compressed more than the portions lying within the mesh areas of the screen which will be permitted, relatively, to expand to the extent of the thickness of the screen. Such areas will also successively present exit areas for the escape of the occluded air from the compressed sheet immediately ahead of them, the sheet being compressed beneath the wires, until such areas themselves pass into the nip of the rolls and are finally closed and compressed by the next succeeding wire of the screen entering the nip of the rolls.

As the sheet progressively passes through the nip of the rolls, the wire covered portions of the sheet emerge from the nip of the rolls, the uncovered portions lying in the mesh portions of the screen between the wires are next uncovered and, being submerged in the impregnating liquid bath, they draw in the liquid upon such exposure under the separating action which is then taking place between the compression rolls and between the screens, and also under the expanding force of the compressed sheet which will tend to expand as a whole. This expansion tends to force the screens further apart and at the same time to draw the liquid into the interfibrous spaces.

As the screens thus open up under the expanding force of the resilient fibers, the fibrous sheet and screen move slightly, relatively to one another. This serves an important purpose of exposing the wire covered portions of the surface of the sheet from which liquid may have been excluded (when the sheet and screens are contacted before immersion) or from which the liquid has been driven into the interior portions of the sheet, due to the greater compression in such area in passing between the pressure rolls. Accordingly, such exposed areas of the sheet, coming from beneath the wires of the screen present fresh fibrous areas, relatively depleted in liquid, and under greater compressive stress. They, therefore, tend to expand more than the free areas and are ready to receive and draw in the impregnating liquid more actively than the less compressed areas lying between the wires, in the mesh spaces.

The screens and intervening fibrous sheet then pass through the liquid, giving an interval of time for such penetration and impregnation of liquid to take place. As they approach the next pair of compression rolls, the screens are gradually drawn together and the wires come to bear upon a different portion of the sheet. As they come to the nip of the rolls such wire covered portions of the sheet are subjected to greater pressure than the uncovered portions lying in the meshes of the screen. This pair of rolls is set more closely together than the first rolls so that the entire sheet is compressed to a lesser thickness than before. The liquid already in the sheet is therefore forced inwardly of the sheet and residual air left in the sheet is forced outwardly through the less dense and/or less compacted areas, which are the areas lying within the mesh spaces of the screen. In other words, each wire of the screen compresses the sheet lying beneath it, forcing liquid into the inner and adjacent parts of the sheet where the pressure is less and driving residual occlusions of air into and through the areas in the meshes of the screen, to escape therethrough and from the sheet.

Upon passing through the nip of the rolls such compression reaches a maximum and upon leaving the rolls the sheet again expands as above described and again draws in more liquid from the bath.

As the sheet passes between successive sets of compression rolls and the thickness of the sheet is reduced, the relative degree of compression of the sheet under the wires of the screen and the compression of the sheet in the mesh portions of the screen becomes greater and greater and the consequent expulsion of air and imbibition of impregnating fluid effects a pumping action resulting in a final and substantially complete removal of air and continuous saturation of the sheet throughout its length, breadth and thickness with the impregnating liquid.

As the sheet emerges from the bath—especially with viscous or coagulable impregnating liquids—the liquid flows off from the exposed surfaces of the screen, and when the sheet comes out from between the screens the fluid in the impregnated sheet, being continuous with any residual liquid contained in the meshes of the screen, sucks the latter from the screen and merges therewith to leave a smooth, continuous surface on the sheet. This leaves the screen substantially clean and the meshes freed from the impregnating liquid.

Before (or after) separating the wire from the sheet, the sheet may be subjected to a passage between a pair of fixed compression rolls, set to a spacing corresponding to the thickness of the ultimate sheet desired. This amounts to a squeeze roll, adapted to squeeze out and rearwardly of the sheet, a sufficient amount of the excess impregnant liquid which the sheet contains, to permit the fibrous structure of the sheet to become correspondingly more compact.

The sheet is then dried, as by passing over banks of steam coils but preferably slowly so as to permit evacuation and evaporation of the volatile component (if any) of the impregnating liquid and to avoid skin effects which may be produced by rapid surface drying. If the impregnating liquid does not contain a volatile solvent or vehicle, it may be considered as the finished product at this stage, or may be given appropriate treatment to set the impregnant liquid to fix it in place against subsequent flow or abstraction from the sheet.

A typical example of apparatus for practicing the invention and of the procedure performed therein will be described with reference to loose cotton as the fibrous sheet material and an aqueous emulsion of rubber latex as the impregnating liquid, reference being made to the drawing in which:

Fig. 1 is a side elevation of the impregnating portion of the machine;

Fig. 2 is an enlarged detail of the driving mechanism and one of the compression rolls; and

Fig. 3 is an exaggerated side view of the sheet, adjacent screens, shown as they pass through the nip of the rolls.

Referring to the drawing, the sheet of light, fibrous cotton material 1, is led from the roll 2 over a support 3 and fed onto the endless foraminous belt or screen 4 which carries it through the impregnating bath 5 contained in the tank 6.

In the instant case the impregnating liquid may consist of an aqueous emulsion of rubber latex, prepared, for example, as follows:

First, mix a 35% emulsion of rubber latex with a small amount of a vulcanizing agent and accelerator (e. g. piperidine) zinc oxide and other finely divided materials, as fillers, in such amount as desired, while preserving a suitable fluid consistency, an antioxidant and a small proportion of a water soluble soap.

A second mixture is made of 10% flour suspended and uniformly dispersed in 90% of water.

Three gallons of the first and one gallon of the second may now be mixed together, to provide a suitable vulcanizable impregnating fluid of vulcanizable rubber latex. This mixture may constitute the impregnating bath 5. But it will be understood that other suitably fluid or even relatively viscous impregnating baths, of various compositions, may also be prepared and used.

The conveying belt or screen 4 is preferably continuous and may be made by weaving the same from wire, without a seam, or by joining two ends of a long strip of screening together. It may also be made from sheet metal which has been suitably perforated with openings or "mesh spaces" which are preferably somewhat larger than the intervening metal partitions or wires. The screen may be made of other materials but is preferably strong, resistant to compression, repellent to the impregnating liquid and, in short dimensions, relatively stiff and form retaining against distortion.

In any event, the lower screen is laid over the roll 7 and thence over compression rolls 8, 9, 10, 11, 12 which are submerged in the impregnating bath and thence over rolls 13 and 14 which stand above the bath at the exit end of the tank. As illustrated, the lower series of rollers, as thus defined, are driven from any suitable source of power, such as a motor or drive shaft (not shown) by means of chain 15, and each roll by the next one to it and in synchronism therewith by means of chain and gear drives 16, 17 throughout the lower series of rolls.

An upper series of corresponding rolls 8', 9', 10', 11', 12', 13', and 14' are mounted above the lower set of rolls, respectively, and are directly opposed thereto. The axes of the rolls pass through the tank walls and are severally mounted in journals 18 carried in standards 19 which are adjustably fastened to the floor (alongside the tank 6) by bolts 21 (passing through slots not shown) and which also serve to carry fixed or adjustable bearings for the axes of the corresponding lower compression roll which likewise extend through the walls of tank 6. The journals of each of the upper rolls 8', etc., are positively adjustable up and down by means of the double screw-thread 22 in the standard and retained against riding up by means of a set screw 23. In this way the space between the rolls (of each pair of opposed compression rolls) is positively adjusted and determined to correspond to the sheet material under treatment.

The upper rolls 8', etc., also carry endless belt 24, similar to the lower belt or screen 4, although the mesh sizes and character of the screen may vary somewhat if desired. It may, for example, be helpful at times to have the upper screen somewhat more porous or of a larger mesh size to permit or induce the more ready escape of air from the upper surface of the sheet than from the lower. The return pass of the upper belt or screen may be steadied by a series of idler rolls 26 which either rest upon the spans of screen between the rolls or are permanently fixed to bear lightly upon the screen.

In case of stretching of the screens (which is of course preferably to be avoided) the standards for the end rolls 7 or 8 and 8' or 13, 13', 14, 14' may be adjusted slightly to take up the slack. But such adjustment is seldom necessary.

The rolls carrying the upper belt or screen may be driven by interconnecting chain and gear drives 27, 28, as in the lower screen, the end roll being directly geared (by deep toothed gearing 29, 31, Fig. 2) with the corresponding gear on the lower drive roll so that both screens are positively driven at the same speed and uniformly throughout their respective paths of travel.

In operation, therefore, the sheet 1 is first delivered upon the top of the lower belt or screen 4 which, as shown, carries the sheet downwardly and into the impregnating bath 5. The screen 4 then carries the sheet into contact with the under surface of the upper screen 24. As the sheet proceeds the opposed screens carry it between them into the nip of the first pair of opposed compression rolls 8, 8'. These rolls are set at a spaced relationship such that the sheet will be compressed somewhat to pass between them. The amount of compression may vary. It may be slight at first and progressively increase, either by an absolute amount (dimension or pressure) from roll to roll or by a proportional amount. As above indicated, the first compression may be effected upon the sheet before it is immersed in the impregnating bath (e. g., by slightly raising both rolls 8, 8' and lowering the level of the bath) so that as it passes between the first compression rolls the occluded air is expelled (and by a high degree of compression a corresponding amount of consolidation and expulsion may be effected) and upon leaving such compression rolls the sheet is allowed to expand beneath the surface of the liquid and thus draw in the liquid, immediately and to a large extent to fill the voids. Such procedure is not always desirable however, for the high compression may destroy the resiliency of the fibers so that there is little or no tendency for the sheet to expand. If the sheet is highly porous, however, the sheet may nevertheless, under such circumstances, while in compacted condition, receive a large amount of fluid, the residual air being expelled subsequently.

As the sheet, carried between the screens 4, 24, leaves the compression rolls 8, 8' it tends to expand forcing the screens apart somewhat (or, vice versa, is drawn apart by the screens), as shown in Fig. 3, but not to the original thickness. In such expansion the impregnating liquid passes through the screens and into the sheet accordingly. It is also distributed laterally between the fibers as the latter tend to rearrange themselves under the pressure changes. The surfaces of the sheet also tend to shift slightly during

such expansion relative to the adjacent screens and also as it is subjected to further compression upon passing between and through the nip of the next pair of compression rolls. This still further promotes penetration and distribution of liquid into and through the sheet and, as the pressure is again applied to the sheet, with the wires contacting with slightly different areas of the surface of the sheet, pressure is applied slightly differently, the local concentrations and pressures of the impregnating liquor are changed, permitting residual entrained air to escape through the localized less dense portions of the sheet and through the meshes of the screen and the liquid to be forced further into such places to replace the displaced air. In this way, minutely subdivided areas of differential pressure are set up and repeated upon both sides and progressively throughout the sheet which function to pump out air and to suck in the impregnating liquid from the impregnating bath in which the sheet is submerged.

Similar action is effected as the sheet is carried between the screens through the nip of compression rolls 10, 10', 11, 11', 12, 12'.

Upon leaving the compression rolls 12, 12' (though a larger or smaller number of compression rolls may be used if desired), the sheet f (still between the screens 4, 24) leaves the impregnating bath and is carried between compression rolls 13, 13' which removes excess fluid, returning the latter to the tank 6. By slight angular twisting as the sheet passes between these rolls and rolls 14, 14', the fibers and impregnating fluid matrix are given opportunity to equalize strains and disposition of one with respect to the other. Rolls 14, 14' still further serve to expel excess liquid, compact the sheet, and to reduce the sheet to an uniform, substantially finished sheet, albeit still moist, of constant thickness and uniform surface properties.

As the sheet leaves the rolls 14, 14' it also emerges from between the screens 4, 24, and the surfaces being substantially free from appreciable excess of the impregnating liquid, they attract and adhere to such fluid as may be contained in the mesh spaces or perforations of the screen and successively suck them out and hold them on the sheet, so that both upper and lower returning screens are substantially free and clean. This may be promoted by providing openings in the rolls 14, 14' whereby suction between the screen and roll may be broken.

The impregnated sheet is relatively strong and may be led directly to a conveyor belt 31, which in the case of latex impregnated sheets, may carry the sheet over (and under) long batteries of steam pipes and thence in festoons through a suitable drier, in which it loses water and may be given supplementary treatments of various kinds to give it the desired characteristics and properties accordingly. Such drying equipment, being of the usual type common in the arts, is not shown.

The resulting impregnated fibrous cotton sheet is characterized by having the impregnating liquid uniformly permeative throughout the sheet, which is correspondingly free from entrained pockets or laminae of air, or layers of different density or strength. It therefore very much resembles leather. If the impregnating fluid contains a volatile liquid vehicle or solvent, such as the water in rubber latex, this will of course be evaporated, after the impregnation step and leave minute voids or capillary pores corresponding to the spaces occupied by the volatile liquid. These voids, however, are very small, uniformly distributed throughout the sheet, and lead to the surfaces of the sheet, thus resembling very much the pore structure and arrangement of leather which permits "breathing," a highly desirable factor in the manufacture of artificial sheet material to be used for leather. Fibrous sheet materials which are penetrated only part way through from the outside surfaces may be prevented from acquiring such structure owing to the formation of a continuous "skin effect" on the inner portions of such penetrated areas, from which the pores extend outwardly but do not pass through the internal solidified "skin" to permit pore formation through the sheet. When uniform impregnation is effected, as by this process, the subsequent vaporization of a volatile constituent of the impregnant is free to escape in both directions and to either or both surfaces of the impregnated sheet, leaving pore spaces which pass completely through the sheet.

Of course, by using an impregnating liquid which is non-volatile a substantially impermeable sheet is produced having a continuous matrix of the impregnating liquid, surrounding and embedding the fibers and forming a continuous impenetrable surface. Such a sheet may retain the impregnating fluid in inherently fluid condition or the liquid may be congealed or solidified as by cooling or by effecting a spontaneous or subsequent setting reaction in the impregnated sheet.

It is especially characterized by freedom from tendency to lamination, in respect of the strength or fibrous structure of the impregnated sheet; also by its freedom from occluded air which, when present, is indicated by unimpregnated portions in the interior of the sheet.

I claim:

1. Method of impregnating thick sheets of loose fibers, comprising the steps of passing the same between a pair of screens and subjecting the screens and intervening sheet to a succession of progressive compressions, while immersed in an impregnating liquid said compressions being of increasing degree.

2. Apparatus for impregnating a sheet of loose fibrous material, comprising a bath of liquid impregnant, a pair of screens adapted to receive the sheet material therebetween, and means for subjecting the screens and intervening sheet material to progressive compression throughout the area of the sheet while in the liquid impregnant.

3. Apparatus for impregnating a sheet of loose fibrous material, comprising a bath of liquid impregnant, a pair of screens adapted to receive the sheet material therebetween, and means for subjecting the screens and intervening sheet material to a succession of progressive compressions throughout the area of the sheet while immersed in the liquid impregnant.

4. Apparatus for impregnating a sheet of loose fibrous material, comprising a bath of liquid impregnant, a pair of screens adapted to receive the sheet material therebetween, and means for subjecting the screens and intervening sheet material to progressive compressions of increasing degree of pressure, throughout the area of the sheet while immersed in the liquid impregnant.

5. Apparatus for impregnating sheets of loose fibrous material, comprising a bath of liquid impregnant, a pair of screens adapted to receive the sheet material therebetween, and means for subjecting the screens and intervening sheet material to progressive compressions successively to

reduce the thickness of the sheet throughout the area of the sheet while immersed in the liquid impregnant.

6. Apparatus for impregnating sheets of loose fibrous material, comprising a bath of liquid impregnant, a pair of screens adapted to receive the sheet material therebetween, and means for subjecting the screens and intervening sheet material to progressive compressions and expansions of the sheet throughout the area of the sheet while immersed in the liquid impregnant.

7. Apparatus for impregnating with aqueous saturants cellulosic web material incapable of supporting its own weight when wetted with an aqueous liquid to produce unwrinkled, unbroken-formation impregnated cellulosic web material comprising lower and upper continuous porous aprons, said lower apron being suspended over leading and following rolls and said upper apron being suspended under leading and following rolls, the suspended portions of said aprons being disposed face to face, the leading roll of the lower apron being located in advance of the leading roll of the upper apron, a feeding device for an impregnating solution being located in following relation to the leading roll of the lower apron, the centers of two following rolls being in a plane perpendicular to the plane of the aprons therebetween, the said leading and following rolls being arranged to support and confine the cellulosic web material between the said upper and lower aprons with a pressure insufficient to force the impregnating solution away from the said cellulosic web material during impregnation and the following rolls being arranged to apply pressure to the impregnated cellulosic web material between the aprons sufficient to force the excess of the impregnating composition away from the same.

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