May 14, 1946. R. C. WHITMAN 2,400,276

OPPOSITE-TWIST WOVEN FABRIC AND METHOD

Filed March 9, 1944 2 Sheets-Sheet 1

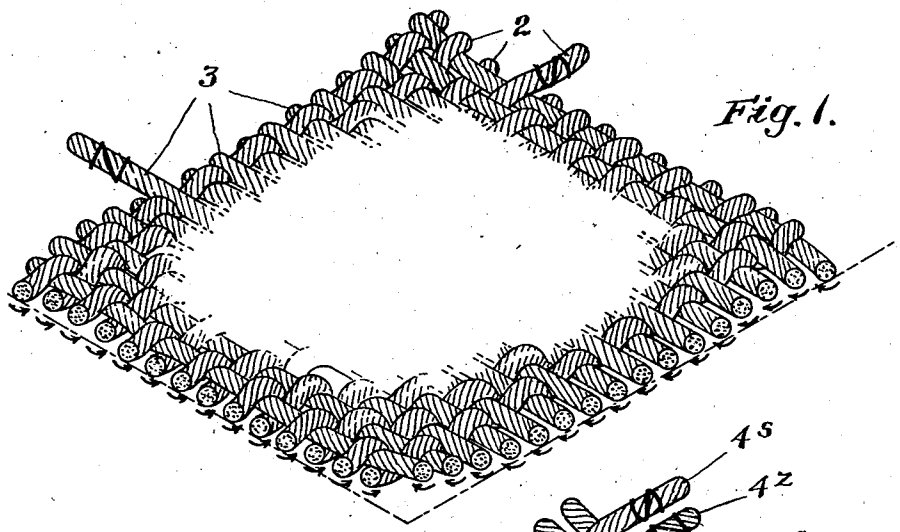


Fig. 1.

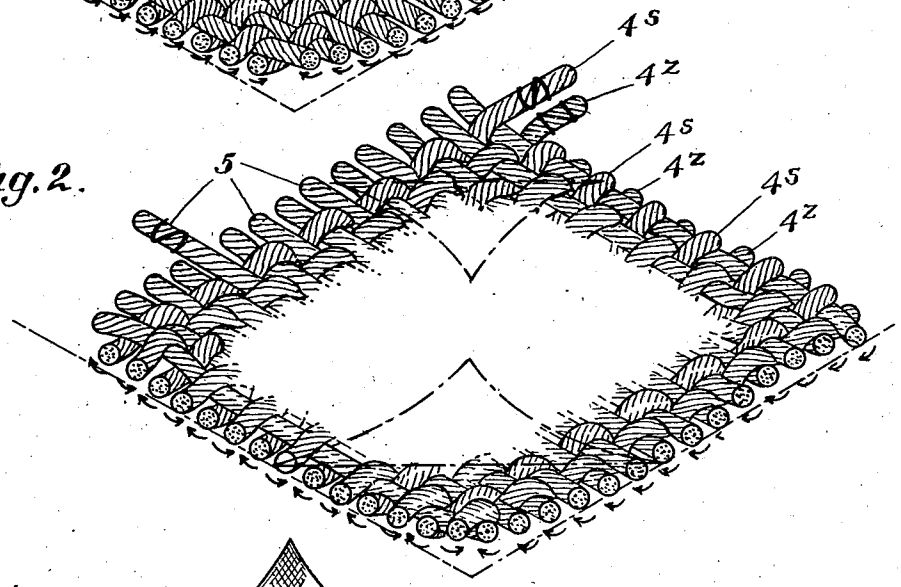


Fig. 2.

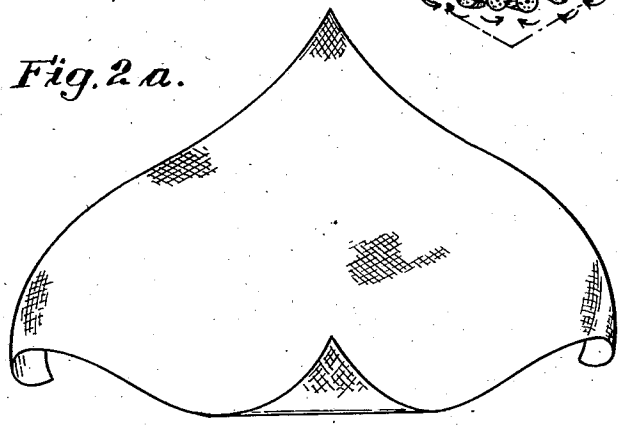


Fig. 2a.

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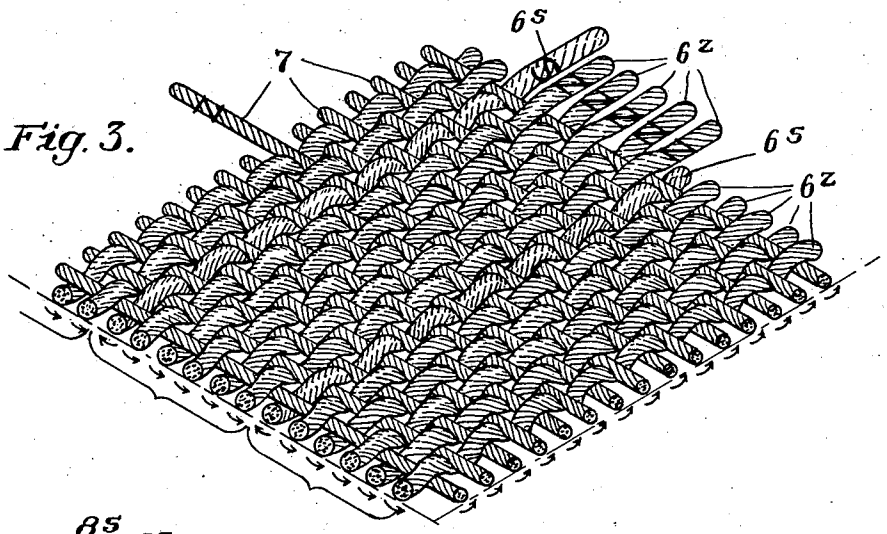
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OPPOSITE-TWIST WOVEN FABRIC AND METHOD

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Fig. 3.



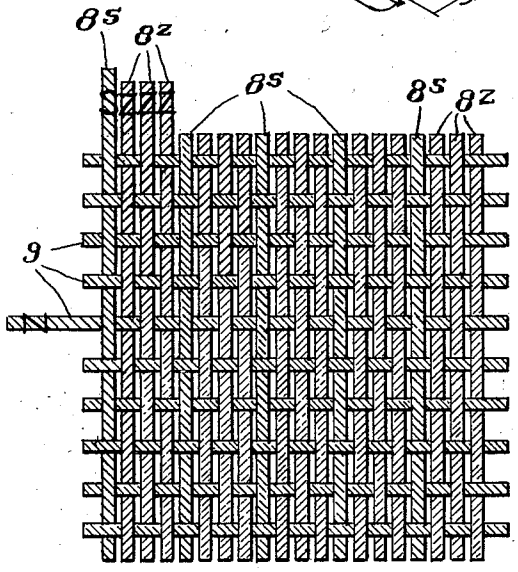


Fig. 4.

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2,400,276

OPPOSITE-TWIST WOVEN FABRIC AND METHOD

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Application March 9, 1944, Serial No. 525,719

12 Claims. (Cl. 28—74)

This invention relates to woven textile fabrics and methods of making the same, and the object of the invention is to provide fabrics having substantially no tendency to curl which are woven using yarns twisted in opposite directions. The principal commercial applications of the invention are found in the field of stiffened woven fabrics to which the invention is particularly directed, though it is also useful in some unstiffened fabrics, principally narrow fabrics.

There are numerous uses for fabrics having little or no curling tendency, for instance, in dress goods, yard goods, and curtain fabrics (e. g. organdies, lawns, voiles, marquisettes, fine muslins, uniform, and print cloths); in narrow fabrics including "slit" goods, tapes, ribbons and the like; and in various mechanical and industrial fabrics, both wide and narrow (e. g. muslins, drills, twills, sheetings) such as those used for radio spiders, condenser and insulating cloths, shoe linings, etc. Though most fabrics do not curl objectionably in the absence of a stiffening treatment, this is by no means universally true, particularly with respect to narrow and "slit" fabrics, and a considerable variety of commonly used fabrics, both stiffened and unstiffened, would be improved materially were it possible to determine and eliminate therefrom objectionable curling and so provide, as the present invention does, a satisfactory and certain basis for substantially eliminating such objectionable curling during not only cutting and fabrication into various articles of manufacture (which is sufficient for many purposes) but also during the utilization thereof—the latter particularly with respect to stiffened fabrics.

It has long been known in the textile art that many fabrics exhibit an undesirable degree of curl. For example, if a typical piece of a commercial light-weight stiff fabric, such as ordinary organdy, say about a foot square, is laid upon a flat surface, it will exhibit a curl such that diagonally opposite corners, for example, the top left-hand corner and lower right-hand corner, will lift from the flat surface and curl back over the central portion of the square of fabric so as to form a scroll. This tendency of certain faries to curl and roll up has been particularly troublesome to manufacturers and processers of fused fine fabrics, to manufacturers of tapes, and generally to manufacturers and users of resin-impregnated or otherwise stiffened woven textile products.

Numerous methods of overcoming the curling problem have been proposed including various chemical and mechanical finishing treatments of the yarns employed and/or of the body of the fabrics; special weaving or treatment of selvages; and special weaving of the body of the fabrics, such as weaving a fabric with right-hand (Z) and left-hand (S) twisted yarns arranged in alternate pairs in the warp and with unidirectionally twisted yarns in the filling, as in Schönholzer, U. S. Patent No. 2,215,938 (Fig. 2), or to use yarns in pairs of alternate twists both in the warp and in the filling (Fig. 3), only the latter of which can possibly achieve—by a mode of operation differing from the present invention and at very considerable manufacturing expense because of requiring box looms—a non-curling stiffened fabric. However, all of these methods have proven incapable of solving the problem, except one which is very expensive, if not prohibitively so (as in Schönholzer Fig. 3) because it involves the use of specialized equipment and extra operations.

The many conflicting proposals for the solution of the long-standing problem of fabric curl, particularly in stiffened fabrics, many of which proposals involve the use of opposing directions of twist of component yarns, evidence both a failure to understand the significance of yarn twist to the phenomena of curl in fabrics and a complete failure to appreciate the presence and importance of other factors which also influence fabric curl as will now be described.

The present invention provides novel fabrics in which undesirable curl is overcome (or controlled or minimized to any desired degree), and provides a method of producing such fabrics without the use of special equipment and without substantial increase in manufacturing cost.

The general object of this invention is to provide textile fabrics both wide and narrow which exhibit substantially no tendency to curl. A particular object is to provide a fabric of such novel characteristics that it will not curl materially or objectionably upon being subjected to a fusing or other stiffening treatment. Further particular objects are to provide non-curling stiffened fabrics and a method of making the same.

The present invention was made only after very considerable study and experimental investigation in the course of which, in accomplishing the above objects, there were made several astonishing and unpredictable discoveries relating to the factors which influence fabric curl, namely, the discovery that yarn size of component yarns is the major factor though but one factor involved in the curl of fabrics and that yarn twist and the number of yarn ends per inch of fabric

in the warp and filling directions have an important effect as hereinafter appears. Fundamentally, it was discovered that the sets of warp and filling yarns have a profound relationship and effect inter se and that the fabric curling or torque effect exerted by a given warp yarn can be and is neutralized or offset by the curling effect of a filling yarn of the same size and the same twist (same number of turns per inch and same direction of twist), and, further, it was discovered that the curling effect of one set of yarns (warp or filling) can be neutralized by the other set of yarns including yarns of both directions of twist, and though said other set also differs from the first set in yarn size, in twist multiple, and in number of yarns per inch of fabric, the difference occurring in one or more of the factors. The method of practising the invention by applying these discoveries in the manufacture of fabrics having substantially no tendency to curl is fully set forth hereinafter.

While the above discoveries are novel contributions to the art, there were also made other discoveries relating to the mechanism of curl of stiffened fabrics which are equally astonishing. My conception as to the true mechanism of fabric curl has been confirmed by study and dissection of numerous test specimens which show that soft unstiffened fabrics that tend to curl are caused so to do by the untwisting of certain dominant component yarns. Study of certain stiffened fabrics, however, resulted in the paradoxical discovery that in such fabrics the curl is caused by an increase in the twist (i. e. a twisting tighter) of the dominant component yarns—these yarns imparting a net curling effect even though the same set of yarns include stiffened yarns of opposite twist. For example, when a foot square piece of a certain commercial broadcloth was laid upon a flat surface, it was observed to curl in that two of the diagonal corners lifted up somewhat from the flat surface and the other two diagonal corners attempted to curl downwardly. The curl here was caused by an untwisting of certain component yarns. However, upon subjecting said piece of fabric to the usual starch stiffening treatment and again laying it upon the table, it was observed that the diagonal corners which tended to curl upwardly before, then tended to curl strongly in the opposite direction, or downwardly, and that those corners which had curled downwardly before curled strongly in an upward direction. This was caused by the component yarns twisting tighter as the result of such stiffening treatment. This phenomena of reversal of direction of curl upon such stiffening has not been known and appreciated heretofore.

By properly applying these discoveries in yarn manufacture and selection, in weave layout and weaving of textile fabrics, one can produce a wide range of novel fabrics having at least one set of yarns with opposite twists and which are characterized by a substantial absence of curl even though stiffened, or by a curl which is controlled to any desired small degree. Furthermore, one can produce the required yarns and such fabrics on standard textile equipment and at no substantial increase in cost over the cost of otherwise similar common textile fabrics of equivalent weight.

In the drawings—

Figs. 1 and 2 are perspective views representing fabrics, much enlarged, and illustrate the modus operandi of curling, Fig. 1 being an unstiffened fabric with warp and filling of opposite twists, respectively, and Fig. 2 being a stiffened fabric with warp of right-hand (Z) and left-hand (S) twisted yarns arranged alternately and with filling of unidirectional twist;

Fig. 2*a* is a perspective view representing typical curl of a small square of the fabrics of Figs. 1 and 2 when wholly unrestrained;

Fig. 3 is a perspective view illustrating one preferred type of a non-curling fabric, much enlarged, of the present invention; and

Fig. 4 is an enlarged diagrammatic plan view illustrating another preferred type of fabric of my invention.

Referring to the drawings, and particularly to Figs. 1 and 2, there are illustrated two portions of different fabrics resting on flat horizontal surfaces (indicated by dashed lines). Fig. 1 represents a conventional unstiffened fabric with warp yarns 2 and filling yarns 3 of opposite twists, respectively, the warp yarns 2 being of S-twist and the filling yarns 3 being of Z-twist. In Fig. 1 the warp yarns 2 tend to untwist (as indicated by the arrows) and, in turn, to lift the lower and diagonally opposite upper corners (as shown) of the fabric from the supporting surface, the two remaining diagonally opposite corners tending to bend in the opposite or downward direction, and the filling yarns 3 tend to untwist in the opposite direction (as indicated by the arrows), and also lift said corners so that the curling tendencies of the two sets of yarns augment each other in lifting said lower and upper corners, and try to bend the other two corners downwardly. If the fabric of Fig. 1 were stiffened, the diagonally opposite left and right corners would strongly curl upwardly, and the other corners downwardly.

Fig. 2 represents a stiffened fabric of unidirectional twist having warp yarns of right-hand (Z) and left-hand (S) twisted yarns, 4S and 4Z respectively, arranged alternately, and filling yarns 5 of unidirectional (S) twist and of the same size as the warp yarns 4 in which the yarns of both sets seek to twist tighter (as indicated by the arrows), the tendency of the yarns of each pair of warp yarns 4 being to offset each other and the wholly unopposed tendency of the filling yarns 5 being to lift the lower and diagonally opposite upper corners from the supporting surface. In order better to show the mechanism of curl, Fig. 2 illustrates it as more nearly flat rather than in the strongly curled position which it would normally assume, as indicated by the dot and dash lines.

Fig. 2*a* shows a curl typical of either of the fabrics of Fig. 1 or Fig. 2 when a piece of such fabric is wholly unrestrained and illustrates how such a fabric, if the curl continues, tends to form a scroll. In accordance with the earlier explanation, then, the curl of a textile fabric is due to the net curling effect of the two sets of yarns on each other.

Fig. 3 illustrates a non-curling stiffened fabric of this invention resting on a flat horizontal support, with warp yarns 6Z and 6S of opposing twists, there being five yarns 6Z for each yarn 6S as shown. These warp yarns are of larger size than the unidirectional Z-twist filling yarns 7, with the latter equal in number of ends but of the required degree of twist (not shown) in which both sets of yarns tend to twist tighter, the net tendency of the warp yarns 6 to lift the lower and upper corners being neutralized by the set of filling yarns 7 so that the corners all lie flat and the fabric does not curl.

Fig. 4 illustrates diagrammatically a stiffened fabric in which the warp yarns 8Z and 8S of opposing twists are twice as numerous and are of the same size and degree of twist (not shown) as the unidirectional Z-twist filling yarns 9, the set of warp yarns being neutralized as to fabric curling tendency by the filling yarns, the excess part of the warp having the same direction of twist as the filling being offset by an equal number of warp yarns of opposite twist direction, providing a fabric having substantially no tendency to curl.

Nearly all woven textile fabrics have as many or more warp yarns than filling yarns so that, from the standpoint of end count, most (but not all) typical applications of the invention fall in between a square weave fabric, with its equal number of ends per inch of warp and filling yarns, and a fabric with a two-to-one or higher ratio of warp to filling ends per inch, though the invention is also applicable to fabrics wherein the number of filling ends per inch exceeds that of the warp. Also, for similar reasons of economical and practical manufacture on modern spinning and weaving equipment, nearly all fabrics heretofore, particularly industrial fabrics, have larger warp yarns than filling yarns. For the same reasons, warp twist has been almost invariably higher than filling twist—in the trade "warp twist" is synonymous with high twist, and "filling twist" is synonymous with low twist.

The foregoing principles of the invention afforded a basis for my derivation of a mathematical equation which, as a practical matter, gives a general guide for successful application and use of the invention in the actual manufacture of non-curling fabrics. The basic equation is as follows:

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w^3}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f^3}}$$

where

M is twist multiple,
N is yarns number (size),
E is end count, and
w and *f* refer to warp and filling, respectively.

In the use of the equation for fabric design and manufacture after the general construction as to end count and yarn size has been determined (for example, in a preferred fabric with a set of opposing twists and a set of unidirectional twist), the equation is applied first only to warp and filling yarns of unidirectional twist, that is, to the unidirectional set of yarns (whether such set be filling, as usually preferred, or warp) and to the yarns of the same direction of twist in the other or second set and the equation is solved so as to determine the number of such latter yarns necessary to neutralize the fabric curling tendency of the first set. The remaining yarns of said second set are then divided equally into yarns of each direction of twist (it being assumed that all the yarns of said second set are of the same size and twist multiple).

Referring to the fabric of Fig. 3, for example, the equation is first applied to filling yarns of unidirectional Z-twist and the required number of warp yarns of the desired size of the same direction of twist necessary to neutralize the fabric curling tendency of said filling yarns is determined—here four warps per six fillings. This leaves two warp yarns for each basic unit of this fabric construction, which two warp yarns are then divided into 1—S and 1—Z—all of the warp yarns in this example being of the same size and twist multiple. This gives the square weave fabric as shown in Fig. 3 in which there are six Z-twist filling yarns for six warp yarns made up of five Z-twist yarns and one S-twist yarn.

In Fig. 4 the procedure is similar only there two Z-twist warp yarns are found to equalize the fabric curling tendency of each two of the unidirectional twisted filling yarns, leaving two warp yarns of opposing twist for each basic unit of this fabric construction.

In accordance with the teachings of this invention, fabric curl can always be avoided by incorporating the correct number of opposite twist yarns (of the required size and twist multiple) in but one set of yarns—the set that would otherwise be dominant from the standpoint of curl—so that the net fabric curling tendency of said set just neutralizes the opposite fabric curling tendency of the other set of yarns. Normally, then, as in the preferred fabrics of this invention, one set of yarns is of unidirectional twist, and in the majority of cases the filling set is of unidirectional twist rather than the warp set for, in such cases, the warp set normally and conventionally would be the dominant set to be modified in accordance with this invention. If the filling set includes yarns of opposite twist, important economic advantages are lost, particularly where box looms would be required to insert singles yarns of opposite twist. Though both sets may include yarns of opposing twist, it is not necessary, and, similarly, important advantages are lost in so doing.

Where each set includes yarns of opposing twist (as well as where but one set does) the basic equation may be applied to give the net fabric curling effect of each set as follows:

$$\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w^3}}\right]_Z+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f^3}}\right]_S=\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w^3}}\right]_S+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f^3}}\right]_Z$$

where M equals twist multiple, N equals yarns number, E equals end count, *w* and *f* refer to warp and filling respectively, and Z and S refer to the respective directions of twist.

Similarly, if either set of yarns includes yarns differing from each other in size or twist multiple, it will be necessary to consider each group of similar yarns separately and add together the results thereof to obtain the total net factor for each set. The twist multiple employed in the equations is the same as that employed in the textile art and equals twist turns per inch of yarn divided by the square root of the yarn number (cotton system), and for the purpose of the equations and in the specification and claims the size of all yarns is expressed on the cotton system, for example, 350 denier rayon yarns are classified approximately as number 15.2; and the expression "end count" is to be taken as meaning the number of yarns per inch of fabric in the designated direction. In the application and use of the invention it is not necessary strictly to adhere to absolute equality as variations from the equality represented by the equations are necessarily encountered in practice, the ultimate test being whether any given

fabric embodies the principles and features of the invention as herein described and claimed.

In the manufacture of stiffened fabrics to which this invention is principally directed, there are various means of stiffening which can be conveniently divided into three general groups. The first and most common involves the application of a water-soluble film or sizing to the surface of the base fabric. This group includes water-solutions of the starches, various common finishing gums, sugars, etc. The stiffening obtained with these products is removed when the fabric is laundered. The second method is to apply a water-carried water-insoluble substance to the base fabric. Various resins such as phenol formaldehyde, urea formaldehyde, casein formaldehyde, the alkyd resins, and the methacrylates are useful for this purpose. Since these chemicals are water-insoluble when applied, or are rendered insoluble after application (by baking the fabric, usually), the stiffness obtained is not immediately or readily removed when the fabric is washed. Effects obtained with such water-insoluble materials as these are called "permanent finishes," although in a series of, say, 10 to 25 launderings, these resins are gradually dislodged from the fabric and their benefits disappear. The two methods may be applied to plain or mixed fabrics or yarns made of any textile fibres including staple or cut staple, natural or synthetic cellulosic fibres or continuous filaments (later referred to). There also may be included silk, wool or Aralac ("casein wool"), nylon, or other non-cellulosic synthetic fibres or filaments, such as vinyl acetate and vinyl chloride copolymers, and vinylidene chloride, for example, those sold under the respective names of Vinyon and Saran, or even inorganic fibres such as glass or asbestos.

The third method is employed only for stiffening base fabrics woven from or including yarns made up of, or which include mixed with other fibres, cotton or other natural cellulosic fibres such as sisal, ramie, hemp or jute, or synthetic cellulosic fibres such as viscose, cuprammonium and other regenerated cellulosic fibres (either cut staple or continuous filament), or cellulose ester fibres (either cut staple or continuous filament) such as cellulose acetate, cellulose butyrate, and cellulose propionate, or mixtures or copolymers of the same. This method involves the use of a chemical which swells and gelatinizes the cellulosic fibres themselves. When this chemical is neutralized or leached out, the cellulose is reprecipitated, the yarns or cellulosic fibres thereof are more or less stuck together, and the whole fabric is markedly stiffened, though not necessarily equally in both directions. Since the stiffening medium is in the cellulose itself, this stiffening method is usually the best so far as wash-fastness is concerned. For fusing agents a very considerable number of chemicals which are known and have been used in the textile art as fusing agents are available for this purpose, for example, in treating a cotton fabric, zinc chloride or fusing agents such as cuprammonium (copper tetramine hydroxide) or sulphuric acid can be used. Other examples are "mixed acids" (nitric and sulphuric), phosphoric acid, a caustic soda solution at −10° C., calcium thiocyanate, and others. Naturally, no strongly alkaline fusing agent should be used on fabrics which include wool or Aralac type fibres. The action of fusing agents on cellulosic fibres, such as scoured cotton and rayon, is well known in the cloth-finishing trade and is referred to in the art as swelling, fusing, gelatinizing or parchmentizing, though herein usually termed "fusing." The methods or processes followed in using these various agents differ but the conditions have been thoroughly worked out for each of them and are well known to those experienced in the trade. For example, cellulosic fabrics fused with zinc chloride are exposed to treatment for a number of hours, whereas goods of a cellulosic composition processed with sulphuric acid are treated for only a few seconds. All three types of treatments in stiffening fabrics including cellulosic fibres and cellulosic yarns produce first a swelling and then cause the fibres to coalesce or adhere somewhat as the swelling is reduced during drying.

In ordinary textile fabrics the individual yarns have a desire to untwist somewhat. If the fabric is wet with water and the yarns are thus swollen, or are swollen by other liquid means, the desire of these yarns to untwist is increased. If the normal yarns could have their diameters decreased, the desire of these yarns to untwist would likewise be decreased, and might be decreased far enough so that they actually try to twist up tighter. This accounts for the fact that swollen and stiffened yarns in a textile fabric, upon drying, and accompanying decrease in diameter, attempt to twist tighter. The fibres of the yarns are stuck together so that they approximate monofilaments. In such coalesced yarns, two or three turns per inch will produce a considerable torsion, whereas in ordinary soft cotton yarns, two or three turns per inch do not produce any detectable torsion. When a yarn is fused, for example, with zinc chloride, it is swelled by the zinc chloride (strongly increasing its desire to untwist), the zinc chloride is then leached out coalescing and solidifying the yarns in a somewhat swollen state (as the zinc chloride is removed, the swelling in the yarn gradually decreases) and, then, as the yarn is dried, its final diameter is somewhat decreased. It is during this drying process that the tendency of the yarn to untwist disappears and the tendency of the yarn to twist tighter becomes evident, the latter tendency, because of the coalescence, being much stronger than the former. This type of reversal of curl or reversal of twist tendency apparently results whenever a yarn is first swollen (either by water of solution or water of condensation), then stiffened or coalesced, and, upon drying, finally condensed, by "condensed" meaning that the diameter of the yarn is decreased, the density of the yarn being increased. The similarity of the foregoing types of stiffening agents from a fabric curl standpoint, and the importance of swelling and subsequent condensation in the production of curl have not been appreciated or understood heretofore. For the purposes of applying the principles and the mathematical equation before referred to, the direction of twist in yarns so swollen and stiffened must be taken and regarded as in the direction of twisting more tightly. If stiffening takes place in the absence of swelling, however, yarns so stiffened will untwist in the same way as they did before being stiffened.

Various stiffened fabrics may be made which include a substantial proportion of yarns in the warp, filling, or both, which are not swollen and stiffened so as to produce a reverse curl (yarns twisting tighter), in such fabrics the warp and filling each including 20% or more of swollen and stiffened yarns with their reverse fabric curling

tendencies offset in general accordance with the foregoing disclosure. In such cases the proportion of yarns not so stiffened (as well as their direction of twist) may be safely disregarded as not significant in view of their relatively negligible effect upon curling as compared with that of the pronounced and very much greater curling effect of the swollen and stiffened warp and filling yarns. Similarly, if but a few soft yarns of opposite twist (than the dominant stiffened warp and filling yarns) be inserted, as, for a pattern effect, for example, they may be disregarded since they do not significantly unbalance the equation.

In the practice of this invention it is essential to provide warp yarns and filling yarns that are spun with precision from uniform card sliver to definite sizes and twist multiples, and so woven that all areas of the body of the fabric are strictly uniform in construction since it is these factors, and their relation to each other, that are depended upon in arriving at the desired result. Even with the most modern equipment, and with carefully controlled spinning-room humidity, it is well known that considerable variation in the yarn size occurs as spinning proceeds. A spinning machine balanced and adjusted to produce 30's yarns may, after a week or ten days' operation, be found to be delivering as fine as 35's or 36's, or as heavy as 27's or 26's, the shift toward lighter yarns usually proceeding faster and further than the shift towards heavier yarns. These variations are usually explained as resulting from humidity changes, temperature changes, stock changes, and machine wear, producing maladjustments.

Standard practice in modern textile mills calls for the analysis of yarns approximately every two weeks, and the readjustment of yarns size prescribed is made usually on the first roving frame, usually called the "slubber," or the second roving frame, known as the "first intermediate." This measure of control is satisfactory for ordinary fabric manufacture, but since it would permit "drifting" of yarn size to the extent mentioned above, it is obvious from the equation underlying this invention that it is entirely inadequate for the practice of the invention. Also, any change in yarn size produces a significant change in twist multiple since the spinning-frame delivers a fixed number of turns per inch to the yarn, rather than a fixed twist multiple. In the manufacture of fabrics of this invention it is recommended that yarn analyses and equipment adjustment as needed be made daily, usually at the second drawing frame rather than on any of the succeeding roving frames. In addition, special care should be taken in the control of spinning-room humidities, etc.

In making use of the equation, actual yarn sizes, as determined by analyses in the spinning-room, and actual twist multiples, as determined by well known formulas involving spinning-frame gears, should be used rather than the "theoretical" or "standard" values. Similarly, actual end counts as reported by the weave room should be used. It is found that usually the slight changes in the end counts occasioned by variations in tension on the loom are not troublesome providing the cloth tension is checked and adjusted daily in the usual way. For fabrics where a substantially complete absence of curl is the requirement, as in radio spiders, it is found that the old style friction let-off on the loom is to be preferred to automatic positive let-off mechanism, such as the "Roper-Draper" or "Bartlett," which permit greater variations in end counts since they control tension with less precision, generally. Also, reasonable care should be taken to avoid any considerable distortion of the woven "neutralized" fabric in subsequent finishing processes. With fairly equal tensions therein so that the end count in the finished fabric is roughly equally higher or equally lower in both the warp and the filling, however, no trouble need be anticipated on this score.

Some examples of the invention are as follows:

Example I

A certain prior art lightweight fabric designed to be stiffened with a hydroxyethyl cellulose finish has an actual end count of 59.4 x 51.4, warp yarns 29.95's with a twist multiple of 4.48 and filling yarns 50.06's with a twist multiple of 3.91. This material shows a marked curl after being stiffened, since it is out according to the equation by 1.002 units in the warp. The reason for the heavy warp yarns in this fabric is that high warp strength is required, and the reason for the light filling yarns is that the weight of the finished product must not exceed certain definite limits. A direct application of the equation (in accordance with my co-pending application Ser. No. 512,211) teaches only that this curl can be avoided by increasing the filling count (which cannot be done here since it would increase the weight of the fabric) or decreasing the warp count (which cannot be done because it would decrease the warp tensile strength) or heavying up on the filling yarn (which cannot be done because it would increase the weight of the fabric) or lightening up on the warp yarn (which cannot be done because it would decrease the warp tensile strength). It would be possible to decrease the curling characteristics of this product by increasing the tightness of twist in the filling yarns and by decreasing the tightness of twist in the warp yarns. The latter would have to be held at a minimum since any significant decrease would significantly decrease the warp tensile strength. On applying the equation it is found that if the filling twist multiple were increased all the way to 6.00, the fabric would still be out by 0.699 unit in the warp, which would be sufficient to generate a very objectionable curl.

In this case, to satisfy the above conditions, the only satisfactory way to eliminate the curl is to include some reverse twist yarns in the warp. On application of the equation, it is found that the warp value is 1.459, the filling value being 0.457. By setting the warp side of the equation equal to this filling value and solving for E, it is found that 18.6 warp yarns per inch will exactly balance the 51.4 filling yarns per inch. Subtracting 18.6 from 59.4, the remainder of 40.8 warp yarns must be balanced between themselves, which means that they must be evenly divided into S and Z-twist yarns. In other words, if the filling is unidirectional with a Z-twist, almost exactly two-thirds of the warp yarns should also be Z-twist, the remaining one-third being S-twist in order to produce a fabric which is substantially balanced according to the equation. If the warp yarns are drawn in ZZS, ZZS, ZZS, etc., with a total sley of 59.4 (39.6Z and 19.8S), a non-curling fabric is produced which exactly satisfies the stipulated fabric specifications and that is out in the warp by only 0.029 unit.

Example II

A fabric for use as a base cloth which will not curl after being impregnated with phenol form-

aldehyde and the resin then set can be made with a standard count of 80 x 60 using 30's yarns with a twist multiple of 4.18 in the warp and 40's yarns with a twist multiple of 3.29 in the filling. When the equation was applied to this fabric, using an actual end count of 79.8 x 59.3, and actual yarn numbers of 30.05's and 40.32's, it is found that the warp has a value of 1.804 units and the filling a value of 0.620 unit, giving a fabric which is out in the warp by 1.184 units. If the filling value of 0.620 is substituted in the warp and that side of the equation is solved for E, it is found that 27.4 warp ends are necessary to balance the curling effect of the filling yarns. The balance of the warp yarns numbering 52.4 must be divided evenly between S and Z and thus balanced against each other in order to produce a fabric which is entirely free from curl. Simplifying, if the filling is woven from 100% Z-twist yarns and the warp has two Z-twist yarns for every one S-twist yarn—the warp pattern being SZZ, SZZ, etc., a non-curling stiffened fabric cloth is produced which, according to the equation, is out by only 0.019 unit in the filling. This example is well suited for the manufacture of radio spiders.

Example III

A base cloth for laminated sheets and tapes may be made from an 88 x 40 (actually 87.8 x 39.7) construction, using 25.03's yarns in the warp with a twist multiple of 4.52 and 39.87's yarns in the filling with a twist multiple of 3.28. The equation shows that this fabric has a warp value of 2.903 and the filling has a value of 0.422, giving a fabric which is out by 2.481 units in the warp. Solving the equation in accordance with the system used in the two previous examples, I find that 12.8 warp ends are necessary to balance the filling, and the remainder of the warp ends should be equally divided between S and Z-twist yarns. Theoretically this calls for a filling which is unidirectionally Z-twist and a warp containing 50.3 ends of Z-twist and 37.5 ends of S-twist every inch. This is approximately a ratio of 4Z to 3S, or one yarn in seven is unbalanced. The pattern in this case is ZSZSZSZ, ZSZSZSZ, etc. Applying the equation to this fabric using a pick count of 87.8 shows that it is out by only 0.007 unit in the filling.

Example IV

A 68 x 56 non-curling organdie is produced as follows: In this fabric the actual end count is 67.8 x 55.4, the warp yarns being 60.31's with a twist multiple of 6.71 and the filling yarns 80.22's with a twist multiple of 6.03. Applying the equation to this fabric indicates that it is out by 0.468 unit in the warp, the filling having a value of 0.371. Solving for the warp yarns as before, we find that 30.0 ends are required to balance the filling, and therefore the balance of 37.8 should be equally split into S and Z-twist yarns. This gives a ratio of almost exactly 5 Z-twist yarns to every two S-twist yarns in the warp providing that the filling is all Z-twist. Using a warp pattern of SZZZSZZ, SZZZSZZ, etc., therefore, a non-curling organdie fabric can be woven to the desired specifications which is out by only 0.012 unit in the filling according to the equation.

Example V

A three-leaf filling twill using novelty yarns in the filling which after fusing is suitable for use as an interlining fabric in heavy clothing is made with an actual end count of 69.5 x 71.3. The warp will consist of 22.60's yarns with a twist multiple of 4.50. The filling yarns will be combined by putting together as a group or separately alternately weaving by a box loom a 13.91's yarn with a twist multiple of 3.75 carrying with it some other yarn of opposite twist which is heavy enough and twisted tightly enough to produce a fabric which will not curl. The equation shows that the warp value for this fabric is 2.689, and the filling value contributed by the 13.91's is 4.864. This means that the additional yarns in the filling must contribute a negative filling value of 2.175 equation units. If I set 2.175 equal to the filling side of the equation, substituting 3.50 as a reasonable twist multiple and solve for the weight of the unknown filling yarns to be used, I find that these should be 22.09's reverse twist in order to produce a fabric which will not curl. Such a fabric would be out in the filling by 0.001 unit.

Example VI

A mosquito netting with a leno weave which will not curl after being stiffened with one of the permanent stiffening agents such as are described heretofore in this application, is made up as follows: This fabric will have a theoretical end count of 28 x 14, using 29.93's yarns with a twist multiple of 4.60 in the warp and 31.88's yarns in the filling with a twist multiple of 3.82. The actual end count of this fabric is 27.7 x 13.5. The warp value according to the equation is 0.701, the filling value being 0.250. This gives a fabric which is out by 0.451 unit and curls significantly. Solving for the warp ends as before, I find that 9.9 warp ends per inch are necessary to neutralize the curling effect of the filling yarns. The balance of the warp ends should be equally divided between S and Z-twist. This result suggests a very simple warp pattern in which two Z-twist yarns are tied in for every one S-twist yarn providing that the filling is 100% Z-twist. Applying the equation once more to this over-all result indicates that the fabric will be out by only 0.016 unit in the filling.

Example VII

A warp twill fabric useful as an interlining and in various industrial applications which will not curl after being stiffened is made with an actual end count of 72.0 x 41.7. The warp yarns are 7.75's with a twist multiple of 4.90, the filling yarns being 12.03's with a twist multiple of 3.52. Applying the equation I find that this fabric is out by 12.66 units in the warp, and that 15.0 warp ends are sufficient to entirely neutralize the curling effect of the filling yarns. If the filling is entirely Z-twist, this calls for drawing in the warp in such a way that 43.5 ends per inch are Z-twist and 28.5 ends per inch are S-twist. There is no simple warp pattern which is apparent around these two figures, so I arbitrarily lift the Z count in the warp to 45.0 and depress the S count to 27.0. This permits a fairly simple warp pattern in which five Z's are drawn in with every three S's. However, it produces a fabric which is out in the warp by 0.63 unit, which is enough to produce a significant curl after any thorough stiffening treatment. Accordingly, it is here necessary to make one final adjustment. The warp twist multiple which was originally set at 4.90 is dropped to 4.20 to further reduce this warp value. According to the equation this gives a warp value of 3.414, leaving a fabric which is out by only 0.078 unit in the warp.

The base or unstiffened fabrics made in ac-

cordance with this invention may conveniently be tested and compared from the standpoint of curl by cutting small five inch squares therefrom, impregnating such squares with a test solution (suitable for the character of the fibres and yarns to be stiffened therein), hot ironing the same, and then noting their deformation under standard conditions, for example, by noting the rise or elevation of any corner from a horizontal supporting surface. The preferred and most searching test for fabrics of cotton and/or viscose rayon is by first impregnating the fabric in a solution made up as follows:

	Parts
Bakelite solution (XR568—partially polymerized phenol formaldehyde solution, 40% Bakelite, 60% methyl alcohol)	4
Methyl alcohol	1
Water	5

The pick-up of the solution by the fabric may, for example, be from 125 to 150% by weight (on the weight of base fabric). The sample is then pressed between two heated metallic surfaces (net total pressure 10 lbs.) and a temperature of approximately 150° C., for 60 seconds in order to completely polymerize and set the resin. The sample is then at once removed and placed without restraint on a horizontal surface, such as a table, and promptly observed. Since this test is so searching, as a practical matter, fabrics so tested may be regarded as having substantially no tendency to curl if the sample remains substantially extended and no corner thereof rises more than 1 to 1½ inches above the supporting horizontal surface upon which it was placed. Fabrics made in accordance with the preferred practice of this invention are well within the amount mentioned. Most of the stiffening or fusing solutions hereinbefore referred to as employed in ordinary commercial applications as practiced in the cloth-finishing trade, will not cause the rise of a corner of a five inch square more than ½ to 1 inch above the supporting horizontal surface.

It will be clear from the foregoing that this invention provides novel fabrics and novel methods of making such products with equipment and materials commonly available, and that the nature of the invention is such that these goods can be produced at an entirely reasonable cost. While I have herein disclosed typical fabrics embodying this invention and suitable methods of making them, it will be understood that the invention is susceptible of embodiment in a great variety of forms within its spirit and scope, and that minor departures may be made from the methods above described while still following the essential teachings of the invention.

Having thus described my invention, what I desire to claim as new is:

1. A textile material of the class described comprising a stiffened mainly cellulosic woven fabric having substantially no tendency to curl after hot ironing, composed essentially of a set of uniform-sized warp yarns and a set of filling yarns, with both sets uniformly dispersed and arranged throughout the body of the fabric, one of said sets consisting of yarns substantially all of unidirectional twist, the other of said sets having yarns of opposing directions of twist including a substantial number of yarns of each direction of twist but consisting mainly of yarns of the same direction of twist as said set of unidirectional twist, said set with opposing directions of twist neutralizing the fabric curling tendency of said set of unidirectional twist by means of a part of its yarns of the same direction of twist, said part of its yarns being so related to said set of unidirectional twist with respect to twist multiple, yarn number and end count as to produce substantially the equality represented by the equation.

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling, respectively, the remaining yarns of said opposing twist set of yarns being substantially half Z-twist and half S-twist.

2. A textile material of the class described comprising a stiffened mainly cellulosic woven fabric having substantially no tendency to curl after hot ironing, composed essentially of a set of uniform-sized warp yarns and a set of filling yarns, one of said sets being lesser in number of ends per inch of fabric than the other of said sets, with both sets uniformly dispersed and arranged throughout the body of the fabric, one of said sets consisting of yarns substantially all of unidirectional twist, the other of said sets having yarns of opposing directions of twist including a substantial number of yarns of each direction of twist but consisting mainly of yarns of the same direction of twist as said set of unidirectional twist, said set with opposing directions of twist neutralizing the fabric curling tendency of said set of unidirectional twist by means of a part of its yarns of the same direction of twist, said part of its yarns being so related to said set of unidirectional twist with respect to twist multiple, yarn number and end count as to produce substantially the equality represented by the equation.

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling, respectively, the remaining yarns of said opposing twist set of yarns being substantially half Z-twist and half S-twist.

3. A textile material of the class described comprising a stiffened mainly cellulosic woven fabric having substantially no tendency to curl after hot ironing, composed essentially of a set of uniform-sized warp yarns and a set of filling yarns, one of said sets being lesser in number of ends per inch of fabric than the other of said sets, with both sets uniformly dispersed and arranged throughout the body of the fabric, the set of filling yarns consisting of yarns substantially all of unidirectional twist, the other of said sets having yarns of opposing directions of twist including a substantial number of yarns of each direction of twist but consisting mainly of yarns of the same direction of twist as said set of unidirectional twist, said set with opposing directions of twist neutralizing the fabric curling tendency of said set of unidirectional twist by means of a part of its yarns of the same direction of twist, said part of its yarns being so related to said set of unidirectional twist with respect to twist multiple, yarn number and end count as to produce substantially the equality represented by the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling, respectively, the remaining yarns of said opposing twist set of yarns being substantially half Z-twist and half S-twist.

4. A textile material of the class described comprising a stiffened mainly cellulosic woven fabric having substantially no tendency to curl after hot ironing, composed essentially of a set of uniform-sized warp yarns and a set of filling yarns, the latter of said sets being lesser in number of ends per inch of fabric than the other of said sets, with both sets uniformly dispersed and arranged throughout the body of the fabric, the set of filling yarns consisting of yarns substantially all of unidirectional twist, the other of said sets having yarns of opposing directions of twist including a substantial number of yarns of each direction of twist but consisting mainly of yarns of the same direction of twist as said set of unidirectional twist, said set with opposing directions of twist neutralizing the fabric curling tendency of said set of unidirectional twist by means of a part of its yarns of the same direction of twist, said part of its yarns being so related to said set of unidirectional twist with respect to twist multiple, yarn number and end count as to produce substantially the equality represented by the equation.

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling, respectively, the remaining yarns of said opposing twist set of yarns being substantially half Z-twist and half S-twist.

5. The method of producing a non-curling, mainly cellulosic woven fabric which comprises spinning, selecting, and weaving a set of uniform warp yarns and a set of uniform filling yarns, one of said sets being of unidirectional twist and the other set including yarns of opposing twist, with the twist multiple, yarn size and end count in one set, and the twist multiple, yarn size, end count and same twist direction of a part only of the other set, all determined and the fabric woven in substantial conformity with the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarn size, E equals end count, and w and f refer to warp and filling, respectively, the different characteristics of yarn and yarn arrangement specified in the equation being adjusted to produce substantially the equality represented by the question, the balance of the yarns of said other set being substantially half Z-twist and half S-twist, said fabric having its respective warp and filling yarns uniformly dispersed and arranged throughout the body of the fabric.

6. The method of producing a non-curling, stiffened, woven mainly cellulosic fabric which comprises spinning, selecting, and weaving a set of uniform warp yarns and a set of uniform filling yarns, one of said sets being of unidirectional twist and the other set including yarns of opposing twists, with the twist multiple, yarn size and end count in one set, and the twist multiple, yarn size, end count, and same twist direction of a part only of the other set, all determined and the fabric woven in substantial conformity with the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarn size, E equals end count, and w and f refer to warp and filling, respectively, the different characteristics of yarn and yarn arrangement specified in the equation being adjusted to produce substantially the equality represented by the equation, the balance of the yarns of said other set being substantially half Z-twist and half S-twist, said fabric having its respective warp and filling yarns uniformly dispersed and arranged throughout the body of the fabric, and then stiffening at least some of the fibres of at least some of said warp and filling yarns by impregnation with a stiffening agent characterized during drying and setting by the evolution of water and finally drying the same, thereby materially stiffening said fabric.

7. A textile material of the class described comprising a stiffened mainly cellulosic woven fabric having substantially no tendency to curl after hot ironing, composed essentially of a set of warp yarns and a set of filling yarns, with both sets uniformly dispersed and arranged throughout the body of the fabric, at least one of said sets including a substantial number of yarns of each direction of twist and having a net fabric curling tendency opposing the opposite fabric curling tendency of the other set and substantially neutralizing the fabric curling tendency of said other set, the warp yarns being so related to the filling yarns with respect to twist direction and multiple, yarn number and end count as to produce substantially the equality represented by the equation:

$$\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w^3}}\right]_Z+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f^3}}\right]_S=\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w^3}}\right]_S+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f^3}}\right]_Z$$

where M equals twist multiple, N equals yarns number, E equals end count, w and f refer to warp and filling respectively, and Z and S refer to the respective directions of twist.

8. A textile material of the class described comprising a stiffened mainly cellulosic woven fabric having substantially no tendency to curl after hot ironing, composed essentially of a set of warp yarns and a set of filling yarns, with both sets uniformly dispersed and arranged throughout the body of the fabric, at least one of said sets including a substantial number of yarns of each direction of twist but consisting mainly of yarns of one direction of twist and having a net fabric curling tendency opposing the opposite curling tendency of the other set and substantially neutralizing the fabric curling tendency of said other set, the warp yarns being so related to the filling yarns with respect to twist direction and multiple, yarn number and end count as to produce substantially the equality represented by the equation:

$$\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w^3}}\right]_Z+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f^3}}\right]_S=\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w^3}}\right]_S+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f^3}}\right]_Z$$

where M equals twist multiple, N equals yarns number, E equals end count, w and f refer to warp and filling respectively, and Z and S refer to the respective directions of twist.

9. A textile material of the class described comprising a stiffened mainly cellulosic woven fabric having substantially no tendency to curl after hot ironing, composed essentially of a set of warp yarns and a set of filling yarns, with both sets uniformly dispersed and arranged throughout the body of the fabric, each of said sets including a substantial number of yarns of each direction of twist and having a net fabric curling tendency opposing the opposite fabric curling tendency of the other set and substantially neutralizing the fabric curling tendency of the other set, the warp yarns being so related to the filling yarns with respect to twist direction and multiple, yarn number and end count as to produce substantially the equality represented by the equation:

$$\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w{}^3}}\right]_Z+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f{}^3}}\right]_S=\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w{}^3}}\right]_S+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f{}^3}}\right]_Z$$

where M equals twist multiple, N equals yarns number, E equals end count, w and f refer to warp and filling respectively, and Z and S refer to the respective directions of twist.

10. A textile material of the class described comprising a stiffened mainly cellulosic woven fabric having substantially no tendency to curl after hot ironing, composed essentially of a set of warp yarns and a set of filling yarns, with both sets uniformly dispersed and arranged throughout the body of the fabric, each of said sets including a substantial number of yarns of each direction of twist but consisting mainly of yarns of one direction of twist, and having a net fabric curling tendency opposing the opposite fabric curling tendency of the other set and substantially neutralizing the fabric curling tendency of the other set, the warp yarns being so related to the filling yarns with respect to twist direction and multiple, yarn number and end count as to produce substantially the equality represented by the equation:

$$\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w{}^3}}\right]_Z+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f{}^3}}\right]_S=\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w{}^3}}\right]_S+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f{}^3}}\right]_Z$$

where M equals twist multiple, N equals yarns number, E equals end count, w and f refer to warp and filling respectively, and Z and S refer to the respective directions of twist.

11. A textile material of the class described comprising a mainly cellulosic woven fabric having substantially no tendency to curl after hot ironing, composed essentially of a set of uniformsized warp yarns and a set of filling yarns, with both sets uniformly dispersed and arranged throughout the body of the fabric, one of said sets consisting of yarns substantially all of unidirectional twist, the other of said sets having yarns of opposing directions of twist including a substantial number of yarns of each direction of twist but consisting mainly of yarns of the same direction of twist as said set of unidirectional twist, said set with opposing directions of twist neutralizing the fabric curling tendency of said set of unidirectional twist by means of a part of its yarns of the same direction of twist, said part of its yarns being so related to said set of unidirectional twist with respect to twist multiple, yarn number and end count as to produce substantially the equality represented by the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w{}^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f{}^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling, respectively, the remaining yarns of said opposing twist set of yarns being substantially half Z-twist and half S-twist, whereby the tendency of the sets of yarns to curl the fabric when stiffened by impregnation with a stiffening agent characterized during drying and setting by the evolution of water is neutralized and the fabric when stiffened is substantially non-curling.

12. A textile material of the class described comprising a mainly cellulosic woven fabric having substantially no tendency to curl after hot ironing, composed essentially of a set of warp yarns and a set of filling yarns, with both sets uniformly dispersed and arranged throughout the body of the fabric, at least one of said sets including a substantial number of yarns of each direction of twist and having a net fabric curling tendency opposing the opposite fabric curling tendency of the other set and substantially neutralizing the fabric curling tendency of said other set, the warp yarns being so related to the filling yarns with respect to twist direction and multiple, yarn number and end count as to produce substantially the equality represented by the equation:

$$\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w{}^3}}\right]_Z+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f{}^3}}\right]_S=\left[\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w{}^3}}\right]_S+\left[\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f{}^3}}\right]_Z$$

where M equals twist multiple, N equals yarns number, E equals end count, w and f refer to warp and filling respectively, and Z and S refer to the respective directions of twist, whereby the tendency of the sets of yarns to curl the fabric when stiffened by impregnation with a stiffening agent characterized during drying and setting by the evoluation of water is neutralized and the fabric when stiffened is substantially non-curling.

ROSS C. WHITMAN.

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Certificate of Correction

Patent No. 2,400,276. May 14, 1946.

ROSS C. WHITMAN

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Page 8, first column, line 59, claim 5, for the word "question" read *equation*; line 65, claim 6, for "woven mainly cellulosic" read *mainly cellulosic woven*; page 9, second column, line 63, claim 12, for "evoluation" read *evolution*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 3rd day of September, A. D. 1946.

[SEAL]

LESLIE FRAZER,
First Assistant Commissioner of Patents.