Jan. 6, 1953 S. L. CLUETT 2,624,245

MODIFIED PAPER AND METHOD FOR ITS MANUFACTURE

Filed Dec. 16, 1947 3 Sheets-Sheet 1

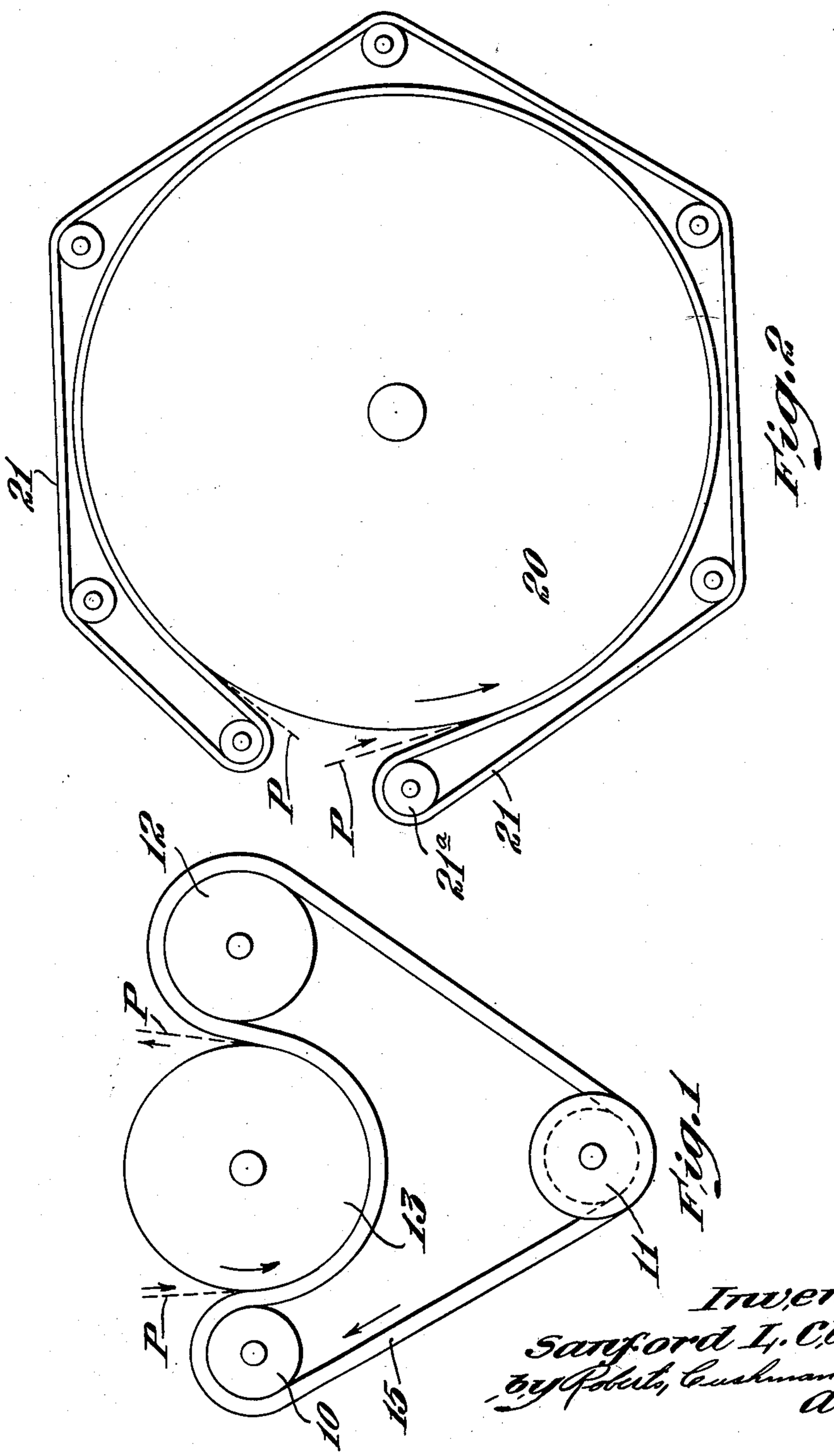

Fig. 2

Fig. 1

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Filed Dec. 16, 1947 3 Sheets-Sheet 2

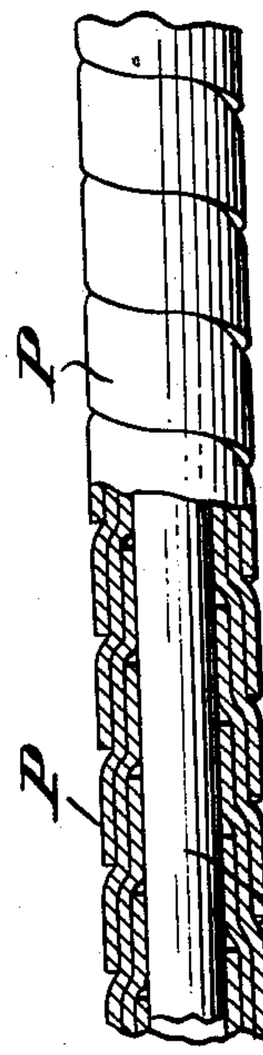

Fig. 6

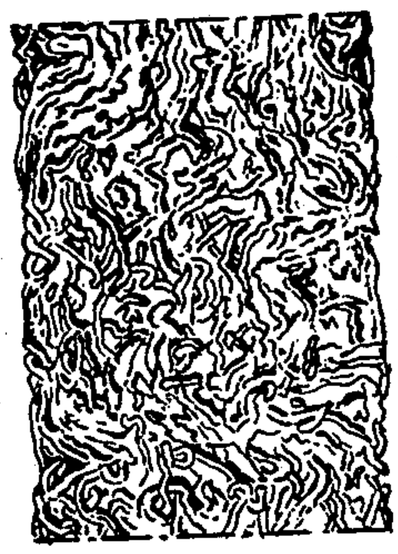

Fig. 5

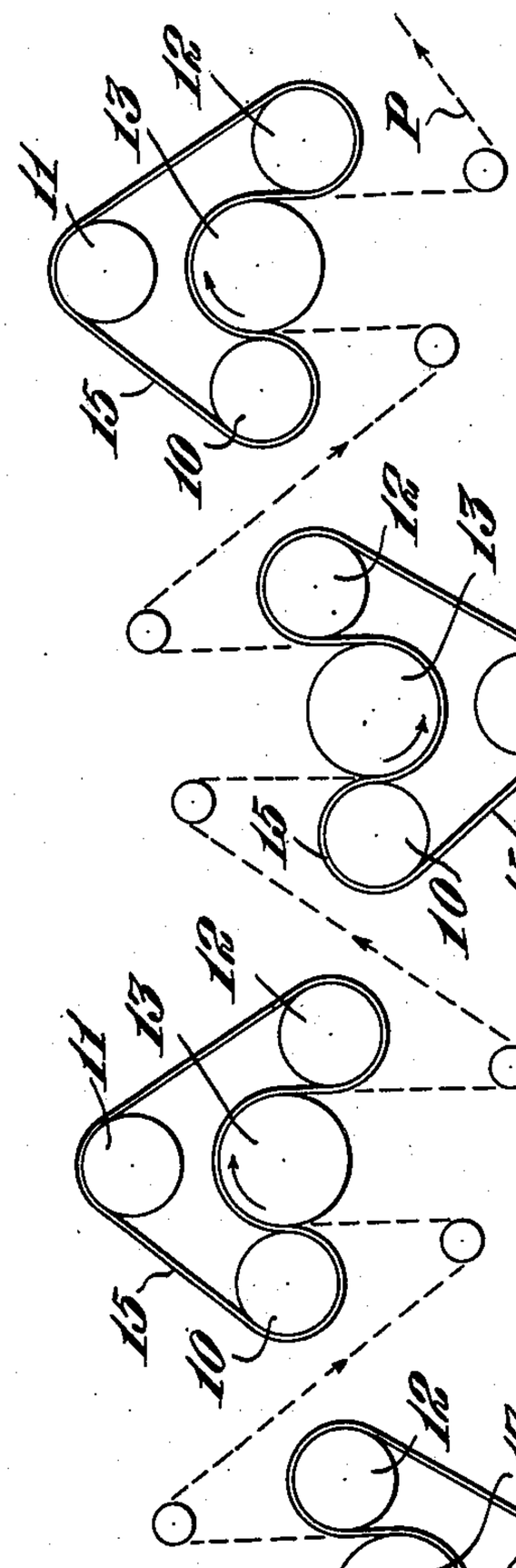

Fig. 3

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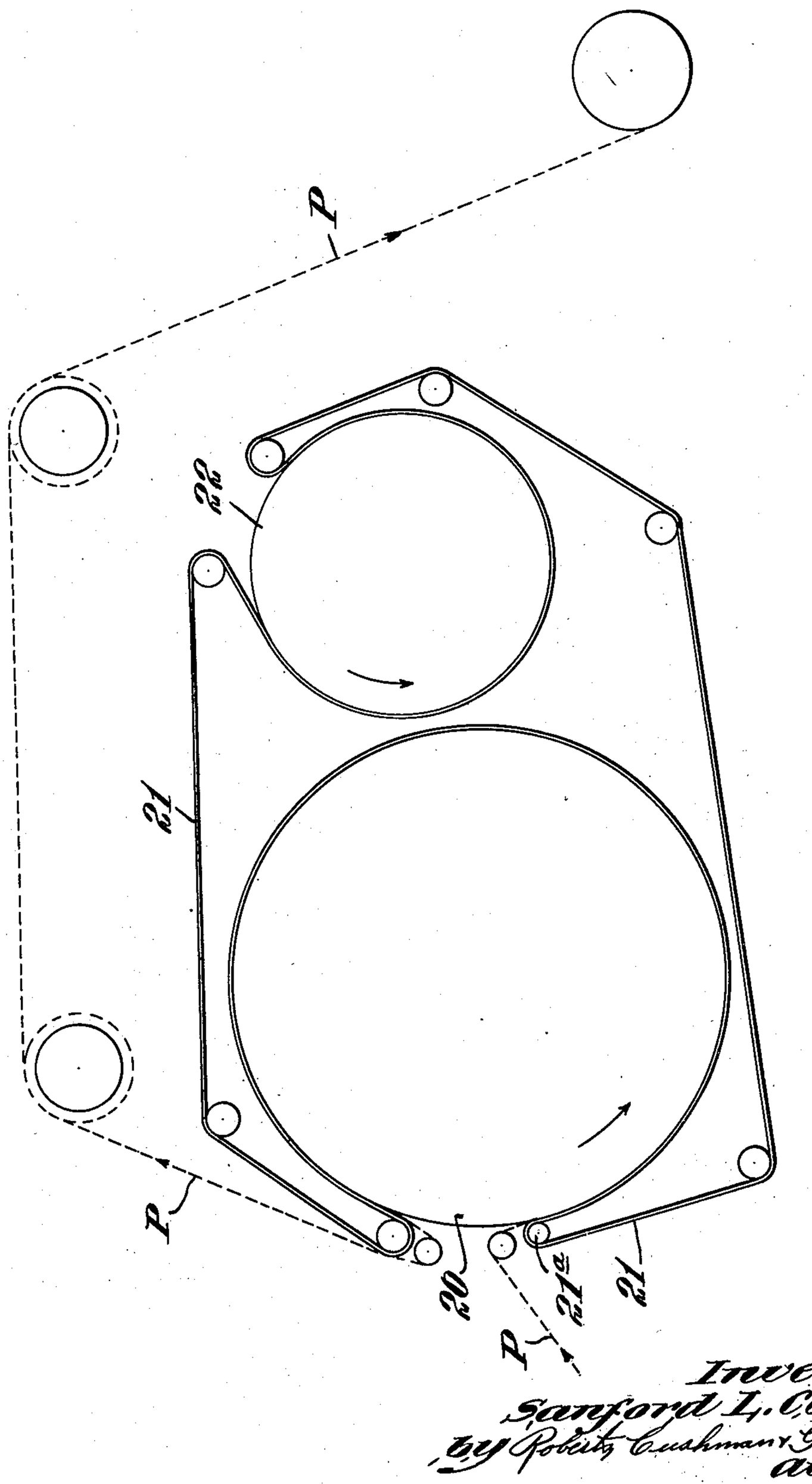

Fig. 4

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UNITED STATES PATENT OFFICE

2,624,245

MODIFIED PAPER AND METHOD FOR ITS MANUFACTURE

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Application December 16, 1947, Serial No. 791,997

13 Claims. (Cl. 92—68)

1

This invention relates to a modified form of paper and particularly aims to increase the extensibility and flexibility of a paper web and the extent to which it can be shaped or worked, particularly when dry. The invention aims to accomplish these results without producing a creping of the paper, and aims to leave the paper in at least approximately as smooth a condition as before or as without the treatment.

The invention contemplates a paper web, such as a strip having plain parallel surfaces with constituent fibres of the material distorted and locally flexed and crowded together by compression of the web in directions parallel with such surfaces, the fibres being cementitiously held together by the finely beaten fibrils and the natural adhesives that are the product of the beaten pulp as well as by the molecular attractive forces that are made possible by the extremely intimate contacts of the fibrillated material, the amount of compression of the web and distortion, flexing and crowding of the fibres being sufficient to impart a marked and controllable and useful extensibility to the web also generally an increased density. Extensibility in paper products has heretofore been secured principally by creping, which has certain limitations and disadvantages. The invention aims to provide a different kind of extensibility which does not depend upon straightening-out of bodily folded or creased zones as in the extension of a crepe paper, but involves rather an extension of distorted or locally flexed or crowded fibers within the body of material between the boundary faces of the web.

Preferably I employ a paper web which is already in a moist and plastic condition such as the newly-laid web in a paper making machine, for example the water-laid web taken from a typical Fourdrinier machine, from which excess water has been removed, but which has not yet been dried and set. A paper wet in this condition is in an excellent condition for further treatment by this invention. Where this newly-laid web is not available, I may employ a previously made web of paper, but it must be first conditioned to a plastic state, such as by prolonged contact with water, preferably hot, until the web has become plastic and deformable.

The conditioning may comprise simply causing a suitable amount of moisture to penetrate the paper thoroughly to render it plastic, for example, soaking the paper in water and allowing it to remain in a wet condition long enough to render it amenable to the subsequent treatment. Such time of soaking may be as short as one minute

2

or as long as one hour or more, dependent upon the paper.

In some cases, dependent upon the constitution of the paper, the plasticizing action of water or other liquid plasticizing agent is supplemented by the heat to which the paper is subjected in the succeeding parts of the process, it being evident that heat tends to soften some of the ingredients of certain types of paper.

The paper, suitably plastic, or being sufficiently near to being plastic that the heat of the subsequent step of the process will render it plastic, and having sufficient moisture removed to cause a certain amount of voids between the fibres, is subjected to the compressing step of the process. In this step the paper is subjected to compression in a direction parallel to the surfaces of the paper productive of a substantial decrease in dimension of the paper, and while the paper is under considerable pressure perpendicular to its surface to restrain it from creping. As the sheet is dried, adherence between the intertwined longer fibres is achieved chiefly by matting together in close adhesion of the longer fibres and the mass of fibrils including both those fibrils attached to the longer fibres and those which have previously been broken free from the longer fibres. The resistance of such a paper to breaking under tensile stress arises from the length and strength of the fibres and from the firmness by which the fibres are bound into a common mass by the matted and mutually adhering fibrils.

In the manufacture of paper according to this invention the paper after the removal of sufficient water to produce a coherent structure, but before drying, is submitted to a process which introduces a distortion of the longer fibres by contracting the area in which they lie and thus the length of the sheet, but without decreasing the actual length of the fibres themselves, while at the same time holding the surfaces of the paper web flat and parallel and preventing thickening the web. During this operation a heavy pressure is maintained on the surfaces of the paper web so as to prevent creping of the web and also for the purposes of forcing the distorted fibres into voids within the paper web so as to bring the fibres into such close contact with each other and with the entangled fibrils as to cause strong bonding and adhesions within the web. Upon subsequent drying, the modified orientation of the fibres and fibrils is retained in the dry state and the sheet takes on firmness and

strength from the mutual adherence of the finely entangled fibrils and other small structures.

When this paper is subjected to tensile stress there is an inertia to reformation arising from the mutual adhesion of the almost continuous distribution of fine fibrils. However as the tensile stress is increased the nearly continuous structure of fine fibrils progressively yields and the internal stress is gradually assumed by the larger fibres until they are straightened out from their previously distorted configuration and the paper sheet assumes an added length closely approximating the length to which the paper web had been compressed. Upon still further increasing the tensile stress the mutual adherence of the fine fibrils which maintains the structure of the larger fibres breaks down locally and the sample ruptures. Paper treated according to this process may be made to have almost any desired elongation even up to as high as 100% of its length. The amount of extensibility imparted to the paper can be controlled by adjustments and the operation of the mechanism for carrying out the process.

When a paper web that has been compressed in this manner is later stretched or extended to impart thereto its full permanent extensibility in excess of the resiliency and elasticity of the web, there appears to be no observable decrease in the thickness of the stretched or elongated web over that before stretching or elongation. In fact, the compressed web slightly increases in thickness when elongated.

A variety of types of apparatus may be employed to practice the process of this invention. Preferred forms of apparatus employ an element having an elastic contractable surface which has relatively high friction against which the paper is pressed by a surface which has relatively low friction, while such contractable surface is contracting, such pressure being sufficient not only to restrain the paper from creping but also to force the paper into such frictional contact with the contracting surface that the paper partakes of some of the dimensional contraction of such surface and consequently is compressed in the direction in which such surface is contracting.

Thus the contracting surface may be that of a traveling belt or blanket running in an endless path, the contracting surface being caused to contract at a place in such path where the direction of such contracting surface of the belt or blanket changes from a convex to a concave course. The low friction surface may be a heated, smooth, highly polished metal surface. The amount of stretchability imparted to the web is substantially equal to the degree to which the web is shortened by the longitudinal compression. One mechanism of this type that can be utilized is shown and described in United States Patent No. 2,021,975. In general, the resistance of the paper to contraction may be such that a number of treatments by such a mechanism may be necessary in order to attain the desired degree of future extensibility. The water must be gradually extracted from the paper web as it is additionally compressed in order to permit increased longitudinal compression of the web and thus additional extensibility. It is impossible to materially increase the density or to decrease the volume of the web if the web is fully saturated.

It is preferable to bring the wet web to the compressing machine with sufficient voids in the web to allow compression to be accomplished. The water may be extracted by any of the known

means such as by suction boxes, rolls or heat, or it may be extracted by the compressing machine itself, in which case the first run through the machine will act largely as a dryer and will not materially compress the web. Thus the paper may be passed a number of times through a single such mechanism, or any desirable number of such mechanisms may be arranged to receive and treat the paper successively, preferably so that both surfaces of the web are alternately in contact with the heated surface. Although mechanism of this type causes a certain amount of drying by applying heat to the web, it is preferred to provide supplemental drying apparatus to facilitate drying. This may comprise the regular drying cylinder or means employed in present paper making, or it may comprise a special apparatus.

In the drawings;

Fig. 1 is a diagrammatic side elevation of simple apparatus useful in performing the compressive contracting step or steps employed in the invention;

Fig. 2 is a diagrammatic side elevation of apparatus which may also be employed in conjunction with the apparatus of Fig. 1;

Figs. 3 and 4 together constitute a diagrammatic view of equipment suitable for continuously subjecting paper to treatment in successive apparatus, the paper first passing from left to right in Fig. 3 and then from left to right in Fig. 4;

Fig. 5 is a sectional elevation on an enlarged scale of a portion of a web of modified paper produced by the invention; and

Fig. 6 is an enlarged view partly in elevation and partly in longitudinal section showing a cable wrapped with the modified paper produced by the invention.

The invention will first be explained by referring to the production of typical products by use of the apparatus of Figs. 1 and 2.

The apparatus of Fig. 1 comprises rolls 10, 11, 12 and a heated driven roll 13 (corresponding respectively to the rolls indicated at 110, 111, 112, and 113 of said patent) and a thick belt 15 with a contractable surface layer, preferably of rubber of durometer hardness sufficient to prevent creping of the paper web. This belt may be formed of natural rubber or rubber substitutes, and preferably it has a strong relatively inextensible layer faced with a readily extensible and contractable surface layer of any suitable material of smooth contractible surface of sufficient hardness and extensibility, rolls 10 and 13 being adjustably movable toward or from each other so as to properly nip the belt 15 between them where the belt passes from roll 10 to roll 13, and roll 12 being spaced away from roll 13 sufficiently to give the belt a short straight run from roll 13 to roll 12. As the belt passes from roll 10 to roll 13, the outer surface of the rubber belt which is convexly curved on roll 10 becomes concavely curved on roll 13 and accordingly shortens. A paper web fed in between the belt and roll 13 where this shortening of the belt surface is taking place is forced into such frictional contact with the contracting surface of the belt that the belt surface tends to compress the web longitudinally, parallel with the surfaces of the web. The roll 13 must be accurately machined ground and finished to a true cylinder of smooth periphery. It is heated not only to cause a partial drying of the web but also to lower the coefficient of friction between the drum and the moist web while at the same time heating the contained water and thus cause

a softening and increased flexibility of the fibres. The resulting loss of water in the web makes room between the fibres for further compression of the web as may be desired. The coefficient of friction between the wet web and the heated drum 13 is most effectively reduced at drum temperatures about 212° F. The coefficient of friction of the surface of the roll 13 is relatively low as compared to the coefficient of friction of the web-contacting surface of the belt 15, so that under the influence of the contracting belt surface the paper web tends to partake of such contraction of the belt surface and slide with relation to the roll surface. During the longitudinal compression of the paper, the tension in the rubber belt 15 is maintained sufficiently high so that with the selected hardness of the belt surface the pressure between the rubber belt 15 and the roll 13 prevents the paper from creping and keeps the surfaces of the paper plain and parallel so that as the web is compressively shortened, individual fibers of the paper which lie generally lengthwise of the web or in the direction of shortening are compressively distorted lengthwise within the body of the web. Rubber is preferred as the material for the contracting surface, such as that of the belt 15, because of its ability to withstand strong tension and heavy pressure transverse to its surface, thus enabling a relatively large and effective contraction of this surface to take place without allowing the paper to crepe in response to such contraction. Rubber is also preferred for its continuously smooth surface and for its ability to grip the paper frictionally to the extent of compressing the paper longitudinally in the presence of the heavy pressure exerted between the belt and roll 13 for prevention of creping. In the apparatus as shown it is preferable that the rubber is reinforced by comparatively inextensible material such as heavy canvas or layers of strong cords so that the necessary high tension in the belt may be maintained and also so that the surface of the belt will expand and contract uniformly while passing over the roller 10 and the heated driving roll 13.

The apparatus of Fig. 2 was employed in conjunction with the apparatus of Fig. 1 principally to facilitate drying the paper web. As shown in Fig. 2 a moisture-permeable felt belt 21 passes over an intake roll 21a and thence onto and around a heated drum 20, holding the paper web against the drum during drying.

To be strongest, paper made by this process should be from the freshly laid web as received from the Fourdrinier or other paper forming machine, and must not be allowed to fully set or dry while being compressed in length; nor must the paper surface be fully dried or set until the desired compression is attained. Fibres when fresh from the pulp have, when pressed together and dried, a strong affinity for each other caused not only by the entwining of the fibres but also by the entanglement of fibrils and by the adhesion of finely beaten parts of the fibrils which cement the paper mass in a strong bond.

In making stretchable paper in this application it is therefore desirable to crowd and distort the fibres to as full extent as it may be desired before initial bonding or irreversible adhesions take place.

When regularly manufactured paper is later rewet, and compressed according to this improved method, the rearrangement of the fibres with local and individual crowding and flexing thereof with the space between the faces of the web as laid breaks some of the earlier formed adhesions and these broken adhesions are not readily reestablished with the same original strength.

Thus although the paper exhibits extensibility, the ultimate strength is generally less than is achieved when freshly laid webs are used.

Webs were made of kraft paper which had been beaten to a freeness of 21 (Schopper Riegler), these webs being made as hand-sheets of approximately 90 pounds ream weight (24 x 36 x 500 basis) and pressed to reduce their moisture content to approximately 70%. The webs were kept in moisture-proof packing so as to retain their moisture and avoid hardening of the paper until the compressive contracting operation.

Various runs of such webs were made, using various combinations of numbers of passes through the apparatus of Figs. 1 and 2, and in the two examples tabulated below the web was initially passed twice through the apparatus of Fig. 2, which had been found helpful in order somewhat to reduce the moisture content and to warm the web, then was passed a number of times through the apparatus of Fig. 1, and then again passed once more through the apparatus of Fig. 2 for final drying.

Example	Passes through apparatus of Fig. 1	Total contraction in percent	Average tensile strength of product in pounds per inch	Average extensibility of product in percent
(a)	6	33	27.36	52.3
(b)	7	44.4	30.20	87.0

Fig. 5 is a drawing, enlarged about 160 times, showing the relation of the fibers of Example (*b*). This view readily illustrates the locally crinkled conditions of the fibers, the plainness and smoothness of the top and bottom surfaces of the web, and the fact that the slight surface indentations (greatly magnified in the drawing) do not traverse the thickness of the web and are not reflected in corresponding projections from the opposite surface.

It will be observed that the products were relatively strong but had a marked and useful amount of extensibility. This extensibility when expressed in per cent represented an extension of the web to and slightly beyond its original lengthwise dimension. That is, taking example (*b*), a contraction of 33% results in a contracted length of 67% of the original length, and an extensibility of 52.3% of such contracted length of 67% represents a return to 102% of the original dimension.

As will readily be apparent, the amount of extensibility imparted to the paper may be varied by varying the amount which the paper is compressively contracted from its initial condition. It is contemplated that in most cases the demand will be for products capable of 10% or more extensibility. The extensibility of paper of the present invention can be distinguished from extensibility produced by creping, in that extension of the present paper involves extension of distorted fibers within the body defined by plain parallel faces of the sheet of web material, whereas extension of creped paper takes place primarily by straightening-out of bodily folded or creased zones of the web with resultant decrease of thickness of the web.

The preferred product of the present invention may readily be distinguished by sight or touch

from many extensible paper products in that both its faces are smooth plain parallel faces. It may be noted here that the products of examples (*a*) and (*b*) discussed above, as well as other products of this invention receive writing well. The smoothness of the product of the present invention is especially useful where it is desired that liquid coating be applied. Thus, liquid water-proofing or water-repellent coatings can be economically applied to the smooth modified paper of the present invention, whereas such coatings would be difficult and costly of application to creased or wrinkled products.

The compressive action which the product has received materially increases its density over that of the web from which it is made. Likewise the product has a density at least approximately as great as, and generally materially higher than, results from ordinary production of a water-laid web from the same or similar paper-making fibers and ordinary finishing of such web as paper of about the same thickness. For instance, various series of extensible papers have been prepared according to the invention by compressively contracting freshly laid but incompletely dried kraft paper. In one such series of relatively heavy weight the amounts of contraction applied to the paper ranged from 14.9% to 38.9% and the resulting ream weight of the products ranged between 108 pounds and 229 pounds. In this series the density of each product lay within the range of 0.023 to 0.033 pound per cubic inch. In another such series of lighter weight the amounts of contraction applied to the paper ranged from 17.3% to 24.3% and the resulting ream weights of the products ranged between 41 pounds and 49 pounds. In this series the density of each product lay within the range of 0.025 to 0.028 pound per cubic inch.

In general, the compressive action to which the paper of the present invention has been subjected during its treatment will not have produced more than a fractional increase in apparent thickness of the paper, either as measured for a single sheet or as measured for a number of sheets piled in bulk, nor any substantial increase in apparent volume, either as calculated for a single sheet or for a number of sheets piled in bulk. For instance, a series of extensible papers has been prepared according to the invention by moistening and compressively contracting kraft paper of 30 pounds ream weight which before treatment had a thickness of 0.0036 inch and an extensibility of 3.1%. The extensibility of the products of this series ranged from 26% to 70% and the thickness ranged from 0.0041 inch to 0.0052 inch.

As will be seen from the above, the invention is applicable not only to light weight papers such as have hitherto been rendered extensible by creping but also to heavy weight papers. For instance, in starting with relatively heavy kraft paper of 90 pounds ream weight, the ream weight of the resulting modified paper is greater than this starting value approximately in proportion to the amount of longitudinal shortening during treatment. Such relatively heavy products are specially suitable for mechanical purposes where strength and thickness are desirable.

An incidental advantage of the invention, of particular utility in connection with the heavier weights of paper, is that the same compressive treatment that imparts extensibility also increases the flexibility of the web along lines perpendicular to the direction of extensibility, this

effect also facilitating use of the heavier grades of paper for mechanical purposes.

Although the preferred procedure is to leave the surfaces of the paper uncreped, the paper may additionally be subjected to creping, in which case it will have not only the extensibility due to the ability of its material to elongate as explained above, but also whatever extensibility may result from the creping. In any such case the total extensibility of the web will very substantially exceed that extensibility which is attributable to straightening-out of the folds or creases which have been imparted by the creping.

An excessive quantity of moisture in the web prior to processing is likely to so impede the compressive contracting operation as to give the impression that the paper will be incapable of being compressively contracted. For instance, it has been observed that one or even several passes of a moist paper through the apparatus has failed to shorten the paper or has resulted in actual elongation of the paper. When, instead of stopping the treatment because of such apparent failure, the treatment is nevertheless continued and the paper is subjected to further passes, it has been found that eventually a pass of the paper through the apparatus would result in substantial shortening and further passes would result in further substantial shortening. This is explainable by the theory that moisture in sufficient quantity will fill up the body of the web and make it, in effect, an incompressible solid which is incapable of shortening as it passes through the nip of the apparatus. Continued passage of the web through the apparatus removes moisture from the web, and thus after some passes that are unproductive of shortening, the moisture will be reduced to a value which allows the web to shorten.

Thus papers that are apparently incapable of shortening can nevertheless be shortened by sufficiently continuing the treatment. However, the necessary number of passes of the web through the apparatus can be reduced by avoiding too high a moisture content at the first run. For 90# kraft paper I have found by experiment that about a 50 per cent moisture content, well distributed throughout the material of the web at all portions of its thickness, operates well and enables some shortening to be secured at the first, or nearly the first, pass of the paper through the apparatus.

On the other hand, sufficient moisture should be present to render the paper amenable to distortion of the fibres by compression exerted parallel with the surfaces of the paper in the presence of confinement against creping of the plain smooth surfaces of the web. The sufficiency of the moisture can best be judged by observing the result of passage of the web through the apparatus. Reduction in plasticity of the paper reduces the amount of shortening.

Uniformity of distribution of the moisture through the web is desirable.

When the moisture content of a web is to be reduced by drying preparatory to compressive shortening of the web, such drying should not be unduly rapid, because too rapid drying tends to harden the exterior of the web while leaving an excess of moisture in the interior of the web. It is contemplated that high frequency or infra red heating of wet paper as the paper comes off the screen of a paper-making machine will be found advantageous in carrying off the moisture evenly throughout the thickness of the web more rapidly than is practicable by use of surface con-

tact of the web with a hot cylinder and thus leave a stronger and more even bond between the fibres when they are crinkled and pushed together in the machine.

In processing large quantities of the material to a predetermined degree of contraction and extensibility, it may be advantageous to pass the web continuously through a plurality of devices such as those of Figs. 1 and 2 arranged to act successively. Thus in Fig. 3 the web P, which has previously been conditioned to an appropriate moisture content, is shown as passing successively through, for example, four devices such as shown in Fig. 1, alternate ones of these devices being inverted so that each surface of the web makes contact alternately with a driven roll **13** and with a rubber belt **15**, thus equalizing the finish of the two surfaces of the paper.

For final drying, the web may pass from the last device of Fig. 3 over the drying cylinders usual in paper making machinery or it may pass into and through the large felt belt dryer of Fig. 4, similar in principle to the apparatus of Fig. 2, being there held in contact with a large rotating steam heated drum **20** by means of a moisture-permeable felt belt **21**. An auxiliary steam heated drum **22** may be employed to dry the felt belt. Following this treatment, the product may be wound up in a roll.

The speeds of the several devices of Figs. 3 and 4 are adjusted relative to each other by any suitable means so that they are progressively slower, to accommodate the progressively shortened web and bring it to its desired final lengthwise condition by the time it is dried and set by the heat of the drum **20** of Fig. 4.

The speed of the felt belt dryer of Fig. 4 may also be adjusted relative to the speeds of the preceding mechanisms so as to adjust the total or net amount of longitudinal contraction of the web and thus, if the web has been contracted to a somewhat greater extent than desired during passage through the several devices of Fig. 3, the felt belt dryer of Fig. 4 may be set to run at a speed which will stretch the web sufficiently in length to deliver the web in the final desired state of contraction.

One of many uses for the modified paper of the present invention is as covering material shaped to fit a tapering support. In this use the enhanced extensibility of the paper enables it to be stretched locally where needed while at the same time allowing the paper to have a snug, smooth fit with its underlying support.

In Fig. 6 of the drawings there is illustrated on an enlarged scale an electric cable **25** wrapped with modified paper produced by this invention. In wrapping a strip of paper spirally around a cable, the strip will overlie one or more thicknesses of itself or of other wrapping material, excepting at its forward or leading edge where it will lie in contact with the bare cable. It must therefore occupy a larger diameter where it overlies one or more thicknesses of itself or other wrapping material than where it overlies simply the bare cable. With ordinary substantially non-extensible paper there is the tendency for the spirally wrapped strip to fail to fit smoothly and snugly at the bare cable where the spiral has its smallest diameter, and to fail to fit smoothly and snugly the various other diameters of underlying layers of the wrapping. With the modified paper of the present invention, however, the portions of the paper strip that overlap other portions thereof are enabled to stretch locally without corresponding stretching of the portion that is to overlie the bare cable. The result as shown in Fig. 6 is that each portion of the wrapping strip, at each diameter, has a smooth snug fit with its underlying support. Also, the product may be used to cover snugly any surface having local irregular projections; or the product may be used where it is desired that there may be extension of the paper without rupture, such as in shotgun shells.

The present invention is particularly useful in the manufacture of "twisting tissue" and paper for use in twine; the product being stronger than paper twine as regularly produced owing to ability of the edges of the employed material to stretch along the edges without rupture, while at the same time retaining resistance against elongation.

The web of cellulose fibers after compression in accordance with my process, has resiliency and elasticity, and as it is stretched beyond its primitive elastic limit it retains retraction resiliency and elasticity until rupture, but during the stretching to rupture, the primitive elastic limit of the web also progressively changes, so that if the stretching forces are removed at any point short of rupture, the web retains its stretched condition except for the retraction due to a residual resiliency and elasticity.

I claim:

1. The process of producing an uncreped paper web of water-laid, adherent, cellulose fibres, with smooth, substantially parallel faces and substantial permanent extensibility in excess of the primitive elastic limit of the web, and which suffers no substantial decrease in thickness when elongated by stretching, which comprises moving said web in a direction lengthwise thereof, and while in the physical condition it possesses as it leaves the wet end of a paper making machine, slowly removing a part only of the moisture from said paper web, and uniformly pushing and crowding the fibres of the partially dried web together in the space between the faces of the web as laid, continuous through the web, and by forces acting in a direction parallel to the faces of the web, opposite to the direction of movement, and throughout the pushing and crowding confining the web against creping by pressures on the web normal to said web faces.

2. The process of producing an uncreped paper of water-laid adherent, cellulose fibres, with smooth, substantially parallel faces and substantial permanent extensibility in excess of the resiliency and elasticity of the web, and which suffers no substantial decrease in thickness when elongated by stretching, which comprises heating the web, while in the physical condition it possesses as it leaves the wet end of a paper making machine, until a part only of the moisture of the web has been removed, then confining said partially dried web between two moving bodies having spaced surfaces, one of which is heated and has relatively low frictional resistance to movement of said web thereover, and the other of which is smooth, contractible and has a relatively high frictional resistance to movement of said web thereover, preventing creping of the web while between said surfaces of said bodies with applied forces normal to and opposing separation of said bodies, and while the web is so confined contracting the area of said surface of said body with said relatively high frictional resistance to carry said web with it over said heated body and thereby compress the web in the direction of contraction and crowd the web fibres into a more compact mass.

3. Process of producing an uncreped paper web of water-laid, adherent, cellulose fibres, with smooth, substantially parallel faces and substantial permanent extensibility in excess of the resiliency and elasticity of the web, and which suffers no substantial decrease in thickness when elongated by stretching, which comprises confining said web, while in a plastic condition, between two moving bodies having spaced surfaces, one of which is heated and offers relatively low frictional resistance to the movement thereover of said paper web, and the other of which is smooth, contractible and offers relatively high frictional resistance to the movement thereover of said paper web, preventing creping of the confined web while between said surfaces of said bodies with applied forces normal to and opposing separation of said bodies, and while the web is so confined contracting the web-contacting area of said other body having the surface offering said relatively high frictional resistance, to contract said web with it over said heated body and thereby compress the web in the direction of contraction of said area and crowd and push the web fibres into a more compact mass.

4. The process of producing an uncreped paper web of water-laid, adherent cellulose fibres, with smooth, substantially parallel faces and substantial permanent extensibility in excess of the resiliency and elasticity of the web, and which suffers no substantial decrease in thickness when elongated by stretching, which comprises slowly removing a part only of the moisture from a paper web in the physical condition it possesses as it leaves the wet end of a paper-making machine before drying, then subjecting this partially but not fully dried web to a plurality of similar successive treatments, in each of which the web is confined between two moving bodies having surfaces, one of which is heated, smooth, and offers relatively low frictional resistance to movement of a wet paper web thereover, and the other of which is smooth, contractible and offers relatively high frictional resistance to the movement thereover of said paper web, preventing creping of the confined web while between said surfaces of said bodies by applied, opposing forces normal to and opposing separation of said bodies, and while the web is so confined contracting the web-contacting area of said body having the surface offering said relatively high frictional resistance, to contract said confined web with it over said heated body and thereby compress the web in the direction of contraction of said area, and crowd and push the web fibres into a more compact mass, and removing moisture from the web between treatments to free the voids in the web of moisture and enable the compressed fibres to fill them.

5. A relatively dense, uncreped paper web formed from adherent, natural cellulose fibers, in their natural physical shape said web being characterized by an uncreped body of approximately uniform density throughout its length and width, devoid of folds and pleats, and having smooth, substantially parallel faces and substantial extensibility beyond its primitive elastic limit, continuous throughout it in a direction parallel to its faces, those of said fibers within the web which lie lengthwise generally in said direction of extensibility being locally, laterally and individually rearranged and compressively distorted lengthwise within the space between said web faces, said web when elongated beyond its elastic limit by tension in said direction suffering no substantial decrease in its thickness.

6. A relatively dense, uncreped paper web formed from adherent, cellulose fibers in their natural physical shape, said web being characterized by an uncreped body, devoid of folds and pleats, and having smooth, substantially parallel faces and substantial extensibility continuous throughout it in a direction parallel to its faces and to an extent well beyond its primitive elastic limit, those of said fibers in said web which lie lengthwise generally in said direction of extensibility being locally, laterally and individually rearranged and compressively distorted lengthwise within the space between said web faces.

7. A relatively dense, uncreped paper web formed of water-laid, adherent cellulose fibers in their natural physical shape, said web being characterized by substantially parallel faces, and by substantial extensibility well in excess of its primitive elastic limit in a direction parallel to its faces, said extensibility being continuous throughout it in said direction of extensibility and those of said fibers within said web which extend generally lengthwise in said direction of extensibility being locally, laterally, and individually rearranged and undulatory lengthwise within the space between said web faces.

8. The process of producing an uncreped paper web of water-laid, adherent, cellulose fibers, with smooth, substantially parallel faces, devoid of folds and pleats, having substantial extensibility in excess of its primitive elastic limit, and suffering no substantial decrease in thickness when elongated by stretching beyond its said elastic limit, which comprises conditioning the web to contain less moisture than its maximum capacity to hold moisture, but sufficient to give the fibers thereof substantial plasticity, then pushing and crowding together, and locally flexing, rearranging and distorting lengthwise, the fibers of the conditioned web, continuous throughout the web, by forces applied in a direction parallel to the faces of the web and opposed to the direction of desired extensibility of the web, and, during such pushing and crowding together and local flexing, rearrangement and lengthwise distortion of the fibers, confining said web against creping, and drying this treated web.

9. A process of producing an uncreped paper web of water-laid, adherent, cellulose fibers, with smooth substantially parallel faces and substantial permanent extensibility in excess of the primitive elastic limit of the web, which comprises establishing a uniformly distributed moisture content in said web which is considerably less than the maximum the web can carry but sufficient to give substantial plasticity to the fibers of the web, moving said web with its established moisture content in a lengthwise direction, and while the web is so moving pushing and crowding the fibers of the web together in the space between the faces of the web as laid and by forces applied in the direction parallel to the faces of the web and opposed to the direction of its lengthwise movement continuously and uniformly over the web, and throughout the pushing and crowding confining the web against creping by pressures on the web normal to said web faces.

10. The process of producing an uncreped paper web of water-laid, adherent, cellulose fibers, with smooth, substantially parallel faces and substantial extensibility beyond the primitive elastic limit of the web, and which suffers no substantial decrease in thickness when elongated by stretch-

ing, which comprises moving said web in a direction lengthwise thereof, and while in the physical condition it possesses as it leaves the wet end of a paper making machine, applying high frequency heating to the web until a part only of the moisture of the web has been removed, while the web is still in a plastic condition, uniformly pushing and crowding the fibers of the moving web together in the space between the faces of the web as laid, continuously throughout the web, and by forces applied in a direction parallel to the faces of the web and opposite to the direction of movement, and throughout the pushing and crowding confining the web against creping by pressures on the web normal to said web faces.

11. The process of producing an uncreped paper web of water-laid, adherent, cellulose fibers, with smooth, substantially parallel faces and substantial extensibility beyond its primitive elastic limit, and which suffers no substantial decrease in thickness when elongated by stretching, which comprises moving said web in a direction lengthwise thereof, and while in the physical condition it possesses as it leaves the wet end of a paper-making machine, slowly removing a part only of the moisture from said paper web, confining said moving partially dried web against creping and simultaneously contracting the face areas of said confined web and pushing and crowding together the fibers of the confined web in the direction parallel to the faces of said web and opposed to said movement, and continuously over said web to increase the density of the web, then removing further but not all of the remaining moisture from the moving compressed web, then reconfining the moving compressed web against creping and while the web is so reconfined further contracting the face areas of the confined web and similarly and further pushing and crowding further together the fibers of the reconfined web, to further increase the density of the web, and then drying this treated web.

12. The process of producing an uncreped paper web of water-laid, adherent, cellulose fibers, with smooth substantially parallel faces and substantial extensibility beyond its primitive elastic limit, and which suffers no substantial decrease in thickness when elongated by stretching, which comprises conditioning said web to contain less moisture than its maximum capacity to hold moisture, but sufficient to give the fibers thereof substantial plasticity, moving said conditioned

web in the direction of its length, confining said moving web, while its fibers are still in a plastic condition, against creping and, while so confined uniformly, over the entire area of the web, pushing and crowding the fibers of the web together by forces acting in a direction lengthwise of the web, and parallel to its faces and causing local relative flexing and rearrangement of, adjacent fibers, entirely within the space between the face areas of the web, to create a denser mass in the web.

13. A relatively dense uncreped paper web formed of water-laid, adherent cellulose fibers in their natural physical shape, said web having smooth, substantially parallel faces and substantial extensibility in a direction parallel to its faces, continuous throughout it in said direction of extensibility and well in excess of its primitive elastic limit, whose fibers have been crowded and pushed together uniformly over the web, in a direction parallel to the faces of the web, in the space between the faces of the web as laid, to provide such extensibility, the crowded and pushed fibers having between them, in that relation, a bond due to initial drying giving maximum and continuing resistance to permanent elongation in said direction, short of rupture of the web.

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