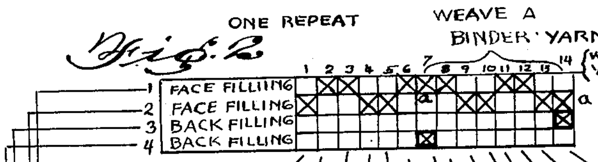
Dec. 16, 1952 — L. LOVE — 2,621,684

FILLING BACKED WATER RESISTANT, AIR PERMEABLE TEXTILE WEAVE

Filed April 6, 1950 — 6 Sheets-Sheet 1

Fig. 2



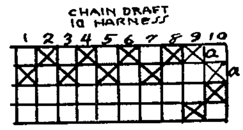


Fig. 3

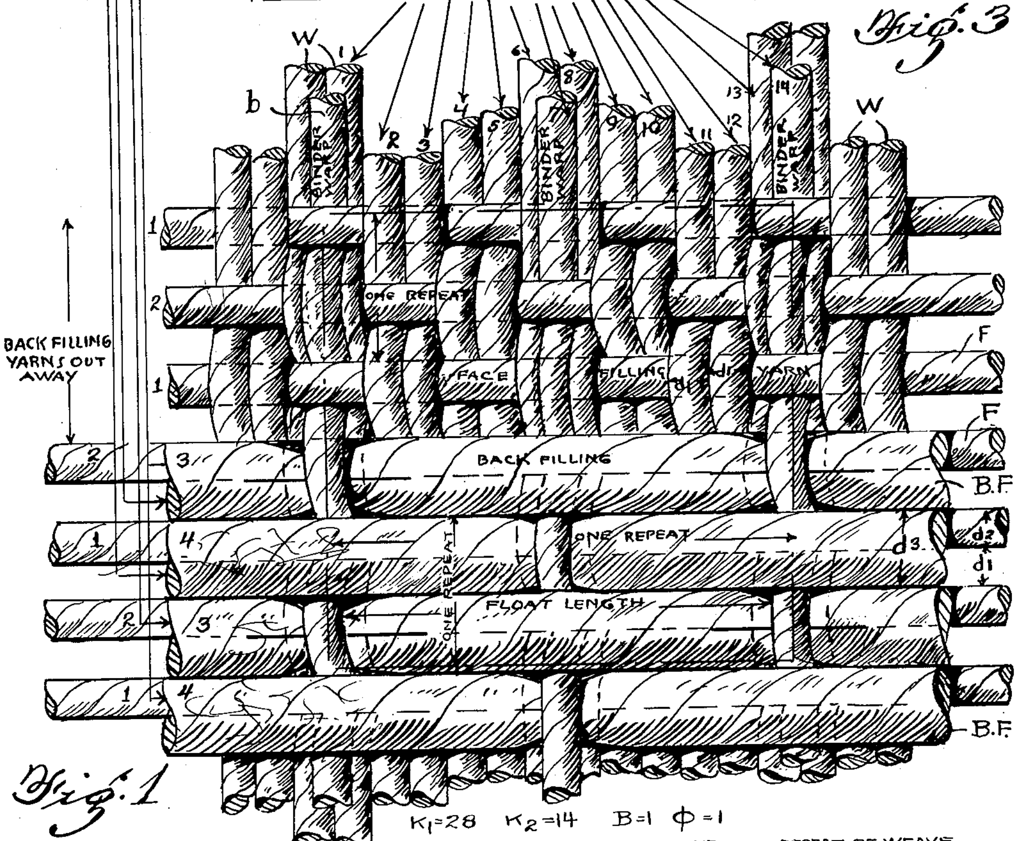


Fig. 1

$K_1=28$ $K_2=14$ $B=1$ $\phi=1$

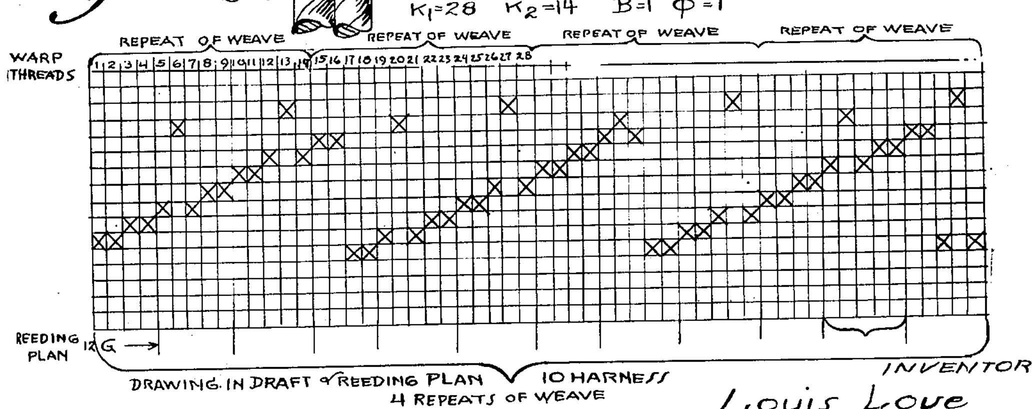


Fig. 4

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FILLING BACKED WATER RESISTANT, AIR PERMEABLE TEXTILE WEAVE

Filed April 6, 1950 6 Sheets-Sheet 2

Fig. 5

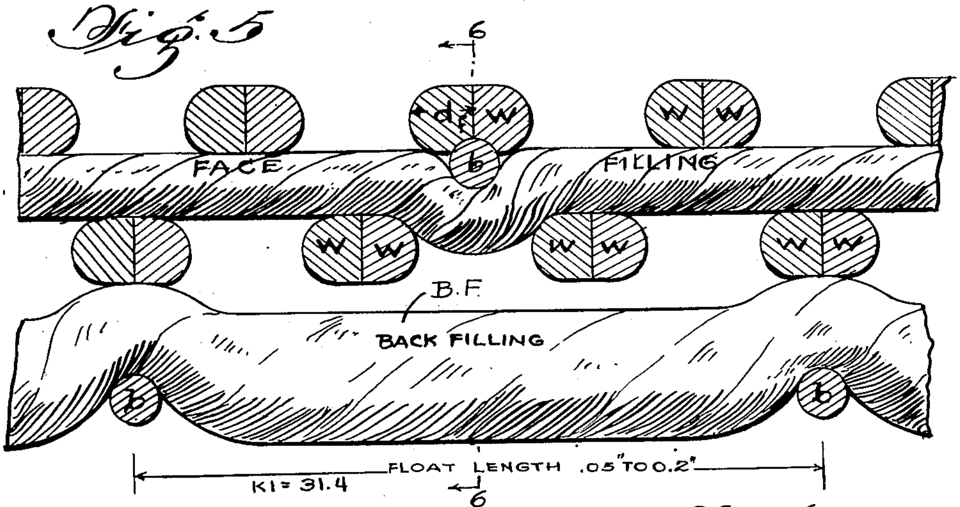


Fig. 6

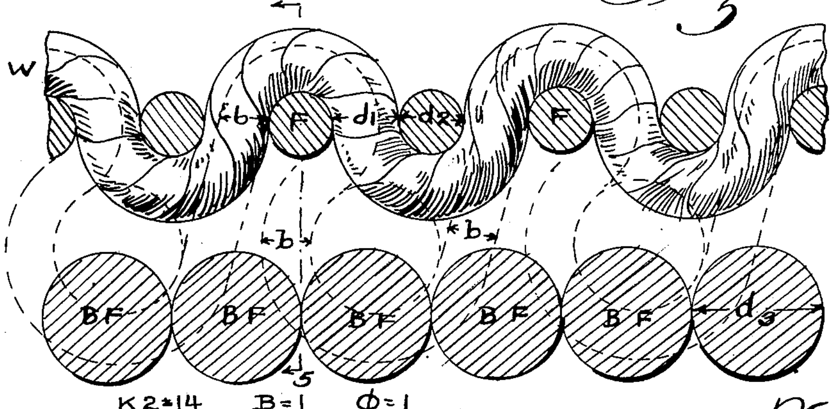
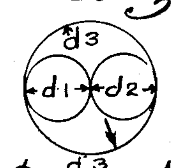


Fig. 7



$$\phi = \frac{d_3}{d_1 + d_2} = 1$$

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Dec. 16, 1952 L. LOVE 2,621,684

FILLING BACKED WATER RESISTANT, AIR PERMEABLE TEXTILE WEAVE

Filed April 6, 1950 6 Sheets-Sheet 3

Fig. 8

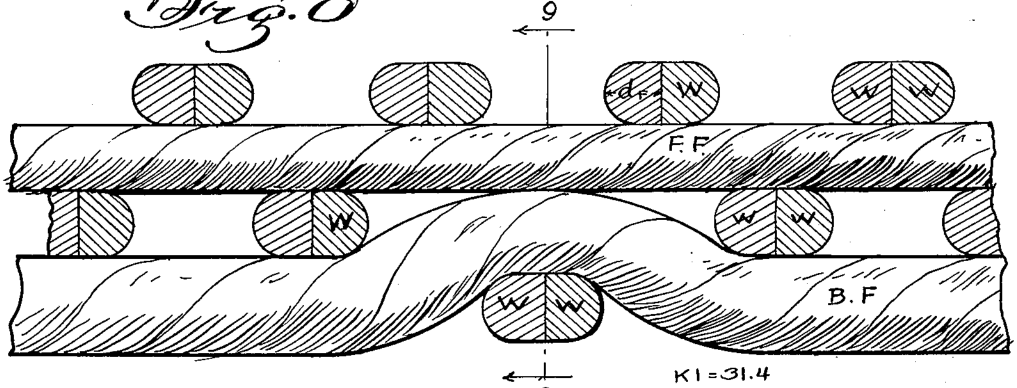


Fig. 9

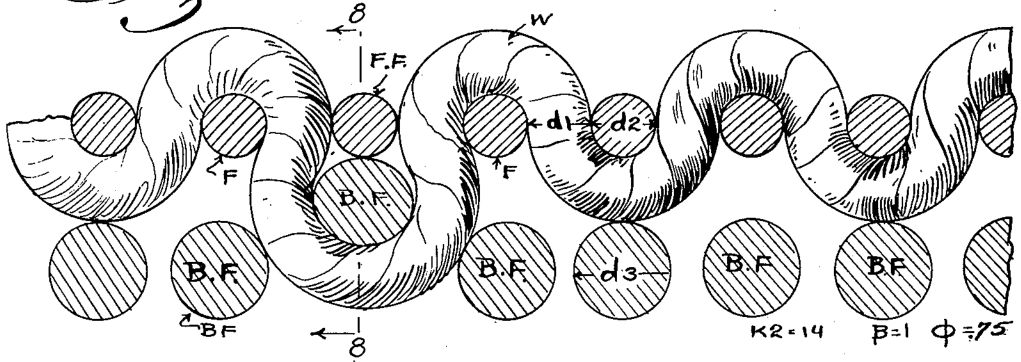
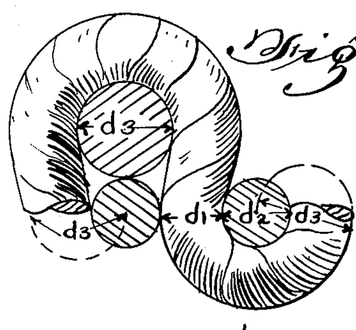


Fig. 10



$$\phi = 0.75 = \frac{d_3}{d_1 + d_2} = \frac{.6}{.4 + .4}$$

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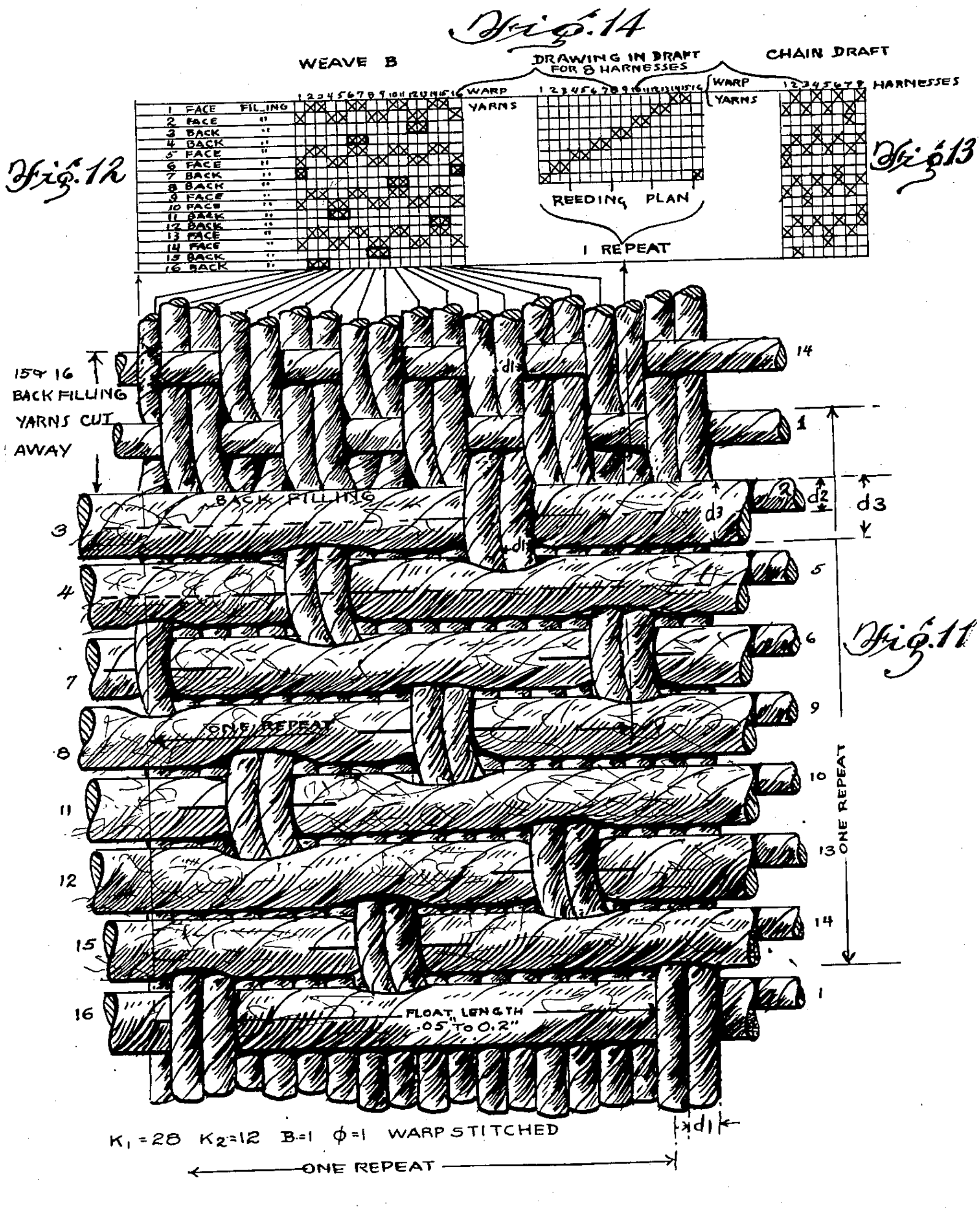
Dec. 16, 1952 | L. LOVE | 2,621,684

FILLING BACKED WATER RESISTANT, AIR PERMEABLE TEXTILE WEAVE

Filed April 6, 1950 | | 6 Sheets-Sheet 4



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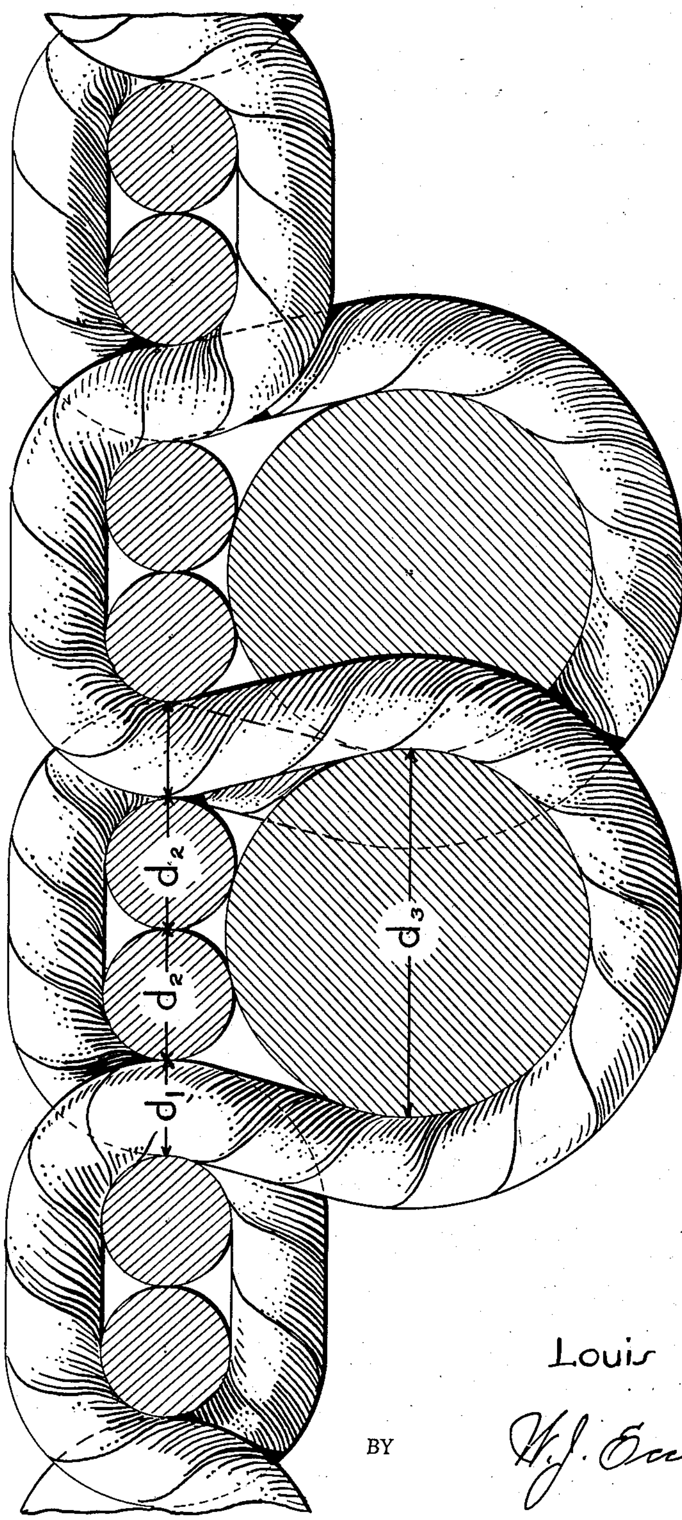
Dec. 16, 1952 L. LOVE 2,621,684

FILLING BACKED WATER RESISTANT, AIR PERMEABLE TEXTILE WEAVE

Filed April 6, 1950 6 Sheets-Sheet 5

Fig. 15



$$\Delta = \frac{d_3}{d_1 + 2d_2}$$

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FILLING BACKED WATER RESISTANT, AIR PERMEABLE TEXTILE WEAVE

Filed April 6, 1950 6 Sheets-Sheet 6

FACE WEAVE

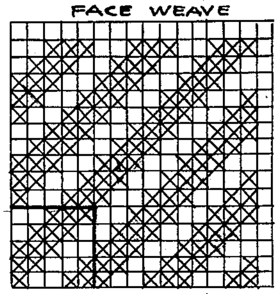


Fig. 16

CHAIN DRAFT WOVEN FACE DOWN

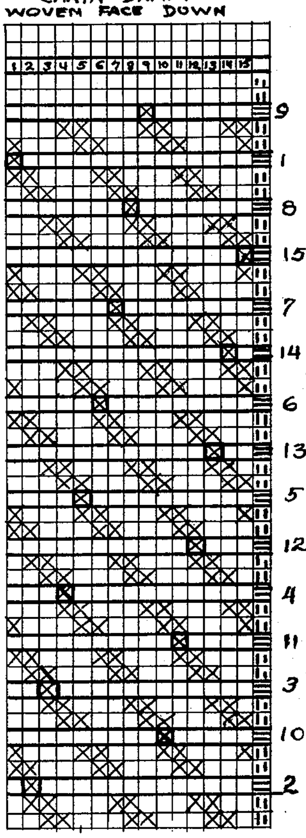


Fig. 17

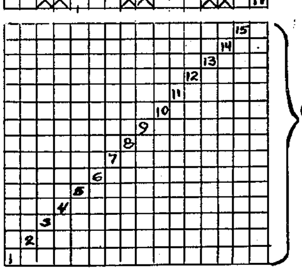


Fig. 18

HARNESS DRAFT

Fig. 19

FACE WEAVE

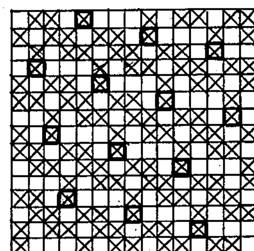
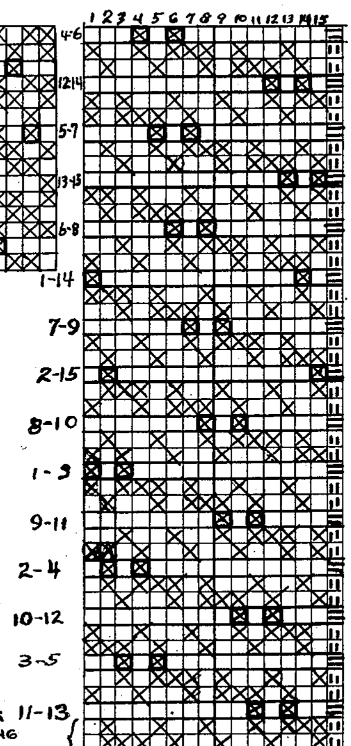


Fig. 20

CHAIN DRAFT WOVEN FACE DOWN



= = BACK FILLING
|| = FACE FILLING

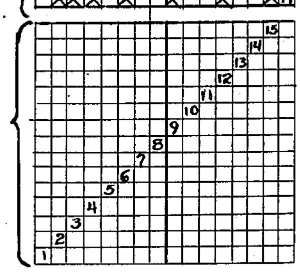


Fig. 21

HARNESS DRAFT

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Patented Dec. 16, 1952 2,621,684

UNITED STATES PATENT OFFICE

2,621,684

FILLING BACKED WATER RESISTANT, AIR PERMEABLE TEXTILE WEAVE

Louis Love, Philadelphia, Pa.

Application April 6, 1950, Serial No. 154,394

12 Claims. (Cl. 139—413)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

1

The invention described herein, if patented, may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

This invention relates to the production of textile fabrics which are water resistant, and more particularly to composite fabrics constructed of filling backed principles, which are so designed as to effectively utilize constituent yarns of selected characteristics in constructions of near maximum cover and density within certain critical limits.

In the prior art, composite fabrics using filling backed, warp backed, double or treble principles of fabric construction have been employed for the purpose of increasing the warmth retaining qualities of cloth, and in order to secure greater weight and substance than can be obtained in a single structure which has equally fine yarns on the surface. Other known purposes of employing backed or double structures are those of appearance and a combination of appearance and weight, examples of the latter being known as reversibles, in which warp backed or double cloth structures are employed in order to provide different coloring or effects on the two sides of the cloth. These prior art constructions possess neither the principles of cloth construction which have been applied in the present invention nor do they possess the desired property of water resistance of the order or class herein disclosed by a construction within the range of critical tolerances specified, together with high thermal insulation, air permeability, shrink resistance, durability and other properties as are herein described.

One of the objects of my invention is to provide a fabric for a self-lined garment or cover, which would afford physiological comfort when worn over a wide range of climatic conditions without the need for additional protective clothing.

One of the principal factors considered in defining a fabric combining qualities which have long been sought, is the factor of superior water resistance and softness and pliability without precluding what might be termed a breathing type of fabric, which is air permeable.

A further quality of the fabric is that it affords high heat insulating properties in addition to being water resistant with a minimum of weight and maximum thickness, as compared to other textiles by which it was sought to attain qualities.

These numerous advantages and features are obtained as a composite form in a single integrated fabric without the necessity for use of a plurality of separate independently woven fabrics each having been designed separately to have one of the advantageous qualities desired. In an effort to approximately or even remotely approach the numerous qualities above-mentioned of my integrated fabric, in accordance with prior art teaching, it was necessary to bring together the plurality of independently woven fabrics in such a relation, for example, as an outer garment (fabric) to afford the quality of water resistance, and an inner one, such as a lining to provide warmth or heat insulating properties. Of course, suitable additional means were also required, in prior art garments to secure the lining material in either permanent or detachable relation with the outer material.

2

So far as the inventor is aware no integrated composite fabric of a single weave has been produced in the priort art, which is like the fabric herein disclosed, relative to the critical requirements to obtain a fabric of minimum weight and maximum thickness and yet retain the qualities of water resistance and warmth in a fabric that can be practically woven by employing ordinary type yarns readily available, and by utilizing the ordinary skill and care with the usual types of machines in weaving.

As to the matter of comfort of the wearer of a water resistant article of wearing apparel, a woven fabric which has the property of air permeability, or otherwise expressed, which permits a certain amount of "breathing" action to take place to afford ventilation of the moisture vapor from wet clothing, as well as the normal skin moisture and perspiration, is far superior to a garment employing a continuous film or coating of rubber, plastic or petroleum resinous material, natural or synthetic. The continuous film, either as a coating or as a laminating film serves as a barrier to exclude water or vapor moisture, but by like token such continuous film precludes the essential property of air permeability or the "breathing" quality of the woven water resistant fabric.

As a further instance to illustrate the importance of critical factors in the choice of materials and the geometry of design and the proportioning of various factors in weaving, so as to obtain a woven fabric which is water resistant and repellent but yet air permeable and which possesses at the same time the requisite softness, pliability and draping properties, reference might be made to a fabric such as water resistant duck or canvas, which because of its stiffness and lack of draping qualities and lack of other desirable qualities as well, would be wholly unsuited for use as a garment of wearing apparel, except for special uses for short periods of time during which comfort is of secondary importance.

It is known that the degree of water resistance of these prior art fabrics is greatly dependent upon the fineness of their interstices, and that in the construction of these prior art fabrics, a sacrifice of softness, pliability and draping quality was made in the effort to secure a complete closure by forcing the component yarns into very close and jammed constructions.

I have discovered that the water resistance of a fabric is dependent not only upon the size of the interstices, but also upon the resilient characteristics of the material serving as a support for the water barrier, and that by providing a suitable material as a support for the water barrier in the form of an integrated backing, I have been able to obviate the necessity for the complete closure of the interstices of the facing fabric and thus permit the construction of highly water resistance fabrics which would be soft and pliable and suited for use as wearing apparel.

The present invention contemplates a composite integrated fabric structure in which the constituent yarns of selected characteristics are so arranged and proportioned within critical tolerances as to present fine interstices with fine yarns on the face of the fabric, while providing a uniformly dense cover of a resilient pile-like material on the back, the thickness of the pile-like backing being greater than that of the facing; the relative thickness of the pile-like backing being an important factor in contributing not only to the attainment of superior water resistance of the composite fabric structure but also to its economic feasibility in view of the fact that such thicker resilient pile-like backing would provide many additional desirable properties; properties, hereinafter more particularly set forth, which no other single or integrated fabric is known to possess.

The physical effect of a relatively thickly napped backing on the water resistance of a fabric whose construction details are embodied in my invention, is that it presents a thick, resilient undersurface to absorb the shock of falling raindrops on the tightly woven but still soft and pliable face fabric, thus greatly delaying breakthrough by the raindrops. It is well known that the transmission of water through a fabric is greatly increased when the undersurface is touched or rubbed. This may be explained by the capillary action of water and must be considered in the evaluation of a water resistant fabric. By providing a lofty, light, homogeneous resilient fibrous understructure, my invention prevents this capillary or wicking action by protecting the undersurface of the face fabric from being rubbed or touched.

The shrink resistance of a fabric in accordance with the present invention is aided by construction details which call for the maximum density of the component yarns. Separate linings are usually more loosely woven and have poor shrinkage properties. An integrated lining, as presented by my invention, is prevented from undesirable shrinkage by the numerous points of interlacing to the stable outer fabric, thus eliminating the distortion of a garment that would occur if a separate lining would shrink more than the outer fabric.

Significance of air permeable, water resistant fabric having a napped pile-like backing

There is a distinct advantage and value in providing a soft, pliable water resistant and repellent woven face of the fabric, having desirable draping qualities, in combination with the fibrous backing formed from the closely spaced, larger, soft spun, filling yarn suitably integrated and napped to provide by the open network of random raised fibers, a comparatively thick, resilient under-surface affording a continuous layer of substantially uniformly distributed, random-shaped air cells in communication with the air-permeable water resistant woven face of the fabric. A further factor contributing to the thermal insulating quality is the more stable air film and layer, entrapped between the face weave and the back filling, where it is not subject to displacement by the normal convective flow of air currents at the surface boundaries of the woven fabric. An effectively entrapped air film within a tight weave would resist displacement by convective wind velocities even though the direction of flow may exert a substantial pressure in a vector at right angles to the fabric surface, say, for example, by wind velocities of from 20 to 30 miles per hour (M. P. H.).

This uniform distribution of the layer of air cells within the fibrous brushed pile-like backing throughout the backing area of the woven facing, together with the trapped air film or layer within the weave between the back filling and the face weave, constitutes an important feature or factor contributing to the production of what may be termed a breathing type of woven, water resistant fabric, having such property independent of and apart from any special treatment by water repellent composition or method. So far as applicant knowns, or has been advised, this is the first water resistant, air-permeable, woven fabric which has such desirable qualities of pliability and draping as to render it suitable for practical manufacture and use as a garment or article of wearing apparel that could be practically and economically made to specifications as to quality of yarn, control of spinning and weaving, that could be satisfactorily met, by American mills.

A further object of providing a textile having a weave, including certain physical details within prescribed critical geometric relationships as described below, is to provide a cotton face, high warp textured, Oxford weave fabric with a wool backed, napped filling, which in addition to properties of high thermal insulation, also possesses properties of shrink resistance following wetting and laundering, greater durability, and a high degree of test performance in the drop penetration test which is suitable for predicting rain resistance.

The term "greater durability" as here used is intended as a general term to embrace the concept of serviceability over an extended period of time during which the fabric is subjected to the usual wear and tear in ordinary use and service, including that of washing and laundering, after which the fabric, by recognized laundering tests has demonstrated its fitness by retaining its properties of water repellency and resistance to water and rain penetration.

While it is desirable to treat the fabric with a water repellent such as by a stearamido methyl pyridinium chloride (sold commercially and available under the trade names "Zelan" and

"Norane") tests have demonstrated and established the fact that certain of the important and characterizing features of the woven fabric, namely, those features of water repellency or resistance to rain penetration and the related resistance to drop penetration as revealed by the drop penetration test, and the draping properties and air permeability, are not dependent upon any particular water repellent treatment, durable or non-durable. Such water repellent treatments can be dispensed with, and the integrated fabric of this invention will still possess good water resistance.

In the art, the above Zelan treatment has been referred to as a "durable" type of water-repellant treatment for fabrics; it is not a permanent type of treatment. The composition and the method employed in the Zelan water repellant treatment of fabrics is understood to be set forth in the following three patents: No. 2,131,362; 2,147,392; and 2,278,417.

If desired, other types of water-repellant treatment generally recognized as being of a non-durable type, may be used. Examples of the non-durable water-repellant type are:

(*a*) The use of various compounds of waxes and oils of vegetable, animal or mineral origin; and

(*b*) The rosin-metal soap types, such as the aluminum soap type, of which there are several on the market, under various trade names.

In fabrics treated with any one of a number of the non-durable type of water-repellant agents, the water repellant action of the fabric is diminished by successive washing and laundering operations.

It is particularly important therefore that the water and rain repellant property of a fabric be present and effective by virtue of the fabric structure, resulting from the relation of the yarns, the materials, their relative sizes, and their integrated relation within critical ranges as determined by the weaving. In such a fabric, intended for use as a garment or article of wearing apparel, it is important and essential, in order to maintain these qualities of softness, and pliability of fabric which go to impart the acceptable draping properties, that in the method of weaving and in the finished woven fabric certain critical factors and constants be recognized and maintained, and that the various elements and factors involving the size, number and relation of the various yarns be substantially maintained within a specified critical tolerance range, in order to preserve those properties essential for a practicable, serviceable, and commercially acceptable product which will meet certain objective standards and recognized tests.

In carrying out the present invention, yarns of suitable characteristics are used which may be of regularly twisted cotton or spun synthetic yarns for the facing, and soft spun wool or spun synthetic yarns, alone or in combination, for the backing. If wool or any other highly shrinkable material is used exclusively, or as the major component of a blend, for the backing yarns, it is necessary in the interests of the appearance of the finished fabric that these yarns be treated to resist shrinkage. The shrinkage characteristics of wool are well known, and the use of untreated wool yarns would seriously detract from the appearance of the more stable face fabric by causing puckers after any wetting out treatment. The newer synthetics, many of which are inherently shrink resistant, may be used for back filling yarns alone, or as the major component of a blend with wool or other highly shrinkable textile material, without the need for a shrink resistant treatment. The wool yarns or other highly shrinkable textile materials may be treated to resist shrinkage by any of the well known methods used in best commercial practice in either stock or yarn form.

A fabric produced according to the present invention owes its superior water resistance as well as other desirable properties to a great extent to its structural form, which comprises yarns in an arrangement which permits the attainment by a very practicable method of a facing of near maximum cover and a high overall density in addition to a thicker backing of near maximum cover. In the description of fabrics produced under the present invention, it is convenient to employ geometric constants to define the relative sizes of the yarns, their arrangement, and their properly spaced relationship to each other within certain critical limits. By means of construction details which follow in the disclosure these yarns are practicably woven into fabrics possessing high water resistance and high thermal insulation value as shown herein by results of recognized tests.

The geometric constants that have been used in my invention are delineated in the attached drawings which are provided for purposes of illustration but not necessarily for limitation. Two types of fabric and a number of modifications are shown as embodying the invention, and employing materials and factors thereof within the critical tolerances defined, to effect the essential properties in the woven fabric of water resistance and air permeability, without sacrifice of softness and pliability in obtaining draping quality and thermal insulating quality. The two types or embodiments are herein referred to as fabrics "A" and "B" and have been woven and tested.

The terms used to describe the geometric constants used in my invention are cover factor (K), beta (β), phi (ϕ), and delta (Δ). Subscripts 1, 2, and 3, refer to the face warp yarns, face filling yarns, and back filling yarns, respectively. "N" designates the yarn number or size. "*n*" refers to the number of yarns per inch.

Cover factor (K) is defined as the ratio of the yarns per inch in the woven fabric, to the square root of the yarn size

$$\left(K=\frac{n}{\sqrt{N}}\right)$$

Maximum undistorted cover factor (K_m) defines the point at which the perimeters of adjacent yarns are calculated to touch by assuming these yarns to be undistorted flexible cylinders. The formulas for yarn diameters are

$$d=\frac{1}{K_m\sqrt{N}}$$

inches.

A maximum distorted cover factor (K_f) is possible in an Oxford weave construction due to the flattening of the paired warp yarns. Both distorted and undistorted values for maximum cover factors are listed below.

	Numbering system	K_m	K_f
Cotton	Inverse	28.00	31.40
Spun synthetic staple (In cotton numbering system.)	do	28.00	31.40
Worsted	do	22.80	25.60
Wool	do	15.42	17.28
Filamentous synthetics (In denier numbering system.)	Direct	2,300	2,577

β (beta) is defined as the ratio of the face filling yarn diameter to the face warp diameter.

$$\beta=\frac{d_2}{d_1}=\frac{\sqrt{N_1}}{\sqrt{N_2}}$$

ϕ (phi) is defined as the ratio of the back filling yarn diameter to the sum of the face warp and filling yarn diameters

$$\left(\phi=\frac{d_3}{d_1+d_2}\right)$$

Δ (delta) is defined as the ratio of the back filling yarn diameter to the sum of the diameter of the face warp yarn and twice the diameter of the face filling yarns.

$$\left(\Delta\text{ (delta)}=\frac{d_3}{d_1+2d_2}\right)$$

In the drawings:

Figure 1 is a composite view showing an enlarged fragmentary broken plan of a preferred type of weave herein identified as fabric "A," having a portion of the back filling yarns cut away in order to show more clearly the high warp texture Oxford type weave of the face, and the manner in which the floated, soft spun back filling yarn is interlaced by a series of separate binder warp yarns at spaced intervals within the range of from 0.05 to .2 inch, to the Oxford weave face fabric. This enlarged fragmentary view illustrates the various warp and filling yarns of the face and the backing, yarns to scale in the approximate relative sizes determined by the constants in the formulas are within the specified range and tolerances of the critical relations and factors, which constants in this figure are $K_1=28$, $K_2=14$, $\beta=1$, and $\phi=1$. A repeat of the weave is shown to consist of 14 warp yarns (12 face and 2 binder) and 4 filling yarns (2 face and 2 back). A repeat of the filling yarns is indicated by arrows on the back filling yarns, #3 and #4, and on the exposed undersurface, which these yarns would cover.

Figure 2 is a draft diagram on design paper showing one repeat of weave of fabric "A" shown in Figure 1. This is a figure separate from Figure 1, but for convenience of reference and understanding, the various face warp yarns and face and back filling yarn symbols are, by appropriate arrows, keyed to and identified with the corresponding yarns in Figure 1. In Figure 2, the various face warp yarns or "ends," are numbered from 1 to 14 in the vertical columns; the separate binder warp yarns are identified as 7 and 14, and are mounted on separate harness frames. The face filling and back filling yarns are symbolically represented by the horizontal rows numbered 1 to 4 at the left of Figure 2.

Figure 3 is a chain draft or pegging plan on design paper for 10 harness frames numbered in vertical columns from 1 to 10, used in weaving the weave "A" of Figures 1 and 2. The harness frames No. 9 and 10 carry the separate system of 2 binder warp yarns identified in Figure 2 in vertical warp columns Nos. 7 and 14. The diagram is here interpreted by the persons skilled in the art and familiar with such draft diagrams, to teach that harness frames Nos. 1, 3, 5, and 7 are simultaneously actuated to a raised position, while harness frames Nos. 2, 4, 6 and 8 are lowered, so as to interlace the face filling yarns, such as No. 2 (see Figures 1 and 2); the interlacing of face filling yarn No. 2 is more clearly shown in the upper portion of Figure 1 showing the back filling yarn removed.

Figure 4 is a drawing in and harness draft (on design paper) for 10 harness frames, and reed plan for four repeats of the weave design, of fabric "A" shown in Figures 1 and 2.

Figures 1, 2, 3 and 4 are to be interpreted by reference to each other in considering the weave of weave "A," in which an independent system of binder warp yarns (7 and 14 in Figure 2), are employed for interlacing the back filling yarns (3 and 4 in Figures 1 and 2). Figures 5 and 6 are other enlarged detail views of the weave of weave "A," which aid in the interpretation of the draft diagrams of Figures 2, 3 and 4.

Figure 5 is a section of weave "A" taken on the line **5—5** of Figure 6 showing the face warp yarns and the tie warp yarn in section; the face filling yarn and back filling yarn are in elevation, and shows the manner in which the back filling yarn is floated over twelve face warp yarns, for an extent of from 0.05 to 0.2 inch. This figure shows the various yarns in their relation to each other in a greatly enlarged but in substantially accurate scaled relation.

Figure 6 is a section of Figure 5 looking in direction of the arrows and taken on line **6—6** of Figure 5, showing the face filling and back filling yarns in section, and the face warp and warp tie yarn in elevation. This figure shows the respective yarn sizes in substantially correct scaled relation.

Figure 7 is an enlarged diagrammatic view graphically illustrating the relation between the three diameters of the yarns d_1, the face warp yarn, d_2 the face filling yarn, and d_3 the back filling yarn. This diagram also graphically emphasizes the significance of the constant ϕ (phi) equals unity in the formula

$$\phi=1=\frac{d_3}{d_1+d_2}$$

Figure 8 is an enlarged fragmentary section of weave "B" (shown in a plan view of Figure 17) taken generally on line **8—8** of Figure 9, showing the face warp yarns in section and the face filling and back filling yarns in elevation when the floated back filling yarn is interlaced by a pair of the face warp yarns to form a float upon fourteen face warp yarns.

Figure 9 is an enlarged fragmentary section of weave "B", taken on line **9—9** of Figure 8, showing the face filling and back filling yarns in section and the face warp yarns in elevation, thus showing the manner in which the face warp yarn interlaces the back filling yarn at certain float intervals within a range of tolerances specified for effective napping at from 0.05 to 0.20 inch.

Figure 10 is an enlarged fragment of that portion of Figure 9 showing the relation between the size and the lay of the three systems of yarn at the position of the fabric where the face warp yarn interlaces the floated back filling yarn; the view serves to emphasize by graphic representation the importance of the cover factor formula defining the constant phi (ϕ)=0.75 (in this particular illustrative example), in terms of the size (diameters) of the three systems of yarns, as in the formula

$$\phi=\frac{d_3}{d_1+d_2}=0.75$$

where the symbols are as hereinbefore defined.

Figure 11 is an enlarged diagrammatic view of a modified form of a fabric herein referred to as weave "B" in which the relative sizes of the three systems of yarns in the face warp, face filling, and back filling yarns are represented substantially to scale and in accordance with the values of the constants as follows: $K_1=28$; $K_2=12$; beta (β)=1 and phi (ϕ)=1. This view diagrammatically shows the undersurface with a portion of the back filling yarns removed to show the arrangement of the face warp and face filling weave, the comparative yarn diameters and the weave used to obtain this arrangement when woven face down. The numbered warp and filling yarns shown in the diagrams and drafts of Figure 14, follow the arrangement and numbers indicated in the weave "B," Figure 12. The weave draft design is conventionally constructed to show the weave to the person skilled in the art of reading and interpreting such draft diagrams. The weave of Figure 11 is identified as weave "B" to distinguish from the weave of Figure 1, identified as weave "A." Specimens of cloth were actually woven in accordance with weave "A" and "B" and tested as herein stated.

Figure 12 is a draft diagram from design paper showing one repeat of the weave "B", shown in Figure 11. This figure is separate from Figure 11, but for convenience of reference and understanding, the various face warp, and face filling or weft yarns, and back filling yarns, are, by appropriate numbers, keyed to and identified with the corresponding yarns in Figure 11. The interlacing of the various back filling yarns by the pair of adjacent warp yarns to form float lengths of from 0.05 to 0.20 inch, is indicated by the raised warp ends represented by the adjacent "X"S in blocks surrounded by the heavy band or outline.

Figure 13 is a chain draft or pegging plan for 1 repeat of the weave design shown in Figures 11 and 12, indicating to the person skilled in the art the order and sequence of operation of the 8 harness frames, identified by numeral 1 to 8 inclusive, to weave the design for one repeat, and to obtain the interlacing of the back filling yarns 3, 4, 7, 8, 11, 12, 15 and 16 (see Figures 11 and 12) by the various pairs of adjacent warp yarns on the independent harness frames.

Figure 14 is a drawing in draft design and reeding plan for one repeat of the weave design shown in Figure 11.

Figure 15 is an enlarged fragmentary view of that portion of the modified version of the fabric (weave "B") in which the face warp yarn falls below two successive filling yarns and interlaces one larger size back filling yarn. The view serves to emphasize by graphic representation the importance of the constant delta (Δ) in the ratio,

$$\Delta=\frac{d_3}{d_1+2d_2}$$

in which delta (Δ) defines the size of the back filling yarn in relation to the sizes of the face filling yarns. The size of the back filling yarn is important to the functional utility of a fabric produced under the present invention in which maximum density must be secured for a larger scale backing without detracting from the density or continuity of the weave of the face fabric.

Figures 16, 17 and 18 show the weave, chain and harness draft of a modified face weave in which the face warp yarns fall below two or more successive face filling yarns to permit the incorporation of one larger size back filling yarn in a two and one arrangement with the face filling yarns.

Figure 16 shows a 3/2 twill weave repeat, marked in with heavy lines carried out to a 15 warp yarn repeat in order to provide for a 15 warp yarn satin stitching arrangement for the back filling yarns (shown enclosed in the chain draft Figure 17) 15 warp ends in this case have been selected to provide a float length of from 0.05 to 0.2 inch, which may be considered suitable for effective napping.

Figure 17 is a chain draft or pegging plan of the weave of Figure 16, woven face down showing the manner in which the back filling yarn is interlaced with and by the various face warp yarns.

Figure 18 is the harness draft for the face weave design of Figure 16 showing 15 harness frames for the 15 warp yarns for each repeat of the design, one harness frame being provided for each warp yarn of each repeat. The harness frames are actuated in the manner and sequence indicated in Figure 17, the chain draft or pegging plan.

Figures 16 to 18 are to be considered as a group and in their relation to each other.

Figures 19, 20 and 21 show a 15 harness satin derivative weave. The 15 harness stitching arrangement shown encircled in the chain draft of Figure 20, may be used with 2 stitching yarns instead of 1, in order to bind the backing more securely.

Figures 19, 20 and 21 are to be considered as a group and show a modified species of the weave employing the various constants within the range of critical tolerance but employing a modified system of interlacing the back filling yarns to the face weave in which two face filling yarns are used for each back filling yarn. Each back filling yarn is interlaced with the face filling weave by a plurality of face warp yarns at non-uniform spaced intervals within any one weave repeat, so as to form float length of the back filling of variable and non-uniform length within any one repeat.

Figure 19 is a face weave design of the modified form referred to in the previous paragraph employing the chain draft or pegging plan as taught by Figure 20 to obtain the variable and non-uniform float length of any one yarn within one repeat of the weave design.

Figure 20 is the chain draft or pegging plan (woven face down) for making the face weave design of Figure 19, employing 15 warp yarns for one repeat, each warp yarn being independently actuated by a separate harness successively in combination with different harnesses during the same repeat of weave.

Figure 21 is harness draft to be considered in connection with Figures 19 and 20. There are 15 warp yarns for one repeat of the weave design, and each warp is carried on a separate harness frame.

The numbers to the left of Figure 20 and to the right of Figure 17 indicate the particular warp yarn and harness frame which is actuated to interlace the particular back filling yarn disposed in the horizontal line adjacent the particular number.

In Figures 16 to 21 inclusive the conventional symbols are employed. The "X" in a square indicates a raised warp or harness frame; on the face weave design the "X" in a square indicates a raised warp in the face of the weave, interlaced over a face filling yarn.

Explanation of certain figures showing two "X" symbols in vertical column representing one raised binder warp yarn.

In Figure 2, the "one repeat of the weave" of weave A, the binder warp yarns represented as warp ends or yarns 7 and 14, are each mounted on separate harness frames No. 9 and No. 10 (see Figure 3), so as to be actuated independently for interlacing with and over the back filling yarns No. 4 and 3, respectively. In Figure 2, in warp end No. 7, the "X" mark in the square opposite "No. 4 back filling" indicates that the binder warp No. 7 is in raised position and is at the surface of the weave of the cloth. The "X*a*" mark in the vertical column with warp yarn No. 7, and in the horizontal row "No. 1 face filling," is consistent with the showing of Figure 1 in which the face filling yarn No. 1 is below the back filling yarn No. 4 which, in turn, is below and interlaced by binder warp yarn No. 7. (See Figure 1 and Figure 2.) The second and upper "X*a*" symbol in the vertical row of binder warp No. 7 (see Figure 2), does not mean or symbolize a relation in which the No. 1 face filling yarn is in contact with or directly interlaced by the raised binder warp No. 7, which is in raised position (see Figure 2), on the harness frame No. 9 (see Figure 3) above the face filling yarn No. 1 as indicated by the symbol "X*a*" in vertical warp column No. 7. The back filling yarn 4 is directly interlaced by binder warp yarn 7; said back filling 4, is also above the face filling yarn 1, and is directly interposed between the binder yarn 7 and the face filling yarn 1.

The explanation in the previous paragraph, directed to an understanding and interpretation of these portions of the diagrams of the drafts on design paper showing one repeat of the weave, and chain draft, at those warp yarns which interlace with and tie in the back filling yarns 3, 4 which also covers a face filling yarn, is equally applicable to other figures such as Figures 11, 12, 16, 17, 19 and 20 in which, more than one "X" symbol appears in a vertical column representing any one warp yarn, which at a certain time during one repeat, is raised to a position to interlace with, and tie-in the back filler yarn, with the face warp yarns. It is not thought to be necessary to repeat the explanation of a fairly comparable situation which may exist in the other figures such as Figures 11, 12, 13, 16, 17, 19, and 20. The unfilled or blank squares, in horizontal rows in one repeat of weave, and harness draft diagrams, usually represent the filling yarn floated at the face or surface of the weave of the textile, with the warp yarn in interlaced relation below and under said filling yarn; this applies to the diagram of a draft design of one repeat of the weave, or harness draft of the common weave. The weave of the present textile is not the conventional simple weave but includes a back filling yarn floated on the back of a facing weave, which in turn includes a separate and independent system of face filling yarns (such as 3, 4 of Figures 1 and 2). The usual simple type of draft design diagram to show the conventional common weave cannot be used alone, but additional means must be provided to identify the back filling yarn, and indicate its relation to the other yarns, and to distinguish from the face filling yarn; it is essential also to indicate the manner and means employed for integrating the back filling yarn into the weave of the fabric to enhance the water resisting characteristics of the face weave. The conventional type of draft design diagrams have herein been modified sufficiently by appropriate symbols to clarify the disclosure.

In the absence of an enlarged view substanstantially to scale, for each of the modified forms, to show the weave and lay of each of the yarns, in the woven fabric, such as shown in Figures 1 and 11, the draft design diagrams of one repeat of the weave and harness draft will convey to the person skilled in the art sufficient information to enable him to set up the harness reed and heddle mechanism of the loom to weave the cloth in accordance with the manipulation of the harness and chain draft diagrams for one repeat of the weave design for the various modified forms hereinafter shown (see Figures 16 to 21).

Referring in greater detail to the drawings, Figure 1 is a composite view of the undersurface with a portion of the back filling yarns cut away showing the high texture warp yarns in the preferred type of fabric using the oxford weave for the face. In single fabrics of high warp textures, the oxford weave lends itself to the attainment of high overall densities essential to the water resistance of a fabric. In the present high warp textured fabric with an additional floated back filling of a defined size larger than the face filling, high overall density for the face of the fabric is best obtained with an oxford weave by employing a separate system of binder yarns. While various means and methods may be employed for effecting the uniform interlacing and integration of the back filling to and with the woven face, Figures 2, 3, and 4 showing the weave, chain and harness draft for one repeat of the weave, when properly understood and interpreted by the weaver skilled in and familiar with his art, is sufficient to indicate the sequence of manipulation of the warp and binder yarns to effect the particular form or method of uniform integration.

Figure 5 is a cross-sectional view of the warp yarns taken on the lines and looking in the direction of the arrows 5—5 of Figure 6, showing the position of the binder warp yarns (*b*). At 6—6 the binder warp yarn *b* is above the face filling, but remains hidden under the paired warp yarns W, thus presenting an unbroken oxford face weave effect. The adjacent binder yarns *b* are below the back filling yarns and show the manner in which the back filling yarn is floated for 12 face warp yarns. These adjacent binder yarns alternate weaving above and below successive face and back filling yarns as shown by the dotted lines in Figure 6.

Figure 6 is a cross-sectional view of the filling yarns, taken on the line and looking in the direction of the arrows at section 6—6 in Figure 5.

These Figures 5 and 6 show the various yarns in their relation to each other in greatly enlarged, but in substantially accurate scale. The warp cover factor $K_1=31.4$ and represents a constant, which when multiplied by the square root of the cotton yarn size or number, indicates the number of cotton yarns per inch to be used in order to obtain the flattened effect of the paired warp yarns. A fabric using a 36/2s cotton warp yarn with a cover factor of 31.4 would have approximately 133 yarns per inch

$$\left(31.4\times\sqrt{\frac{36}{2}}\text{ or }18\right)$$

A float of 12 threads of this number would therefore occupy a length of .0903 inch

$$\left(\frac{12}{133}\text{ inches}\right)$$

which falls within the prescribed limits of .05 to .2 inch—the specified range of float lengths desired for effecting napping.

Figure 6 also shows the yarn sizes in substantially correct scaled relation. The paired face warp yarns (w) may be observed to do most of the bending and weave with the face filling yarns (F) in a one up and one down arrangement, known as the oxford weave. It is shown that one-half of the perimeter of the contiguous face filling yarn F is interlaced by the face warp yarn (w). This relationship between the diameters of warp and filling yarns is supplied by the ratio β (beta) and for this example is shown to be 1 (one-unity), since the diameters of these yarns are equal.

The geometric principles used for the face oxford weave fabric to increase its water resistance require the maximum number of face filling yarns (n_2) that can be obtained with a given β (beta). The formula for approximating this maximum number per inch of the cloth in the inverse yarn numbering system is:

$$n_2\ (\text{max})=\frac{K_m\beta\sqrt{N_2}}{1+\beta}$$

in which

$$\frac{K_m\beta}{1+\beta}$$

equals the filling cover factor (k_2), and the desired β approximates 1.2. In Figure 6, β is shown to be 1.0. K_m is given for cotton at 28, and by substitution, the resultant filling cover factor $(K_2)=14$, which is a constant, when multiplied by the square root of the cotton filling yarn size, results in a close approximation of the maximum number of filling threads that can be placed in a fabric of maximum warp texture.

Certain of these principles are known in the art and have hitherto been applied only to single cotton fabrics for the improvement of their water resistance, but such cloth was not successful as lacking pliability and and draping quality and other disadvantages as herein noted.

In order to obtain a fabric having superior and outstanding water resistance, my invention provides for an additional system of closely spaced, larger, soft spun, back filling yarns suitably floated, and integrated and napped as a backing. Figures 1–6 have been presented to illustrate the relative positions, the relative sizes, and the spatial requirements of the various yarns used, and to designate the method of their integration into a stable, practical fabric. The following explanation and formulas are provided in order to present the means of reducing the scale of illustrated diagrams to the scale of a fabric in terms of yarn sizes, through the employment of constants (K) which express the relationship between construction variables such as yarns per inch (n) to the yarn size or number (N), and ratios β (beta), φ (phi), and Δ (delta), which define the relative sizes of the yarns used.

It may be seen in Figures 5 and 6 that the diameter (d_3) of the back filling yarn may be larger than the diameter (d_2) of the face filling yarn since the back filling yarns do not interlace as frequently with the face warp yarn. The size of the back filling yarn that may be used is provided for by the ratio ϕ (phi)$=1$ in the fromula

$$\phi=\frac{d_3}{d_1+d_2}$$

which, interpreted, means that the diameter of the back filling yarn (d_3) is equal to the sum of the diameters of the face warp yarn (d_1) and the face filling yarn (d_2). This relation is shown in Figure 1 in which the back filling yarn is shown to scale as being of a diameter equal to the sum of the diameters of the face warp and filling yarns respectively. Figure 7 is an enlarged diagrammatic view graphically illustrating the relation between the three diameters of the yarns, the face warp yarn (d_1), the face filling yarn (d_2), and the back filling yarn (d_3) where $(d_1)=d_2$ and where

$$\text{beta }(\beta)=1=\frac{d_2}{d_1}$$

This diagram also graphically emphasizes the significance of the constant ϕ (phi) equaling unity in the formula

$$\phi=1=\frac{d_3}{d_1+d_2}$$

With the number of warp yarns that have been prescribed for the single fabric $(K_1=K_f\sqrt{N})$, the face filling and added back filling are woven alternately in a 1 and 1 arrangement, or in the 2 and 2 arrangement as shown in Figure 2.

The number of face filling yarns per inch that should be used in an equal arrangement with the back filling yarns (1 and 1, or 2 and 2) may be defined as the maximum obtainable in the weaving of the integrated structure within certain calculated tolerances. This definition allows for a reduction from the number prescribed for a single fabric, which number cannot be reached due to the jamming of the larger back filling yarns.

Since greater thickness, compactness, and a more uniform distribution of the fibrous understructure are obtained through the employment of larger back filling threads as prescribed by phi $(\phi)=1$, in the ratio

$$\frac{d_3}{d_1+d_2}$$

and since these factors contribute greatly to the attainment of superior water resistance as well as higher thermal insulation, the relatively larger size of the back filling yarns is used, while a reduction of the face filling yarns per inch is permitted within defined limits to allow for the spatial requirements of the larger back filling yarns and their integration into the fabric structure. The preferred range of values for phi (ϕ) is .9 to 1.2, while a permissible range is .7 to 1.3. The consequent reduction of face filling yarns per inch caused by the spatial requirements of the larger back filling yarns when phi (ϕ) is greater than 1, is considered in the modified formula for n_2 (maximum)—

$$n_3\ (\text{max.})=\frac{K_m\beta\sqrt{N_2}}{(\phi)(1+\beta)}$$

when phi $(\phi)>1.0$. While other means, herein disclosed, may be used to attach the larger, soft spun, back filling yarns to the face fabric, the employment of binder yarns solely for this purpose is preferred because these yarns permit a more closely integrated structure of the component yarns within the prescribed relationships which provide for superior water resistance. The binder yarns (*b*) may be placed between the paired face warp yarns (W,W) of the oxford weave at specified intervals, so that a repeat of the interlacing of these binder yarns (*b*) with the saft spun back filling yarns (BF) permits a float of the back filling yarns of a length of from 0.05 to 0.20 inch, within the range of tolerances for effective napping. These binder yarns (*b*) may weave with the face filling yarns along with the paired warp yarns (W,W), except that they alone engage the back filling in a specified arrangement, one of which is shown by enclosed Xs in the weave of Figure 2. These binder yarns (*b*) are assigned to fall beneath the paired warp yarns (W, W) and leave the appearance of the face unchanged. The binder warp yarns may have a smaller diameter than the regular face warp yarns and may be of a different material such as nylon.

Since the float length of the soft spun, back filling yarns is important to the effective napping properties of these yarns, the definition of this length, in inches, makes it independent of the scale of the fabric. The float length defined in inches permits the calculation of the number of warp yarns between interlacing points after the determination of the number of warp yarns per inch, the formula for which is $n_1 = K_f\sqrt{N}$. $\therefore n_1 \times$float length (inches)=member of yarns between interlacings. A minor adjustment in the number of warp yarns between interlacing points may be necessary in order to provide suitable stitching points for the binding yarns so that they do not disturb the appearance of the face fabric. The defined float length range of .05 to 0.2 inch permits an adequate latitude for the utilization of various types and qualities of fibers which may be used in the back filling yarns for the attainment of a desirable lofty, light, durable fibrous understructure through napping.

Figure 3 is a harness draft showing one repeat of the design of the fabric weave shown in Figures 1 and 2. An X mark within the squares represents a raised warp yarn lying over the face filling yarn. A ten harness draft is shown. The raised binder warp yarns are shown as an X within a square, in the columns indicated by the arrows in Figure 2. This draft indicates the floating of the back filling yarn (BF) over 12 warp yarns (W) before such back filling yarn is tied to the face by the binder warp yarn (*b*) which is carried on a separate harness 9, 10 (Figure 3) from the face warp yarns (Figure 3, yarns 1 to 8 inclusive). For one repeat of the fabric design, there are two tie warp yarns, each carried on separate harness frames. The relation of the back and face filling yarns to the face warp and the warp yarns respectively is indicated in Figure 2 by the identifying designations 1, 2 face filling and 3, 4 back filling, in the column to the left of the draft. In the draft weave one repeat diagram (Figure 2), each vertical row of squares represents one warp end of yarn, and each horizontal row of squares, represents a filling-weft-yarn, also referred to as a "pick" of the weave. In Figure 3, the "chain draft 10 harness" diagram, the vertical numbered rows represent a harness frame, and not merely one warp yarn as in Figure 2.

In the conventional draft design diagrams of a common weave, for either the harness or the chain (or pegging plan) draft, or plain weave design, the squares which are filled in or, with some identifying symbol, represent a raised harness, and a warp yarn in a correspondingly raised position in the "shedding" of the filling or weft yarn. In the diagram of one repeat of the weave design, a square filled-in with a symbol such as an "X," or other symbol, represents a raised warp yarn, usually at the face or surface, and disposed above and interlaced with a filling yarn.

A chain draft or pegging plan on design paper indicates how and in what order the harnesses must be lifted so that the warp ends drawn through them will interlace with the filling according to the desired weave; in other words, the chain draft or pegging plan shows which harnesses are to be raised and which lowered on each pick.

Figure 11 is a composite view showing an enlarged fragmentary broken plan of a modified version of a highly water resistant fabric, having high thermal insulation value herein identified as weave "B." A portion of the back filling threads is cut away in order to show the high warp texture Oxford type weave of the face, and the manner in which the floated, soft spun, back filling yarns are interlaced, by raising the paired face warp yarns above them in a uniformly distributed arrangement which permits the back filling yarns to float over the warp yarns for lengths which have been defined as within the range of from 0.05 to 0.20 inch. The float length being important to the effective napping properties of the back filling yarns is defined in inches, independent of the scale of the fabric. The float length determines the number of warp yarns between interlacing points of the back filling yarns and is used to determine the weave and the number of harness to be used. The stitching arrangement with the paired warp yarns is shown enclosed in weave B of Figure 12 and illustrated in Figure 11. The vertical spaces in the weave B, numbered from 1 to 16 represent the warp yarns and are attached by lines to the corresponding yarns in the diagram. A repeat of 16 warp yarns would ordinarily necessitate the requirement of 16 harness for the weaving of this fabric, but in this case the paired warp yarns, in an Oxford weave arrangement, weave as one yarn and may be placed on eight harnesses as shown by the drawing in plan in Figure 14 and chain draft in Figure 13. The stitching arrangement with the paired warp yarns has been therefore based on an eight harness satin weave which permits a uniform distribution of stitches throughout the fabric. The selection of a stitching weave with uniform distribution of stitching points is a precaution taken to prevent a distortion that could occur in a fabric, especially after being subjected to laundering. This system of stitching may be modified by other weaves using more or less harnesses in order to provide desired float lengths, uniformly spaced. Figures 12 to 14 have been provided to show the method of integrating the back filling yarns, which indicate to the persons skilled in the weaving art, the order and sequence in which the yarns for the face warp, face filling, and back filling are manipulated by the harness, reeding plan, and the shuttle arrangement for the face and back filling yarns respectively.

The constants which define the numbers and relative sizes of yarns in a fabric using this warp stitched method of integrating the back filling yarns may be determined by formulae which have been presented for the binder stitched fabric "A." In Figure 11, $K_1=28$, $K_2=12$, $\beta=1$, and $\phi=1$. These constants differ from those of the preferred weave "A" in that K_2 in Figure 1 equals 14. This difference in the filling cover factors is illustrated by the comparative closeness of the back filling yarns in Figure 1 and the closeness in Figure 11. The filling cover factor $K_2=14$ in Figure 1 defines the maximum cover or closeness of the yarns from the formula:

$$K_2=\frac{K_m\beta}{1+\beta}=\frac{28\times 1}{1+1}=14$$

The filling cover factor (K_2) of 14 cannot be obtained in weave "B" of Figure 11, while retaining the other constants in view of the spatial requirements of the interlacing paired warp yarns. These yarns are part of the face fabric and are firmly bound. They therefore are more restricted than separate binder warp yarns which may be of a smaller diameter and more pliable. Greater cover for the backing yarns under these conditions may be obtained through the use of binder yarns. The employment of binder warp yarns is therefore preferred because they permit a more closely integrated and compact fabric structure of the component yarns as defined. Weave "A" using binder yarns is shown to have a higher degree of water resistance by the results of recognized test methods used to evaluate this property. These results are presented and follow in this disclosure.

Since the physical effect of a soft spun, larger, back filling yarn, integrated in the prescribed manner, improves the water resistance of a fabric to the extent that this property is not entirely dependent on the rigid adherence to the openness or tightness as presented by the prescribed formulas, more open structures which to a great extent retain the superior water resistance and other properties as claimed, may be permitted within defined cover factor limits and weaves. These relaxed restrictions permitted with my invention are important as a factor contributing to pliability, and draping property of a more open fabric without seriously impairing its inherent water resistance. Fabric "B" with approximately 20% less than the maximum tightness as determined by formula, is shown by recognized tests to have a water resistance far superior to a single fabric without the integrated floated backing as herein disclosed.

The significance of K_1 and K_2 in the description of my invention is that the values for these constants provide a convenient method of indicating the cover in projection of each of two systems of yarns (warp and filling) in terms of the construction variables ordinarily used, such as textures and yarn sizes. This cover c_1 may be expressed in percentage by the formula:

$$\frac{K_1\times 100}{K_m}=\frac{d\times 100}{p}=c_1(\%)$$

A cover factor of 28, from the above formula, indicates 100% cover. It may be seen in Figures 1 and 11 that the proportion of the area covered by the projection of the warp yarns which have a cover factor of 28 is 100%. It may also be seen that the proportion of the area covered by the projection of the filling yarns is limited to 50%, due to the space required for the interlacing of the warp yarns. This space is occupied by the distance equal to the diameter of the warp yarn, which is equal to the diameter of the filling yarn (β (beta)$=1$). Fifty per cent cover is expressed by the cover factor

$$K_2=\frac{K_m\beta}{1+\beta}=\frac{28\times 1}{1+1}=14$$

A reduction in the warp cover as expressed by the warp cover factor (K_1) allows a corresponding increase in the filling cover as expressed by the filling cover factor (K_2), by the space made available for the bending of the filling yarns.

Total cloth cover (C) is only possible when one system of yarns such as the warp yarns in Figures 1 and 11 have a maximum cover factor ($K=28$). Systems of yarns (warp, filling) having more than a cover factor of 14, restrict the opposing system from making a complete closure due to the insufficient space allowed for the bending of the opposing system. Cloth cover (C) may be defined by the formula:

$$C=\frac{1-(K_m-K_1):(K_m-K_2}{K_m^2}\times 100(\%)$$

The principles used to obtain a greater measure of water resistance in a single fabric necessitate maximum warp cover within very close tolerances and maximum tightness or compactness for the filling yarns. The critical nature of these requirements to the water resistance of a single fabric is indicated by the high quality, uniform, multi-ply yarns, spun and woven under carefully controlled conditions. It is evident that the need of high warp texture to provide complete closure is to a large extent overcome by the added support, supplied by an extra system of soft spun filling yarns of maximum cover and thickness. The softness of these back filling yarns, which is an added aspect, enables them to flatten and fill the interstices. While in the prior art single fabric high warp cover is the sole means of obtaining maximum cloth cover; in the wool backed fabric here disclosed, it is only a supplementary means or a part one of numerous elements in a successful whole. The greater cover and uniform density thus obtained with the soft spun filling yarns permits a reduction of the high warp textures within defined limits without seriously impairing the water resistance of the integrated structure.

Filling cover factor limits have been defined as those imposed by practicality, viz., the maximum filling yarns obtainable in the integrated structure. This definition allows for a reduction from the calculated cover factor which, at best, can only be a close approximation due to the irregular nature of the cloth structure, and the ability of the weaving mechanisms to process the varied constructions. Preferred weave "A" is shown to have a filling cover factor of approximately 20% less than the prescribed values for filling cover factor K_2 and yet possess superior water resistance. A further extension of K_2 tolerances to include the use of larger values for ϕ must be considered. Within the specified critical tolerances, water resistance much superior to that of an equivalent single fabric is made possible by a combination of factors, such as the high warp texture, the physical effect of a large soft spun backing, and method of integration.

The openness of a fabric, which to a large degree affects the water resistance of the integrated structure, can be determined from the cover factors of the various yarns used. The limits of openness, however, are governed by practical considerations in fabric manufacture. The prescribed fabric calls for one system of yarns, such as the warp yarns, to do all the bending or crimping so as to permit the proper integration of an additional system of large backing yarns. Such a system requires a very high cover factor. A reduction in the value of this warp cover factor would permit an increase in the value of the cover factor for the filling yarns. The space remaining between the reduced number of warp yarns per inch by using a lower warp cover factor would permit the bending and consequent increase in the number of filling yarns per inch.

This investigation brought out that practical fabrics incorporating my invention could be made within certain specified tolerances and yet retain a large measure of effective water resistance. These tolerances or limits of openness may be expressed as a percentage of the prescribed cover factors for these fabrics as follows:

$$K_1 = K_f(1 \pm .30)$$

$$K_2 = \frac{K_m\beta}{\phi(1+\beta)}(1 \pm .35)$$

Although it is preferred that

$$\beta \text{ (beta)} \frac{d_2}{d_1}$$

have a value approximating 1.2, the geometric principles that have been used with my invention may be modified to include a range of values for β of .9 to 1.3, and an extended range of permissible values for β of .75 to 1.5. Similarly, these geometric principles may be modified to include a range of values for

$$\phi \text{ (phi)} \frac{d_3}{d_1+d_2}$$

of .9 to 1.2, and an extended range of permissible values for phi (ϕ) of .7 to 1.3.

The geometric principle calling for a high warp texture with an Oxford weave of a textile fabric may be used in the practice of my invention to include other short float weaves for the face fabric such as twills, satins, or their derivatives, having warp yarn floats of up to four face filling yarns and filling yarn floats of up to eight warp yarns. The greater float of eight warp yarns may be used because the higher warp texture results in shorter float lengths. In addition, the float of eight warp yarns admits the possibility of using two warp yarns as one. These modifications may exist within the geometrical constants and tolerances which have been set up to described the fabrics of my invention in both the preferred binder stitched type "A" and the modified warp stitched type "B."

Certain other modified forms are herein shown (see Figures 15 to 21), wherein the face fabric weaves include a weave in which the warp yarns fall below two or more successive face filling yarns in the weave repeat with an arrangement of two face filling yarns to one back filling yarn. The size of the back filling yarn using this arrangement may be determined by the ratio Δ (delta) which is a constant similar to ϕ (phi). Δ (delta) is defined as the ratio of the back filling diameter to the sum of the warp diameter and twice the diameters of the face filling yarns

$$\frac{d_3}{d_1+2d_2} = \Delta$$

In the description of this modified version, utilizing two face filling yarns to one back filling yarn, Δ (delta) replaces ϕ (phi) in defining the size of the back filling yarns, while the other constants such as K_1, K_2, and β (beta) are retained to define the geometry of the face fabric. The limits of yarn floats defined in the modification of the face fabric weaves to other than the Oxford weave are also retained. These permit the use of short float weaves, having warp yarn floats of up to four face filling yarns by the warp yarns and filling floats of up to eight warp yarns. The desired value for Δ (delta) with the two face and one back filling yarn arrangement is .9. A preferred range of values is from .8 to 1.2, and a permissible range is from .6 to 1.3. With this modification, binder stitching or warp stitching may be employed.

Figure No. 16 is a conventional draft design diagram of the face weave of a modified form employing two face filling yarns to one back filling yarn, and shows a

$$\frac{3}{2}$$

twill weave carried out to a 15 warp yarn repeat in order to provide for a 15 warp yarn satin stitching arrangement for the back filling yarns (shown by heavy boxed square in the chain draft diagram for weaving face down, in Figure 17). With this system of stitching the back filling to the woven face, a float of 15 face warp ends has been indicated which would provide a float length of the back filling yarns approximating the length of the back filling yarns of the preferred weave "A," provided the warp cover factors (K_1) and warp yarn diameters (d_1) are equivalent.

Figure No. 17 is a conventional representation by diagram of a chain draft-woven face down of the draft diagram of the face weave shown in Figure 16.

Figure No. 18 shows a harness draft diagram for making the textile design shown in Figures 16 and 17; this draft indicates that 15 harness frames are employed, one for each one of the 15 face warp yarns in one repeat of the weave design. The numbers 1 to 15 represent the harness frames, one for each harness frame. The numbers to the right of the chain draft, Figure 17, are in horizontal alignment with a row of squares representing a back filling yarn which is interlaced to the face weave by the harness frame of the particular number opposite the particular back filling yarn. The particular system of interlacing of one back filling yarn to two filling yarns of the woven face, in accordance and in combination with the geometry of the weave within critical range of tolerance of dimensions, under the formulas herein set forth provides for heavier back filling which serves a double function of first entrapping an air film or layer within and between the weave of the face and the interlaced back filling yarn; while such air film permits air permeability, such, for example, as for the ventilation and carrying off or outward of wearing apparel, moisture vapor from normal body perspiration, such entrapped air film and layer offers a certain measure of resistance to a too ready displacement and rapid circulation by convection boundary currents of air; particularly when such air convection currents are on the outer side of the woven face. The second function and purpose of the interlaced heavier back filling yarn, is to serve as a basis for a napping or brushed pile as an additional means of forming a system of intermeshed fibers on the innerside of the woven cloth so as not to be directly subjected to the convective currents of air that may be moving on the outer face of the fabric. Such fibers form a layer of relatively low density (as compared with the relatively tightly woven face) which serves to entrap intercommunicating air cells in a layer of greater thickness than the film of air within the weave entrapped between the face weave and the back filling yarn. The entrapped air cells within the napped fibers or back of the back filling yarn are uniformly distributed over the back face of the back filling yarn and in such position may carry off and ventilate body moisture vapors such as from perspiration. The high vapor pressures incident to the conditions of body temperature and higher relative humidity are factors which contribute toward the elimination of body perspiration through the type of "breathing" fabric disclosed herein, but yet will exclude and prevent the penetration of water moisture when the woven face of the fabric is on the outside of any garment where it is exposed to the weather elements.

In accordance with the prescribed principles and physical details, two wool backed fabrics, samples "A" and "B" have been constructed (fabric "A" being representative of my invention, employing binder yarns and fabric "B" being warp stitched). These fabrics have been tested and are shown to posess an outstanding degree of water resistance in addition to high thermal insulation value, excellent launderability, and increased durability. They use regular commercial 2-ply cotton yarns and at their maximum texture maintain a soft pliability. The wool yarn for the back filling was previously subjected to a shrink resistant treatment. The water resistance of these fabrics was found to exceed that of the best American version of the English Shirley cloth, even after prolonged laundering.

Fabric "A" of these test fabrics had K_1=about 33.54, β=about 1.225, ϕ=about 1.07, and K_2= about 11.25.

These two fabrics may be generally described as woven fabrics of high water resistance, having unnapped face material of a short float weave, having warp yarn floats of up to four face filling yarns and face filling floats of up to eight face filling yarns, the face yarns being integrated with additional floated filling as a napped backing. The ratio of the count (number per inch) of the face filling yarns to the count of the back filling yarns is a constant Z which in fabric "A" is the integer 1, and in fabric "B" is the integer 2. The cover factor in both types of fabrics is represented by the formula

$$K_1=\frac{\text{Number of warp yarns per inch}}{\sqrt{\text{warp yarn number}}}=31.4(1.0\pm.35)$$

The ratio between the diameters and the face filling yarns and face warp yarns is represented by the constant β in the equation

$$\beta=\frac{d_2}{d_1}$$

said β having a value of .1 to 1.3. The ratio between the diameters of the face warp, face filling and back filling yarns in both fabrics is represented by X in the formula

$$X=\frac{d_3}{d_1+d_2Z}$$

in which

d_3=diameter of the back filling yarn
d_2=diameter of the face filling yarn
d_1=diameter of the face warp yarn.

said X having a value of .7 to 1.3 when Z=1 and a value of from .6 to 1.3 when Z=2. The cover factor of the face filling yarns in both fabrics is represented by the formula

$$K_2=\frac{\text{Number of face filling yarns per inch}}{\sqrt{\text{Filling yarn number}}}=\frac{28\beta(1.0+.35)}{X(1+\beta)}$$

wherein β and X have the above meanings. It will be seen that these values exactly correspond to those given in the earlier set forth cover factor formulae employing ϕ and Δ values, respectively.

The tests of the various properties possessed by the wool backed and control cloth were performed in accordance with Federal Specification for Textiles, General Specifications, Test Methods, CCC-T-191*a*, dated April 23, 1937, and supplement dated October 8, 1945, with the following results:

According to the drop penetration test, wool backed fabric, weave "A" resisted water penetration for over 72 hours; and weave "B" resisted water penetration for over 14½ hours, whereas a single cotton Oxford water resistant fabric, which represents the best American commercial version of the English Shirley cloth, and which was treated identically the same as the wool backed fabrics with a water repellent compound, resisted water penetration for approximately 54 minutes. Weave "A" of the present invention was tested by the drop penetration tester in the greige, without finishing, napping, or a water repellent treatment, desized, and was shown to resist water penetration for over 31 hours.

The durability of the water resistance of the wool backed fabrics, type "A" and type "B," as compared to the single cotton Oxford water resistant fabric, was shown by the results of the drop penetration tests after these fabrics were given a prescribed laundering and wet mechanical action treatment. After this treatment, the wool backed fabric, type "A," resisted water penetration for an average of over 20 hours, type "B," for over 2 hours, and the cotton Oxford, single, water resistant cloth, for under 16 minutes.

The thermal insulation values of the wool backed fabrics, were compared to that of a combination of a single cotton Oxford fabric and a regular standard all wool Army lining cloth of approximately the same weight as the wool backing of the wool backed cloths. The values obtained for the wool backed cloths showed that these cloths had approximately three times the thermal insulation value of the separate cotton and wool lining material tested together.

The shrinkage results of the wool backed fabrics, after being given a regular cotton laundering, showed that the shrinkage of type "A" was 4% warpwise by 0% fillingwise, and that the shrinkage of type "B" was 5% warpwise by 0% fillingwise. These results are considered acceptable by the Army, for whom woolen fabrics must not shrink more than 5% warpwise by 4% fillingwise, after a much less serve wool laundering. The differences in the shrinkage characteristics between cotton and woolen fabrics would be evidenced in the distortion that could occur in a cotton, wool lined garment after laundering; a laundering problem which has been overcome by means of the integrated lining as prescribed by the present invention.

The tear resistance, which is very poor especially across the low number of filling yarns of a single cotton Oxford water resistant fabric, has been improved by over 100% by the addition of an extra system of wool filling yarns. The integrated wool lining, in turn, is much more durable than a separate wool lining due to the added support provided by the more durable face fabric.

The preceding test results together with evaluations have been presented on properties that are measurable by recognized laboratory test methods. Other properties, less measurable, but evident are appearance and comfort. Versatility and economy may also be mentioned.

A separate thin cotton fabric of the weight used for the face fabric of my invention has poor crease resistance. Combined wits a resilient backing, as prescribed in my invention, a thicker, more resilient fabric is formed which prevents the sharp bending which causes creases. A garment made of the backed fabric thus retains its shape longer and greatly enhances the appearance of the wearer.

A garment made of the backed fabric is less binding than that requiring a separate lining or sweater. The firmly bound napped backing material does not have the restricting and creeping action of a loosely held, seamed, lining material, especially in the arms and armpits. The greater resiliency of the backed fabric prevents it from clinging to the body.

This cloth as defined has useful application for many supplementary items of apparel and equipage. Steps have been taken to use it in gloves, hats, coats, raincoats, snow suits, trousers, bed rolls, ground cloths. It may be used for tarpaulins, foot coverings, tents, shoe lining, filter cloths, and auto tops (without napping).

The practicality of the backed cloth from the standpoint of production and economy may be shown by the following estimates. The question of costs and price, of course, is one involving a number of relative factors. While no costs for the backed fabric on a production scale are available, it may be reasonably and logically estimated from costs of sample yardage that it will be roughly $2.60 per square yard for a 16 ounce fabric. In comparison the cost of a separate cotton fabric of a fairly comparable construction to the facing is approximately $1.30 per square yard. A separate wool or spun nylon lining which may be used with this material to give a comparable measure of thermal insulation would have to be at least 12 oz. per square yard and cost approximately $2.80. Thus, a combination of materials of expected equivalency in thermal insulation but which would have inferior water resistance and other less desirable properties as described, would cost approximately 58% more and use up 50% more wool or spun nylon, meanwhile adding unnecessary weight. To these savings must be added those of the costs in fabricating separate linings into a garment of comparative thermal insulation. In addition, wool and nylon materials are so difficult of procurement during periods of emergency that these materials are placed on the critical conservation of material list by the Army.

What I claim:

1. A woven fabric of high water resistance, having a face material of a short float weave, said weave having warp yarn floats of up to four face filling yarns and face filling floats of up to eight face warp yarns, said face yarns being integrated with additional floated filling as a backing, said fabric comprising face warp and filling

yarns, and back filling yarns floated under said woven face to provide a back surface, in which the ratio of the number of said face filling yarns to the number of said back filling yarns is an integer of from 1 to 2, in which the diameter of said back filling yarns substantially exceeds the diameter of said face yarns, and in which the face warp has a cover factor whose value substantially exceeds the value for the cover factor of the face filling.

2. A water resistant fabric according to claim 1, wherein said face warp yarns and face filling yarns are members of the group consisting of cotton and spun synthetic staple yarns, and wherein said back filling yarns are members of the group consisting of wool and spun synthetic staple yarns.

3. A water resistant fabric according to claim 1, wherein said face warp and face filling yarns are cotton and wherein said back filling yarns are shrink resistant wool.

4. A woven fabric of high water resistance, having an unnapped face material of a short float weave, said weave having warp yarn floats of up to four face filling yarns and face filling floats of up to eight face warp yarns, said face yarns being integrated with additional floated filling adapted to form a napped backing, said fabric comprising face warp and filling yarns, and back filling yarns floated under said woven face adapted to provide a pile-like back surface, in which the ratio of the number of said face filling yarns to the number of said back filling yarns is an integer of from 1 to 2, in which the diameter of said back filling yarns substantially exceeds the diameter of said face yarns, and in which the face warp has a cover factor whose value substantially exceeds the value for the cover factor of the face filling.

5. A woven fabric of high water resistance, having an unnapped face material of a short float weave, said weave having warp yarn floats of up to four face filling yarns and face filling floats of up to eight face warp yarns, said face yarns being integrated with additional floated filling adapted to form a napped backing, said fabric comprising face warp and filling yarns, and back filling yarns floated under said woven face adapted to provide a pile-like back surface, in which the diameter of said back filling yarns substantially exceeds the diameter of said face yarns, and in which the face warp has a cover factor whose value substantially exceeds the value for the cover factor of the face filling, said back filling yarns being equal in number per inch to the number of face filling yarns per inch.

6. A woven fabric of high water resistance, having an unnapped face material of a short float weave, said weave having warp yarn floats of up to four face filling yarns and face filling floats of up to eight face warp yarns, said face yarns being integrated with additional floated filling adapted to form a napped backing, said fabric comprising face warp and filling yarns, and back filling yarns floated under said woven face adapted to provide a pile-like back surface, in which the diameter of said back filling yarns substantially exceeds the diameter of said face yarns, and in which the face warp has a cover factor whose value substantially exceeds the value for the cover factor of the face filling, said face filling yarns being twice in number per inch to the number of back filling yarns per inch.

7. A woven fabric of high water resistance, having an unnapped face material of a short

float weave, said weave having warp yarn floats of up to four face filling yarns and face filling floats of up to eight face warp yarns, said face yarns being integrated with additional floated filling adapted to form a napped backing, said fabric comprising face warp yarns arranged in closely packed groups in an Oxford-type weave arrangement, face filling yarns, back filling yarns floated under said woven face adapted to provide a pile-like back surface, and additional binder warp yarns disposed beneath and concealed by groups of said face warp yarns and interlaced with said back and face filling yarns, the diameter of said back filling yarns substantially exceeding the diameter of said face yarns, and the face warp having a cover factor of a value substantially exceeding the value for the cover factor of the face filling.

8. A woven fabric of high water resistance, having an unnapped face material of a short float weave, said weave having warp yarn floats of up to four face filling yarns and face filling floats of up to eight face warp yarns, said face yarns being integrated with additional floated filling adapted to form a napped backing, said fabric comprising face warp yarns arranged in closely packed groups in an Oxford-type weave arrangement, face filling yarns, back filling yarns floated under said woven face adapted to provide a pile-like back surface, and additional binder warp yarns disposed beneath and concealed by groups of said face warp yarns and interlaced with said back and face filling yarns, said face filling yarns being equal in number per inch to the number of said back filling yarns per inch, the diameter of said back filling yarns substantially exceeding the diameter of said face yarns, and the face warp having a cover factor of a

value substantially exceeding the value for the cover factor of the face filling.

9. A water resistant fabric according to claim 4, wherein said face warp yarns and face filling yarns are members of the group consisting of cotton and spun synthetic staple yarns, and wherein said back filling yarns are members of the group consisting of wool and spun synthetic staple yarns.

10. A water resistant fabric according to claim 4, wherein said face warp and face filling yarns are cotton and wherein said back filling yarns are shrink resistant wool.

11. A water resistant fabric according to claim 4 wherein said back filling yarns have a float length of about .05 to about .2 inch.

12. A water resistant fabric according to claim 4, wherein said face warp yarns and face filling yarns are members of the group consisting of cotton and spun synthetic staple yarns, and wherein said back filling yarns are members of the group consisting of wool and spun synthetic staple yarns and have a float length of from about .05 to about .2 inch.

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The following references are of record in the file of this patent:

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Number	Name	Date
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