US 20060292953A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0292953 A1**

Ashley et al. (43) **Pub. Date: Dec. 28, 2006**

(54) **FLAME-RESISTANT FIBER BLEND, YARN, AND FABRIC, AND METHOD FOR MAKING SAME**

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(21) Appl. No.: **11/159,379**

(22) Filed: **Jun. 22, 2005**

Publication Classification

(51) **Int. Cl.**
D03D 15/12 (2006.01)
D03D 15/00 (2006.01)

(52) **U.S. Cl.** **442/197**; 442/302; 442/310

(57) **ABSTRACT**

A fiber blend, a yarn spun from the fiber blend, and a fabric made from the yarn, wherein the fiber blend comprises: (a) about 40 wt.% to about 65 wt.% modacrylic fibers containing antimony, or FR acrylic fibers; (b) about 10 wt.% to about 50 wt.% cotton fibers or FR cotton fibers; (c) up to about 25 wt.% nylon fibers; and (d) greater than about 3 wt.% and less than 10 wt.% para-aramid fibers. The fabric is over 90 percent dyeable and is capable of achieving ASTM F1506 certification with an Arc Thermal Performance Value greater than 8.0 cal/cm^2. The fabric is woven or knitted, and has a weight of about 4.0 oz./yd.^{2} to about 10.5 oz./yd.^{2}. The fabric is suitable for garments worn during activities in which there is potential for exposure to flame and/or electrical arc.

FLAME-RESISTANT FIBER BLEND, YARN, AND FABRIC, AND METHOD FOR MAKING SAME

BACKGROUND OF THE INVENTION

[0001] The present invention relates to flame-resistant fabrics woven or knitted from yarns that are made from fiber blends.

[0002] Flame-resistant fabrics (also variously referred to as "fire-resistant", "flame-retardant", and "fire-retardant" fabrics) are fabrics that, once ignited, tend not to sustain a flame when the source of ignition is removed. A great deal of investigation and research has been directed toward the development and improvement of flame-resistant fabrics for use in various products such as bedding, clothing, and others. Flame-resistant clothing is often worn by workers involved in activities such as industrial manufacturing and processing, fire-fighting, electrical utility work, and other endeavors that entail a significant risk of being exposed to open flame and/or electrical arcs.

[0003] Flame-resistant fabrics include both fabrics that are treated to be flame-resistant as well as flame-resistant fabrics made from inherently flame-resistant fibers. The former types of fabrics are not themselves flame-resistant, but are made flame-resistant by applying to the fabric a chemical composition that renders the fabric resistant to flame. These types of fabrics are susceptible to losing their flame-resistance when laundered repeatedly because the flame-resistant composition tends to wash out. In contrast, inherently flame-resistant fabrics do not suffer from this drawback because they are made from fibers that are themselves flame-resistant.

[0004] Various types of inherently flame-resistant (FR) fibers have been developed, including modacrylic fibers (e.g., PROTEX® modacrylic fibers from Kaneka Corporation of Osaka, Japan), aramid fibers (e.g., NOMEX® meta-aramid fibers and KEVLAR® para-aramid fibers, both from E. I. Du Pont de Nemours and Company of Wilmington, Del.), FR rayon fibers, oxidized polyacrylonitrile fibers, and others. It is common to blend one or more types of FR staple fibers with one or more other types of non-FR staple fibers to produce a fiber blend from which yarn is spun, the yarn then being knitted or woven into fabrics for various applications. In such a fiber blend, the FR fibers render the blend flame-resistant even though some fibers in the blend may themselves be non-FR fibers, because when the FR fibers combust they release non-combustible gases that tend to displace oxygen and thereby extinguish any flame.

[0005] As an example, United States Patent Application Publication US 2005/0025963 to Zhu discloses an intimate blend of staple fibers having 10 to 75 parts by weight of at least one aramid fiber, 15 to 85 parts by weight of at least one modacrylic fiber, and 5 to 30 parts by weight of at least one polyamide fiber.

[0006] Another blend of staple fibers is disclosed in United States Patent Application Publication US 2004/0192134 to Gibson et al. The blend includes at least about 60 percent FR fibers (modacrylic and/or aramid) and up to 40 percent synthetic or natural non-FR fibers such as cotton or wool.

[0007] U.S. Pat. No. 6,787,228 to Campbell et al. discloses a yarn formed of a blend of fibers including at least about 70 percent modacrylic fibers combined with at least about 3 percent high-performance, high-energy-absorptive fibers such as aramid.

[0008] In the United States, it is desirable and often required for clothing worn by certain types of workers to pass standard performance specification F1506 of the American Society for Testing and Materials (ASTM). This standard, entitled "Standard Performance Specification for Flame Resistant Textiles Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electrical Arc and Related Thermal Hazards", sets various standard performance specifications for a fabric, among which are specifications for the ability of the fabric to self-extinguish after being ignited. When the ignition source is removed, the fabric must self-extinguish in less than 2 seconds and have less than a 6-inch char length according to ASTM Test Method D6413 ("Standard Test Method for Flame Resistance of Textiles", also referred to as the Vertical Flame test). The F1506 performance standard also includes standard test ASTM 1959 ("Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing"), which measures the level of protection that the fabric provides against electrical arc exposure. The ASTM 1959 test establishes three levels of electrical arc protection as measured by the fabric's Arc Thermal Performance Value (ATPV), expressed in cal/cm^2; at least Level II certification (ATPV greater than 8.0 cal/cm^2) is required for clothing worn by many electrical utility workers. ASTM F1506 also has minimum performance specifications for tensile breaking strength (40 pounds) and tear-resistance (4.0 pounds) of the fabric under standard test conditions.

[0009] In addition to the above-noted performance specifications of fabrics, other properties are also important if a fabric is to be practical and commercially viable, particularly for clothing. For instance, the fabric should be durable under repeated industrial launderings and should have good abrasion-resistance. Furthermore, the fabric should be readily dyeable to dark, solid shades of color, and should be comfortable to wear.

[0010] As noted above, there are various fiber blends, yarns, and fabrics that purport to provide some degree of flame-resistance. However, the prior art known to the applicant does not disclose or suggest the specific fiber blend and fabric of the present invention, which has been found to possess distinct advantages and characteristics, including passage of ASTM F1506 and Level II certification for electrical arc protection. The fabric is also comfortable to wear, is abrasion-resistant, is durable under repeated industrial launderings, and is over 90 percent dyeable.

BRIEF SUMMARY OF THE INVENTION

[0011] More particularly, the present invention provides a fiber blend, a yarn made from the fiber blend, and a fabric made from the yarn, wherein the fiber blend comprises: (a) about 40 wt.% to about 65 wt.% modacrylic fibers containing antimony, or FR acrylic fibers; (b) about 10 wt.% to about 50 wt.% cotton fibers or FR cotton fibers; (c) up to

about 25 wt.% nylon fibers; and (d) greater than about 3 wt.% and less than 10 wt.% para-aramid fibers.

[0012] Advantageously, the modacrylic fibers contain at least about 7 wt.% antimony based on the weight of the modacrylic, and more preferably at least about 10 wt.% antimony.

[0013] In one embodiment, the fiber blend comprises about 45 wt.% to about 55 wt.% modacrylic fibers, about 20 wt.% to about 30 wt.% cotton fibers, about 15 wt.% to about 20 wt.% nylon fibers, and about 5 wt.% to about 9 wt.% para-aramid fibers.

[0014] A yarn in accordance with one embodiment of the invention comprises the above-noted fiber blend spun into yarn. The yarn can be spun in various ways, including ring spinning, air jet spinning, and open-end spinning.

[0015] A fabric in accordance with one embodiment of the invention has a weight of about **4.0** oz./yd.^{2} to about 10.5 oz./yd.^{2}, more preferably about 7 oz./yd.^{2} to about 9.0 oz./yd.^{2}. The fabric can be woven (e.g., a woven twill or plain weave) or knitted. The invention also provides clothing made from the fabric.

[0016] The fabric in accordance with the invention is dyeable to dark or solid shades because the fiber blend is over 90 percent dyeable. More specifically, the modacrylic fibers are dyeable with basic dyes, the cotton fibers are dyeable with fiber-reactive or direct dyes, and the nylon fibers (if present) are dyeable with acid or disperse dyes. Only the para-aramid fibers are not dyeable, and they comprise less than 10 percent of the fiber blend such that they do not interfere with the attainment of solid shades. Additionally, the fiber blend does not include any other fiber types that would require dye procedures and/or processing conditions that would be incompatible with the fiber constituents of the blend. For example, the blend does not include meta-aramid fibers because they require dye bath temperatures greater than 230° F. and the use of a carrier that reacts negatively with modacrylic.

[0017] The invention also provides a method for making a flame-resistant fabric, comprising the steps of forming an intimate blend of fibers comprising about 40 wt.% to about 65 wt.% modacrylic fibers containing antimony, about 10 wt.% to about 50 wt.% cotton fibers, up to about 25 wt.% nylon fibers, and greater than about 3 wt.% and less than 10 wt.% para-aramid fibers; forming the blend of fibers into yarn; and knitting or weaving the yarn to form fabric.

[0018] In another embodiment of the invention, the method further comprises the steps of dyeing the fabric with basic dye to dye the modacrylic fibers, and dyeing the fabric with fiber reactive or direct dye to dye the cotton fibers. When nylon fibers are included in the fiber blend, the dyeing steps also comprise dyeing the fabric with acid or disperse dye to dye the nylon fibers. The dyeing steps preferably are carried out by exhaust dyeing at a dye bath temperature not exceeding about 230° F. Preferably, the fabric is first dyed with the basic dye, then the fabric is dyed with the fiber reactive or direct dye, and finally the fabric is dyed with the acid or disperse dye. Optionally, a dye fixative can be used to fix one or more of the dyes.

[0019] The fabric made in accordance with the invention has an advantageous combination of properties. The fabric is able to pass the ASTM F1506 specification, and in fact can achieve a char length of less than 5 inches, well under the 6-inch maximum permissible value according to the specification. Additionally, the fabric can achieve NFPA 70E Level II certification for protection against electrical arc exposure. This is achievable with relatively low fabric weights such that clothing made of the fabric is perceived as being comfortable to wear; the inclusion of cotton provides softness and moisture wicking, which further aids the comfort. Cotton also forms a char that assists in the flame-resistance performance. The nylon is included for durability and strength, as well as the ability to be thermoset for shrinkage. It has also been found that inclusion of nylon aids in improving the electrical arc protection. The para-aramid is included for its inherent flame-resistant properties, strength, and very low shrinkage even with repeated industrial launderings. The cotton content also allows the optional application of a resin to the fabric for further shrinkage control, if desired or needed in a particular instance. Furthermore, the fabric is over 90 percent dyeable such that dark, solid shades can be achieved.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0020] The present inventions now will be described more fully hereinafter with reference to particular embodiments and examples of the inventions. However, these inventions may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements.

EXAMPLES

[0021] Fabric samples were made from yarn spun from a blend of 50 wt.% modacrylic, 25 wt.% cotton, 20 wt.% nylon, and 5 wt.% para-aramid staple fibers. The modacrylic fibers used for these samples contained 10% antimony. The staple fibers had lengths ranging from about 1.5 inches to about 2.0 inches. The modacrylic fibers had a denier of 2.0, the nylon fibers had a denier of 1.8, and the para-aramid fibers had a denier of 0.84. Two separate batches of yarn were made from the fiber blend. One yarn was ring-spun 25/2 cotton count yarn and the other yarn was air jet-spun 25/2 cotton count yarn. Fabric was woven from each type of yarn. The fabric constructions in each case were 76 warp ends/inch and 56 picks/inch in a 2×1 right-hand twill pattern. The fabric made with the ring-spun yarn weighed 8.2 oz./yd.^{2} and the fabric made with the jet-spun yarn weighed 8.6 oz./yd.^{2}. The two types of fabric were tested according to ASTM F1506, and the results are included in Table I below:

TABLE I

FABRIC	WIDTH	WEIGHT (oz/yd)	ATPV[1] (cal/cm^2)
RING-SPUN	58–59"	8.2	8.2
JET-SPUN	59–60"	8.6	8.7

	FLAMMABILITY[2]					
	AFTERFLAME DURATION (secs.)		CHAR LENGTH (inches, warp/fill)		DIMENSIONAL CHANGE[3] — IL@140° F.* (%, warp/fill)	
	RING	JET	RING	JET	RING	JET
ORIGINAL	0.00/0.00	0.00/0.00	5.5/4.2	4.4/4.4		
After 5 IL	0.00/0.00	0.00/0.00	4.1/3.6	4.2/3.9	2.9/1.1	2.4/2.4
After 10 IL	0.00/0.00	0.00/0.00	4.1/3.6	3.5/3.5	0.4/0.7	0.8/0.3
After 25 IL	0.00/0.00	0.00/0.00	4.5/4.3	4.2/4.6	0.7/1.0	1.1/0.7
After 50 IL	0.00/0.00	0.00/0.00	5.1/5.1	4.6/4.7	1.9/1.3	1.5/2.1
After 75 IL	0.00/0.00	0.00/0.00	3.9/4.1	4.4/4.5	2.9/1.8	2.7/1.9

	BREAKING STRENGTH[4] (lbs, warp/fill)		TEAR-RESISTANCE[5] (lbs, warp/fill)		FLEX[6] (cycles to failure, warp/fill)	
	RING	JET	RING	JET	RING	JET
ORIGINAL	209/132	200/127	13/9	11/7	8400/6500	9500/6300
After 5 IL	215/139	203/134	12/8	10/7	3600/4600	5300/5300
After 10 IL	196/130	209/136	10/6	11/8	5800/6200	3600/4500
After 25 IL	181/122	197/128	10/7	9/6	3100/4000	2500/3400
After 50 IL	203/135	181/116	9/6	8/5	2300/2600	2300/3300
After 75 IL	194/128	190/126	8/6	8/6	1400/1900	1600/1900

*Shrinkage was not performed on the same sample at each interval
[1]ASTM 1959 Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing
[2]ASTM D6413 Standard Test Method for Flame Resistance of Textiles (Vertical Test)
[3]AATCC 96, Light Soil Release Wash and Dry Procedure, described below.
[4]ASTM D5034 Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)
[5]ASTM D1424 Standard Test Method for Tearing Strength of Fabrics by Falling-Pendulum Type (Elmendorf) Apparatus
[6]ASTM D3885 Standard Test Method for Abrasion Resistance of Textile Fabrics (Flexing and Abrasion Method)

[0022] The ASTM F1506 performance specification requires a fabric to meet the following criteria:

[0023] Afterflame duration: 2 seconds maximum

[0024] Char length: 6 inches maximum

[0025] Breaking strength: 40 lbs. minimum

[0026] Tear-resistance: 4.0 lbs. minimum

[0027] Dimensional change: 3% maximum

[0028] ATPV $\geqq$8.0 cal/cm^2 for Arc Level II rating

[0029] The flammability test according to standard ASTM D6413 entails vertically suspending a fabric sample measuring 12 inches long by 3 inches wide (with the length direction vertical) and igniting the lower end of the fabric and then removing the source of ignition. The duration of the afterflame following removal of the ignition source is measured in seconds, and the char length of the charred portion of the fabric is measured. The fabric is tested in both warp and fill directions (i.e., samples having the length direction parallel to the warp direction are tested and other samples having the length direction parallel to the fill direction are tested).

[0030] The dimensional change test entails subjecting fabric samples to repeated laundering and drying cycles. At various incremental numbers of cycles, the percent dimensional change of the fabric is measured in both warp and fill directions, based on benchmarks applied to the fabric prior to laundering. The laundering and drying procedure was designed to substantially duplicate a typical industrial laundering and drying process, and comprised a Light Soil Release procedure, as follows:

[0031] Laundering Procedure—Light Soil Release (formulated for 15 lb. load)

[0032] 1) Break, 12 gallon water level, 140° F., 5 min., ⅓ cup Paragon Plus*

[0033] 2) Carryover, 12 gallon water level, 130-140° F., 3 min., no chemicals

[0034] 3) Rinse, 24 gallon water level, 120-130° F., 1 min., no chemicals

[0035] 4) Rinse, 24 gallon water level, 120-130° F., 1 min., no chemicals

[0036] 5) Sour, 12 gallon water level, 90-100° F., 4 min., ¼ oz. sodium silicofluoride (Fluor-o-cide)**

[0037] *Paragon Plus is a detergent available from Paragon Products, Inc.

[0038] **Sodium silicofluoride (Fluor-o-cide) is a product of UNX, Inc.

[0039] The procedure is to launder (in a Milnor washer), centrifugal extract, and then dry at a temperature of 140-160° F. for 20 minutes followed by 10 minute cool down.

[0040] In the breaking strength test according to standard ASTM D5034, the fabric sample is put into a machine that grips the fabric with two clamps. One clamp is stationary and the other moves away at a controlled slow rate, thus applying tension until the fabric breaks or ruptures. The test is performed in both the warp and fill directions. The highest tensile load in pounds just at the moment the fabric breaks or ruptures is recorded.

[0041] The tear-resistance test according to standard ASTM D1424 measures the resistance of the fabric to tearing under a controlled force. The test indicates the material's resistance to tearing when there is an initial tear in the fabric. The fabric is tested in both warp and fill directions.

[0042] The flex abrasion test according to standard ASTM D3885 measures the resistance of the fabric to abrasion under flexing. A narrow strip of fabric is folded through 180° around a wear-resistant folding bar and held between two flat clamps. Sufficient vertical loading is applied to prevent the fabric from rippling while reciprocation loading parallel to the long dimension of the tensioned fabric specimen is applied. The number of cycles of abrasion to cause the specimen to break is determined.

[0043] Fabric made from each type of yarn was also tested for electrical arc protection according to ASTM 1959. The fabric made from ring-spun yarn was tested to have an ATPV of 8.2 cal/cm^2. The fabric using jet-spun yarn was tested to have an ATPV of 8.7 cal/cm^2. Thus, both fabrics met the performance required for NFPA 70E Level II certification.

[0044] As the results in Table I indicate, in the flame-resistance test, the fabrics made in accordance with the invention self-extinguished immediately and had char lengths well below the maximum permissible 6 inches established by performance standard ASTM F1506. The fabrics had less than 3 percent dimensional change in both warp and fill directions after 75 industrial launderings at 140° F. wash and dry temperatures. Breaking strength of both fabrics was far in excess of the minimum 40 pound level required, and tear-resistance was well in excess of the minimum 4.0 pound level required, even after 75 industrial launderings. It is also believed that fabrics made in accordance with the invention should also be capable of meeting the more-stringent standards required for NFPA 2112 certification (which includes the ASTM F1930 "Test Method for Evaluation of Flame-Resistant Clothing for Protection Against Flash Fire Simulations Using an Instrumented Manikin"), and testing to verify this is currently in progress.

[0045] An additional fabric sample was made using the same fiber constituent percentages as for the first two examples given above, except that the 10% antimony modacrylic fibers were replaced by 15% antimony PROTEX® M modacrylic fibers from Kaneka Corporation of Osaka, Japan. The fiber blend was jet-spun into 25/2 cotton count yarn, which was then woven into fabric using a 2×1 right-hand twill pattern. The jet-spun yarn is more economical to produce than ring-spun yarn, and the abrasion-resistance of fabric made with jet-spun yarn is slightly better than that of fabric made with ring-spun yarn. The wicking performance of the fabric was evaluated using an industry-accepted test method, described below:

[0046] Wicking Test Procedure

[0047] 1. Condition fabric (4 hours at 65% relative humidity, 70° F.)

[0048] 2. Cut samples, 7"×1", 2 in warp direction and 2 in fill direction

[0049] 3. Draw lines with non-soluble ink across width of samples spaced 1" apart

[0050] 4. Place 500 ml of distilled water in a 600 ml beaker

[0051] 5. Hang the test specimen from a ring stand into the beaker so that the narrow end of the fabric is immersed to a depth of 1".

[0052] 6. Measure the distance the water has moved up the fabric after 15 minutes

[0053] 7. Report the average of the two samples in each direction.

[0054] For the fabric as produced and prior to laundering, the initial wicking performance was 4.25 inches in both the warp and fill directions. After 50 industrial washes, the wicking performance was 7.00+inches in the warp direction, and 6.25 inches in the fill direction.

[0055] The dyeability properties of the fibers are also important. An advantage of the fiber blend of the invention is that the chemicals and temperatures required for dyeing the various types of fibers do not interact negatively with each other. Advantageously, the fabric contains less than 10 percent of the para-aramid fibers (which are not dyeable), and thus is over 90 percent dyeable. Therefore, dark, solid shades can be achieved by dyeing each of the dyeable fiber types in the fabric. The dyes are all applied in an exhaust dyeing procedure. The preferred dye procedure is to dye the fabric (or the yarn from which the fabric is made) first with basic dyes to dye the modacrylic fibers. Next the fabric or yarn is dyed with fiber reactive or direct dyes to dye the cotton fibers. Finally, the fabric or yarn is dyed with acid or disperse dyes to dye the nylon fibers. The maximum temperature reached in the dye bath is not greater than 230° F. in each dyeing procedure. The modacrylic fibers cannot withstand temperatures greater than 230° F. Optionally, one or more dye fixatives can be used for fixing one or more of the dyes.

[0056] Alternatively, fabric with a heather appearance can be achieved by dyeing only some of the fiber types such as just the modacrylic fibers.

[0057] The invention is susceptible to numerous variations within the scope of the appended claims. As one example, a fiber blend comprising 50 wt.% modacrylic, 25 wt.% cotton, 20 wt.% nylon, and 5 wt % para-aramid can be spun into yarn and the yarn can be made into a 4.0 oz./yd.^{2} plain weave for arc Level I certification. An 8.3 oz./yd.^{2} plain weave rip-stop fabric can also be made. A 6.0 oz./yd.^{2} plain weave rip-stop can also be made. These are only some of the many variations that can be made within the scope of the claims.

[0058] Fabric made in accordance with the invention may also be vat dye printable. The military has a nylon/cotton

product that it uses for camouflage garments. The current fabric is not fire-resistant. The fabric of the present invention may provide a fire-resistant fabric containing nylon and cotton that is printable with a camouflage pattern.

[0059] Another property of potential significance is the air permeability of the fabric. It is thought that air permeability has some effect on the performance of fabric in the electrical arc test. The lower the air permeability, the better the fabric may perform in that test. Samples of fabric in accordance with the invention have been calendered to reduce the air permeability of the fabric. A sample of fabric was tested for air permeability after it was finished, after it was finished and sanforized, and after it was finished, sanforized and calendered. The results were 17.0, 14.1, and 10.3 cfm, respectively. Thus, calendering can significantly reduce the air permeability, which may be effective in improving electrical arc protection provided by the fabric.

[0060] Fiber blends in accordance with the invention can be made from fibers having various staple fiber lengths and various deniers. Suitably, the fibers can range in length from about 0.5 inch to about 2.5 inches. The modacrylic, nylon, and para-aramid fibers can have a denier ranging from about 0.5 to about 3.0. Yarns can be made in accordance with the invention in various sizes, as single-ply or two-ply yarn, although two-ply yarns are preferred for strength and durability. With respect to two-ply yarns, the yarns can vary in cotton count sizes from 64/2 to 15/2, more preferably from about 38/2 to 15/2.

[0061] Finally, in another embodiment of the invention, the modacrylic fibers can be replaced, in whole or in part, by flame-resistant acrylic fibers and the cotton fibers can be replaced, in whole or in part, by flame-resistant cotton fibers treated in fiber or fabric form. For instance, the FR acrylic fibers can comprise Lufnen acrylic fibers available from Kanebo of Osaka, Japan. These fibers comprise a long-chain synthetic polymer containing acrylonitrile groups modified with a flame-retardant.

[0062] Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

What is claimed is:

1. A flame-resistant fabric, the fabric being formed with yarn comprising a blend of fibers, the blend comprising:

about 40 wt.% to about 65 wt.% modacrylic fibers containing antimony;

about 10 wt.% to about 50 wt.% cotton fibers;

up to about 25 wt.% nylon fibers; and

greater than about 3 wt.% and less than 10 wt.% para-aramid fibers.

2. The flame-resistant fabric of claim 1, wherein the modacrylic fibers contain at least about 7 wt.% antimony based on the weight of the modacrylic.

3. The flame-resistant fabric of claim 1, wherein the blend comprises:

about 45 wt.% to about 55 wt.% modacrylic fibers;

about 20 wt.% to about 30 wt.% cotton fibers;

about 15 wt.% to about 20 wt.% nylon fibers; and

about 5 wt.% to about 9 wt.% para-aramid fibers.

4. The flame-resistant fabric of claim 1, wherein the blend comprises:

about 50 wt.% to about 55 wt.% modacrylic fibers;

about 20 wt.% to about 25 wt.% cotton fibers;

about 15 wt.% to about 20 wt % nylon fibers; and

about 5 wt.% to about 7 wt.% para-aramid fibers.

5. The flame-resistant fabric of claim 1, having a weight of about 4.0 oz./yd.^{2} to about 10.5 oz./yd.^{2}.

6. The flame-resistant fabric of claim 1, having a weight of about 7.0 oz./yd.^{2} to about 9.0 oz./yd.^{2}.

7. The flame-resistant fabric of claim 1, wherein the fabric is woven.

8. The flame-resistant fabric of claim 1, wherein the fabric is knit.

9. The flame-resistant fabric of claim 1, wherein the fibers are dyed with basic dye to dye the modacrylic fibers and/or are dyed with fiber reactive or direct dye to dye the cotton fibers.

10. A garment constructed from the flame-resistant fabric of claim 1.

11. A method of making a flame-resistant fabric, comprising the steps of:

forming an intimate blend of staple fibers comprising:

about 40 wt.% to about 65 wt.% modacrylic fibers containing antimony;

about 10 wt.% to about 50 wt.% cotton fibers;

up to about 25 wt.% nylon fibers; and

greater than about 3 wt.% and less than 10 wt.% para-aramid fibers;

spinning the blend of staple fibers into yarn; and

knitting or weaving the yarn to form fabric.

12. The method of claim 11, further comprising the steps of:

dyeing the modacrylic fibers with basic dye; and

dyeing the cotton fibers with fiber reactive or direct dye.

13. The method of claim 12, wherein the dyeing steps are carried out at a dye bath temperature not exceeding about 230° F.

14. The method of claim 12, wherein the blend of staple fibers includes nylon fibers, and further comprising the step of dyeing the nylon fibers with acid or disperse dye.

15. The method of claim 14, wherein the fibers are first dyed with the basic dye, then the fibers are dyed with the fiber reactive or direct dye, and finally the fibers are dyed with the acid or disperse dye.

16. The method of claim 12, further comprising using a dye fixative to fix the dyes.

17. The method of claim 11, further comprising the step of applying a resin to the fabric for shrinkage control.

18. The method of claim 11, wherein the fabric is woven in a twill pattern.

19. The method of claim 11, wherein the spinning step comprises ring spinning the blend of staple fibers into yarn.

20. The method of claim 11, wherein the spinning step comprises air jet spinning the blend of staple fibers into yarn.

21. The method of claim 11, further comprising the step of calendering the fabric to reduce air permeability of the fabric.

22. A blend of staple comprising:

about 40 wt.% to about 65 wt.% modacrylic fibers containing antimony;

about 10 wt.% to about 50 wt.% cotton fibers;

up to about 25 wt.% nylon fibers; and

greater than about 3 wt.% and less than 10 wt.% para-aramid fibers.

23. The blend of fibers of claim 22, wherein the modacrylic fibers contain at least about 7 wt.% antimony based on the weight of the modacrylic.

24. The blend of fibers of claim 22, wherein the blend comprises:

about 45 wt.% to about 55 wt.% modacrylic fibers;

about 20 wt.% to about 30 wt.% cotton fibers;

about 15 wt.% to about 20 wt.% nylon fibers; and

about 5 wt.% to about 9 wt.% para-aramid fibers.

25. The blend of fibers of claim 22, wherein the blend comprises:

about 50 wt.% to about 55 wt.% modacrylic fibers;

about 20 wt.% to about 25 wt.% cotton fibers;

about 15 wt.% to about 20 wt % nylon fibers; and

about 5 wt.% to about 7 wt.% para-aramid fibers.

26. A yarn formed from a blend of fibers comprising:

about 40 wt.% to about 65 wt.% modacrylic fibers containing antimony;

about 10 wt.% to about 50 wt.% cotton fibers;

up to about 25 wt.% nylon fibers; and

greater than about 3 wt.% and less than 10 wt.% para-aramid fibers.

27. The yarn of claim 26, wherein the yarn is ring-spun.

28. The yarn of claim 26, wherein the yarn is air jet-spun.

29. The yarn of claim 26, wherein the yarn is open-end spun.

30. A flame-resistant fabric, the fabric being formed with yarn comprising a blend of fibers, the blend comprising:

about 40 wt.% to about 65 wt.% FR acrylic fibers;

about 10 wt.% to about 50 wt.% FR cotton fibers;

up to about 25 wt.% nylon fibers; and

greater than about 3 wt.% and less than 10 wt.% para-aramid fibers.

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