

TITLE

FLAME RESISTANT FABRICS

BACKGROUND OF THE INVENTION

5 Fabrics made of high temperature and flame
resistant fibers have been very useful in protective
apparel. Although many advances have been made in
designing comfortable fabrics and garments made from
these fibers, there are still certain aesthetic and
10 subjective reasons to desire flame resistant apparel
which also incorporate natural fibers. To meet this
need, fabrics have been made from combination yarns,
that is yarns containing both natural and high
temperature and flame resistant staple fibers.
15 Although fabrics made from such combination yarns may
be made into comfortable garments, the fabric's
resistance to high temperature and flame has been
reduced to such an extent that the addition of flame
retardants are necessary to enhance the thermal
20 protection of the fabric. Typically flame retardants
are applied to the natural staple fibers or the
fabrics made from these combination yarns as topical
treatments. The addition of topical treatments may add
weight and often stiffness to the fabric as well as
25 provide only temporary effectiveness since such treated
fabrics tends to lose this protection with wash and or
wear cycles.

 The object of the present invention is to provide
a fabric combining flame resistance and comfort that
30 may be formulated in a way to balance thermal
performance and cost.

 Another object of the present invention is to
provide a comfortable, flame resistant and cost
efficient fabric that does not require the use of
35 topical flame retardant treatments.

 Another object of the present invention is to
provide a strong fabric where flame resistance and cost
may be balanced.

Fabrics have been made from combination yarns to achieve certain fabric properties. US Pat. Nos. 4,941,884 and 4,900,613 to Green disclose comfortable fabrics of high durability made from warp yarns containing a blend of at least 15% by weight high modulus and at least 30 % by weight low modulus fibers woven with fill yarns containing low modulus fibers (usually cotton). Blended high and low modulus fibers were required in the warp yarns to provide proper shrinkage for increasing the abrasion resistance.

Canadian Patent No. 1034842 discloses a protective fabric comprising interwoven warp and weft threads of dissimilar properties with an asymmetric weave, changing from one surface of the fabric to the opposite surface of the fabric to achieve varying energy absorption properties throughout the depth of the fabric.

European Patent Application 310,199 discloses a bulletproof woven fabric made from filaments or yarns having high strengths and high moduli and consisting of polymers of ultrahigh molecular weights, wherein the warp filaments or yarns consist of other polymers than the weft filaments or yarns.

Both UK Patent Application 2,025,789 and Japanese Patent Application Publication Sho 59(1984)-9053 disclose fabrics reinforced by the insertion or substitution, at some frequency in the fabric, of higher strength adjacent yarns in the warp and/or weft directions. Japanese Patent Application Sho 62-26900 teaches a reinforced aramid fabric having groups of low strength yarns inserted or substituted in the fabric weave in the warp and/or weft directions. Such reinforced fabrics are designed for increased tear resistance and have not been designed with considerations for comfort or thermal protection.

SUMMARY OF THE INVENTION

The present invention provides a woven flame resistant fabric comprising dissimilar warp and fill

yarns, the warp yarns comprise staple or filament fibers and have a Limiting Oxygen Index of at least 27, and the fill yarns comprise natural fibers and wherein the ratio of warp to fill yarn ends in the fabric is at least 1.0. More preferred are warp yarns have a
5 Limiting Oxygen Index of 28 or more.

In the present invention the fibers of the warp yarn may have a modulus of from about 100 to 800 g/dtex. Although fibers moduli of from 100 to about
10 250 g/dtex may be preferred for some uses.

It is preferred that the warp yarn comprises fibers selected from the group consisting of aramid, polybenzimidazole, polybenzoxazole, melamine, poly(phenylene sulfide), polybenzothiazoles, polyimide,
15 polyetherimide, polyamidimides, novaloid and modacrylic fibers and the fill yarn fibers are selected from the group consisting of cotton, silk, wool, rayon and FR rayon. The warp yarn may be formed of fibers that are m-aramid or p-aramid fibers or mixtures of these fibers
20 and may also incorporate about 5% by weight or less electrically conductive fiber, particularly sheath-carbon-core fibers.

A preferred fabric for protective apparel is a fabric wherein the fibers of warp yarn are sulfonated para-aramid fibers and the fill yarn is cotton. P-
25 aramid fibers having a modulus of from 100 to not more than 200 g/dtex are particularly useful in fabrics for protective apparel and garment uses.

The present invention also provides protective
30 apparel comprising a woven flame resistant fabric having dissimilar warp and fill yarns, the warp yarns comprise staple or filament fibers and have a Limiting Oxygen Index of at least 27, and the fill yarns comprise natural fibers and wherein the ratio of warp
35 to fill yarn ends in the fabric is at least 1.0.

It is preferred for the apparel use that the woven fabric contains warp yarn fibers selected from the group consisting of aramid, polybenzimidazole, polybenzoxazole, melamine, poly(phenylene

sulfide), polybenzothiazoles, polyimide, polyetherimide, polyamidimides, novoloid and modacrylic fibers and the fill yarn fibers are selected from the group consisting of cotton, silk, wool, rayon and FR rayon. Useful
5 protective apparel may be made where the warp yarn fibers are m-aramid and the fill yarn fibers are FR rayon. More preferred is protective apparel where the warp yarns are p-aramid fibers having a modulus of from 100 to about 250 g/dtex. Most preferred is protective
10 apparel where the warp yarns are sulfonated p-aramid fibers and the fill fibers are cotton.

In protective apparel of claim 11 the warp yarn may further comprise about 5% by weight or less of an electrically conductive fiber. And for protective
15 apparel it is preferred that the warp yarns are staple fibers.

DETAILED DESCRIPTION

This invention provides flame resistant woven fabrics, where the yarns used for the warp and the fill
20 (or weft) are not alike. This fabric may be used in protective apparel or for tents, tarps and other uses where a balance of fabric stiffness, fabric durability, high temperature, flame resistance, and low cost are desired.

25 In the subject fabric, warp yarn fiber selection provides the fabric with high temperature and flame resistance, while fill yarn selection provides the comfort and cost efficiency. In these woven fabrics, the warp yarns partially cover protect the fill yarns.
30 And it is believed that the warp yarns thereby protect the fill yarns from flame and high temperature. Therefore, by selecting the warp yarns to be only those yarns that have an LOI of 27 or more, the warp yarns provide thermal protection to both the fill yarns and
35 to the fabric as a whole, thus fill yarns may then be selected to have the properties that make the fabric comfortable and cost effective.

In the present invention, the warp yarns are made high temperature and flame resistant fibers. High

temperature and flame resistant fibers those fibers having a Limiting Oxygen Index (LOI) of at least about 27, and preferably 28 or more. Preferred fill yarns are yarns made from natural fibers, but fill yarns
5 could be selected from natural or synthetic fibers. Special consideration must be given the selection of fill and warp yarns to provide a fabric that is suitable for a protective apparel. Even with these special considerations, fabrics of the present
10 invention encompass a wide selection of yarns, and provide strong, comfortable and durable fabrics that meet military and industrial standards for high temperature and flame resistance.

For fabrics suitable for protective apparel, fill
15 yarns of this invention are selected from natural fibers. Natural fibers are those fibers found or derived from nature, including fibers such as cotton, rayon, and other cellulose based fibers as well as those fibers which are deemed to have some natural
20 flame retarding properties, such as wool and silk. Rayon spun containing a flame retardant (known as FR rayon) is particularly useful in the present invention. Nylon, polyester and other synthetic fibers which melt on exposure to high temperature are not suitable when
25 used as a major component in a fill yarn for a protective apparel fabric. Since these fibers melt on exposure to high temperatures, their presence may contribute to or aggravate burns.

In fabrics designed for uses other than protective
30 apparel, fibers from polymers such as nylon and polyester may be acceptable for use when blended with natural fibers.

Fill yarns of the present invention may also contain electrically conductive fibers such as
35 synthetic sheath-carbon-core staple or continuous filament fibers. Such fibers reduce the possibility of sparking and are much preferred over fibers having a topical antistatic treatment. It is recommended that

such sheath-core fibers be used at a concentration of 5% by weight.

The warp yarns in the present invention must have an LOI of 27 or more. High temperature and flame resistant fibers useful in the present invention for making protective apparel fabrics include, for example, aramid, polybenzimidazole, polybenzoxazole, melamine, poly(phenylene sulfide), polybenzothiazoles, polyimide, polyetherimide, polyamidimides, novaloid and modacrylic fibers. These fibers decompose without the production of noxious fumes when exposed to flame. Useful fibers include those sold under the trademarks: Kevlar (E.I. DuPont, NOMEX (E.I. DuPont), BASOFIL (BASF), TECHNORA (Akzo) KYNOL (Carborundum) and RYTON (Phillips Chemical Company).

The warp yarn as a whole must have a LOI of 27 or more for the fabrics of the present invention. The actual selection of fibers used to make the warp yarn will be determined by the Thermal Protective Performance Test (TPP) or other evaluation standards that the fabric is required to meet. For example, actual exposure conditions or temperatures and the length of the exposure (time) will influence the selection of fibers used in the warp and /or the fill. In some cases the warp may contain up to as much as 30% by weight fibers having an LOI of less than 27, while the warp yarn as a whole has an LOI of 27 or more.

Warp yarns of the present invention may also contain electrically conductive fibers such as synthetic sheath-carbon-core staple or continuous filament fibers. Such fibers reduce the possibility of sparking and are much preferred over fibers having a topical antistatic treatment. Non-permanent topical treatments compromise the performance of the fabric of the present invention which is inherently heat and flame resistant. When sheath-core electrically conductive fibers are incorporated into the warp yarn,

it is recommended that the concentration of these fibers be about 5% by weight or less in the warp yarn.

For maximum comfort, staple yarns are preferred for the warp yarn and for the fill yarns.

- 5 High or low modulus fibers may be used in the warp yarns of the present invention since fiber modulus is not an essential consideration in these fabrics. The Warp yarn fibers having a modulus of from 100 to 800 g/dtex are suitable for use in the present invention.
- 10 Lower modulus fibers, that is those fibers having a modulus of less than 250 g/dtex or in the range of 100 to 200 g/dtex are preferred for apparel fabrics which are in direct contact with the wearer so that the fabric has adequate comfort. Higher modulus fibers may
- 15 be acceptable for use in fabrics that are to be used for specific purposes or in specific locations within a garment where wearer comfort is of less importance.

- Particularly useful in the fabrics of the present invention are the m- and p-aramid fibers. Such fibers
- 20 include high modulus fibers such as disclosed in US Pat. No. 3,767,756 to Blades. Fibers having lower moduli include those made by the processes disclosed in US Pat. No. 5,336,734 to Bowen et al., US Pat. No. 5,330,698 to Allen et al. & US Pat. No. 3,671,542 to
- 25 Kwolek. Since the use of the fibers having a lower modulus provides a fabric of improved comfort, p-aramids having moduli in the range of from about 100 to less than 200 g/dtex are preferred. Most preferred are the sulfonated p-aramid made according to in US Pat.
- 30 No. 5,336,734.

The aramid fibers may be made from homo or co-polymers. The only requirement is that the warp yarn have an LOI of 27 or more.

- It is desirable for strength and durability that
- 35 the warp yarns be made from fibers which are all one type of high temperature and flame resistant polymer. For example, the warp yarn may be 100% by weight p-aramid. Where maximum mechanical strength is not important, warp yarns made from mixtures of high

temperature and flame resistant fibers may be used. The use of mixed staple fibers may also provide additional comfort or aid in providing additional thermal performance. For example, a commercial blend of 5% by weight p-aramid and 95% by weight m-aramid fiber yarns is used for its improved thermal performance over 100% m-aramid yarns. Another useful blend of p-and m- aramid fibers for the warp yarn is 60% by weight p- aramid, 40% by weight m-aramid.

10 Staple fibers made from stretch broken continuous filament fibers as well as cut staple fibers may be used in making the warp yarns of the present invention.

The warp yarns themselves may be of different polymer compositions or could be made from plys of different staple yarns or continuous filament fibers so long as the warp yarns meet the LOI requirement. Selection of warp yarns or fiber mixtures for warp yarns employed in the design of the fabrics of the present invention may be used to achieve an overall fabric flame resistance that meets various industry requirements or standards. Thus, a fabric of the desired comfort, durability, cost and flame resistance can be designed according to the present invention for specific situations.

25 Unless the fabric is intended for a non-garment use, flame resistant or retardant topical treatments applied to fabrics are not recommended for use in the present invention since these fabric treatments stiffen the fabric, decrease wearer comfort and tend to be temporary in nature.

Again to achieve maximum fabric mechanical strength, fill yarns according to the present invention are typically made from one type of natural fiber, for example 100% cotton fill yarns. Where maximum mechanical strength is not essential, mixtures of staple fibers may be used in the fill yarns, for example, fill yarns containing cotton and wool.

The ratio of warp ends per inch to fill ends per inch in the fabrics of the present invention range from

1 to about 3, and a range of 1 to 2.5 is preferred. For garment use, this ratio range is essential since fibers in the warp yarns and the fibers in the fill yarns work together not only to provide flame resistance and durability but also comfort. In the present invention it is preferred that all warp yarn fibers are inherently flame resistant, that is the warp yarns containing only fibers having an LOI of 27 or more. It is preferred that the fill yarns be from natural fibers. Although there is no limitation on the LOI of the fill yarn fibers, fill yarns may, if desired have an LOI of 27 or more.

The present invention provides a cost effective flame resistant fabric that may be designed for both comfort and mechanical performance.

The fabrics of this invention are useful in various protective garments, including fireman's turnout coats, military apparel and various types of protective overalls. Further, these fabrics can be made into shirts, pants, and other apparel normally worn in industrial or hazardous environments. The fabrics of this invention may also be useful in non-garment applications where one desires to balance thermal protection and cost. Tarps, tents or other fabrics used to cover and protect people or property may be made from the fabrics of the present invention.

The present invention is illustrated in the following example which is not intended to limit the invention.

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EXAMPLES

Plain weave, ripstop fabrics were prepared from the following yarns and were woven according to MIL-C-4436.

Yarns were as follows: the yarns identified as m-aramid are staple fiber yarn of 100% poly(phenyleneisophthalamide); those identified as Z200 are staple yarns of sulfonated p-aramid fiber sold by E.I. DuPont of Wilmington, DE as Z200; FR rayon indicates fire retardant rayon staple yarns; blends of

fiber in staple yarns are identified by the fibers in the blend. These are nylon/cotton; blends of m-aramid/cotton and blends of m-aramid/cotton/Z200 and blends of Z200/cotton. (NOMEX is a registered trademark of E. I. DuPont.)

The resulting fabrics were tested for grab strength (ASTM-D-5034 ; results are reported in pounds(lbs)); trapezoidal tear strength (ASTM-D-5733; results are reported in pounds(lbs)); Elmendorf tear strength (ASTM D1424 ; results are reported in pounds(lb.)); Tabor abrasion(ASTM-D-1044; results are reported in cycles to failure) and Thermal Protective Performance, TPP (method reported in *Fire Technology* V. 13 N.1 Feb. 1977; results are reported in seconds times 2 (s x 2) to a second degree burn).

The control fabric was a commercial fabric of 50% nylon and 50% cotton yarn in both the warp and fill direction. This fabric was selected as the control because it is a durable and comfortable fabric used to make garments for military, industrial and general work garments. It is a strong, durable and comfortable fabric, but does not provide thermal protection. As the Table below shows, the use of warp yarns according to the present invention provides a fabric having surprising thermal protection properties combined with strength and durability.

The data is summarized in the Table, below.

TABLE: FABRIC EVALUATION

<u>Fabric Sample</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>Control</u>
<u>Fill</u> <u>YARNS:</u>	100% FR rayon	97/3* FR rayon/ nylon	100% cotton	70/30 Z200/ cotton	50/50 m-aramid/ cotton	50/50 nylon/ cotton
<u>Warp</u> <u>YARNS:</u>	100% m-aramid	100% m-aramid	Z-200	70/30 Z200/ cotton	50/50 m-aramid/ cotton	50/50 nylon/ cotton
<u>Fabric Weight</u>	7.0	7.1	6.0	4.5	6.1	6.8
<u>w/f,</u> <u>ends</u>	2.5/1	2.5/1	1.9/1	1.5/1	2.3/1	2/1
<u>Grab,</u> <u>w/f</u>	284/73	268/77	285/42	130/63	98/90	264/165
<u>Trap</u> <u>Tear,</u> <u>w/f</u>	95/14	91/27	55/6	17/12	15/7.5	60/24
<u>Elm.</u> <u>Tear,</u> <u>w/f</u>	8.3/11	8.9/19	14+/12.2	13/10	7.6/6.3	14/12
<u>Tabor</u>	588	-	760	465	-	1300
<u>TPP</u> <u>sec</u>	12.8	14.1	11.5	10.0	-	-
<u>Ignite</u> <u>in air</u>	N	N	N	Y	Y	Y

* The fill yarn was FR rayon with a nylon ripstop filament yarn.

- 5 The total composition of the fill yarn in weight % was 97 FR rayon
3 nylon filament.

In the Table, fabric weight is shown in oz/yd², Grab Strength (Grab), Trapezoidal Tear (trap tear) and Elmendorf Tear are in pounds; Tabor Abrasion (Tabor) is in cycles to failure. The term w/f means the result reported in the warp and then the fill direction. The warp and fill yarn compositions are reported in weight % of the respective yarn. The ratios are shown as weight % as indicated. For example 50/50 nylon/cotton means a 50% by weight mix of nylon fibers with a 50% by weight mix of cotton fibers were used in making the yarn. Ignite in air means ignition in air. The result is reported as either yes (Y) or no(N). If the fabric does not ignite, it means that the fabric, after being exposed to a flame for 3 to 5 seconds, did not ignite and continue to burn.

The fabric samples A, B and C are fabrics of the present invention. Samples D and E are present to provide a comparison between fabrics of the present invention and fabrics made according to prior art methods of making thermally protective fabrics. Samples D and E are woven from intimately blended staple yarns.

Comparing Samples C and D, one sees that both fabrics have the about same weight ratio of Z200 to cotton in the fabric, but the distribution of the high LOI fiber is distinctly different. In C the high LOI fiber is distributed over the fabric surface with the cotton in the interior fill yarns; while in D, unlike in C, cotton is present and evenly distributed on the fabric surface. In addition, in C the warp yarns are all Z200 while the fill yarns are all cotton. These warp and fill yarns are stronger than the intimately blended staple yarns of D. For example, comparing the average of the warp and fill data shows the following for C/D respectively, Grab, 164/96; Trap Tear, 31/14; and Elm., 14/12. Looking to the test results, the difference in surface flammability as measured by the ignition in air test is very different for C compared to D.

Comparing strength data for C and D by averaging the warp and fill values reported above, C is a stronger fabric than D. Both fabrics are about equal to one another in the TPP test.

- 5 Fabrics A and B compared to E show the same differences as those of the C and D comparison, that is in each case a stronger fabric that does not ignite in air.

WHAT IS CLAIMED IS:

1. A woven flame resistant fabric comprising dissimilar warp and fill yarns, the warp yarns comprise staple or filament fibers and have a Limiting Oxygen Index of at least 27, and the fill yarns comprise natural fibers and wherein the ratio of warp to fill yarn ends in the fabric is at least 1.0.
2. The fabric of claim 1 wherein the warp yarns have a Limiting Oxygen Index of 28 or more.
3. The fabric of claim 1 wherein the fibers of the warp yarns have a modulus of from about 100 to 800 g/dtex.
4. The fabric of claim 1 wherein the fibers of the warp yarn have a modulus of from 100 to about 250 g/dtex.
5. The fabric of Claim 1 wherein the warp yarn comprise fibers selected from the group consisting of aramid, polybenzimidazole, polybenzoxazole, melamine, poly(phenylene sulfide), polybenzothiazoles, polyimide, polyetherimide, polyamidimides, novaloid and modacrylic fibers and the fill yarn fibers are selected from the group consisting of cotton, silk, wool, rayon and FR rayon.
6. The fabric of claim 1 wherein the fibers of the warp yarn are m-aramid or p-aramid fibers or mixtures of these fibers.
7. The fabric of claim 1 wherein the warp yarn incorporates about 5% by weight or less electrically conductive fiber.
8. The fabric of claim 6 wherein 60 % by weight of the warp yarn fibers is p-aramid and 40% by weight are m-aramid fibers.



9. The fabric of claim 1 wherein the fibers of warp yarn are sulfonated para-aramid fibers and the fill yarn is cotton.

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10. The fabric of claim 1 wherein the fibers of the warp yarn are m-aramid or p-aramid fibers or mixtures of these fibers and wherein the p-aramid fibers have a modulus of from 100 to not more than 200 g/dtex.

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11. The fabric of claim 1 wherein the warp yarn fibers are m-aramid and the fill yarn fibers are FR rayon.

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12. Protective apparel comprising a woven flame resistant fabric having dissimilar warp and fill yarns, the warp yarns comprise staple or filament fibers and have a Limiting Oxygen Index of at least 27, and the fill yarns comprise natural fibers and wherein the ratio of warp to fill yarn ends in the fabric is at least 1.0.

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13. The protective apparel of claim 12 wherein the woven fabric contains warp yarn fibers selected from the group consisting of aramid, polybenzimidazole, polybenzoxazole, melamine, poly(phenylene sulfide), polybenzothiazoles, polyimide, polyetherimide, polyamidimides, novaloid and modacrylic fibers and the fill yarn fibers are selected from the group consisting of cotton, silk, wool, rayon and FR rayon.

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14. The protective apparel of claim 12 wherein the warp yarn fibers are m-aramid and the fill yarn fibers are FR rayon.



15. The protective apparel of claim 12 wherein the warp yarn fibers are p-aramid wherein the p-aramid fibers have a modulus of from 100 to about 250 g/dtex.

5 16. The protective apparel of claim 12 wherein the warp yarn further comprises about 5% by weight or less of an electrically conductive fiber.

10 17. The protective apparel of claim 12 wherein the warp yarns are staple fibers.

18. A tarp or tent comprising the fabric according to claim 1.

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