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(54) Title: FLAME RESISTANT FABRIC FOR PROTECTIVE CLOTHING AND UPHOLSTERY APPLICATIONS AND ITS USE

(57) Abstract: The fabric of the invention is a flame resistant fabric for use in FR upholstery applications and personal protective clothing, which provides a high level of comfort, protection from flames and other heat sources such as electric arc and liquid metal splash characterized in that it is made from a yarn, which is an intimate blend of FR cellulosic fibres with FR polyamide fibres.



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Flame Resistant Fabric for Protective Clothing and Upholstery

Applications and its Use

Field of application

5 A new flame resistant fabric has been invented that uses the properties of known flame resistant cellulosic fibres combined with new flame resistant polyamide fibres to produce a fabric with exceptional resistance to flame, surprising physical properties and enhanced comfort to the user compared to other flame resistant fabrics.

10 "Flame resistance" is a characteristic of a material such as a fibre or fabric that does not burn in a normal air atmosphere. When exposed to a flame, it will not support combustion when the flame is removed. "Flame resistance" should not be confused with "flame retardant" which is a term used to describe a chemical substance that imparts flame resistance to fabric. Flame retardant
15 is also used to describe fabrics which exhibit a reduced rate of burning but may not offer any protection to the user from flames. The abbreviation "FR" for the purposes of this invention means "flame resistant" or "flame resistance".

It is well known that flame resistant fabrics, especially those made from flame resistant fibres, can be used to give protection against exposure to flame. It is
20 normal practice that fire fighters wear garments that will protect the user from flame in a hazardous situation. The garment is expected to prevent direct exposure to flames of the clothed user's skin, thereby reducing the risk of suffering burn injuries.

25 Other professions where protection from flame is required include police and security personnel, military personnel, and workers in the gas and petroleum industries.

Protective clothing for molten metal splash protection is used by welders and
30 metal industry workers. In the metal industry high levels of energy are used to melt metal and to create electric arcs. Therefore protective clothing is needed to protect against liquid metal splashes and against electric arcs. Utility

personnel working on high voltage installations may be exposed to small metal splashes, when electric arc is produced accidentally.

It is highly desirable that fabrics used in these applications should be comfortable to wear, should perform well physically and be aesthetically suited to the task – colour appearance, style and feel.

It is common for workers who use personal protective clothing to be working in a high stress environment with a high work load leading to high physiological energy consumption. This physiological strain leads to generation of body heat and moisture inside the garment. It is highly desirable that fabrics used for the construction of the garments should be capable of dissipating body heat and moisture to prevent over heating (heat stress) of the user's body. Fabrics that allow body heat and moisture to escape produce garments that feel more comfortable to wear and also prolong the working time that can be achieved without exceeding maximum physiological stress levels.

It is well known, that cellulosic fibres can give enhanced comfort compared to synthetic fibres. This is, because cellulosic fibres are hydrophilic and absorb moisture vapour and liquid water. Controlling the movement and distribution of water in the fabric is an inherent property of a cellulosic fibre.

In the intended applications, fabrics are expected to be unaffected by all activities that they are subjected to. This means they need to have high tear strength, high abrasion resistance and good resistance to snagging.

Fabrics also need to retain their appearance over a prolonged period of use and care. Therefore fabrics need to be washable and have good washing stability, low shrinkage, good pilling performance, and good colour fastness to washing and light.

It is common for organizations that equip workers with personal protective clothing to require that the clothing conforms to the organisation's corporate colours. There are also many cases where the colour of a garment is

important for its function such as black for riot police or high visibility yellow, orange or green for fire fighters and industrial workers. Therefore it is highly desirable that fabrics used for these applications can be dyed easily to a wide range of colours and give good fastness performance.

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This invention is a flame resistant fabric suitable for use in FR upholstery fabrics and in garments intended to protect workers in the metal industry and the utility industry from accidental exposure to flame, molten metal and electric arcs. The fabric produces garments which are comfortable to wear, have a minimal effect on the physiological performance of the wearer and have excellent physical properties,

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Prior Art

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Textile materials vary considerably in their ability to resist flame and hence protect underlying materials. Most fabrics made from natural fibres and from synthetic fibres will burn when exposed to flame. The rate of burn and ease of ignition are determined primarily by the chemical nature of the polymer from which the fibre is made and the construction of the fabric. Many polymers, such as cellulose, polyester and nylon will burn readily. The rate of burn is lower the heavier a fabric is. Wool is the most common natural fibre which has flame resistant properties to some degree – heavy weight wool fabrics will not burn readily and are used in fire fighter's clothing historically.

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Fabrics for protection against molten metal splash as used in the metal industry including welding application are often extremely heavy and stiff. Fabric weights are ranging from 330 to 600g/m². They are made from materials such as flame resistant treated cotton.

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Fabrics can be treated to make them flame resistant by applying an appropriate chemical to the fabric. The first FR treated fabrics used inorganic salts such as aluminium hydroxide, antimony trioxide and borates to make cotton fabrics flame resistant. These were effective but were non-durable to washing.

Organic phosphorous containing compounds that are reacted onto the cotton either by grafting or network formation are more durable and are widely used. Two of the leading brand names are Proban® and Pyrovatex®. While these finishes are durable, they can be removed by harsh chemical treatments and the level of finish reduces with the number of washing cycles. The finish application has an adverse stiffening effect on the fabric. Fabrics of this type are in use for protection from flame, molten metal splash and electric arc. When exposed to flame, molten metal or electric arcs, fabrics of this type will not burn, but become highly embrittled and may break open leaving the wearer's skin exposed to the hazard.

The protection properties of fabrics against liquid Iron splashes are classified by a three-stage system: E1 characterizes the lowest resistance while E3 stands for the highest molten iron resistance. For an E3-fabric a fabric weight of at least 450g/m² FR treated Cotton is needed. Common FR treated cotton fabrics of a fabric weight of 290g/m² only shows E1 properties.

The first flame resistant man made fibres produced were made by the viscose process. A high viscosity liquid flame resistant additive was dispersed in the spinning solution prior to extrusion of the fibre. The liquid was trapped in the cellulose by physical means as very small bubbles. The result was effective as a flame resistant fibre, but the additive could be removed by repeated washing. The strength of the fibre is reduced in proportion to the amount of additive included. The additive was withdrawn from the market due to safety concerns and production of the fibre was discontinued.

An improved flame resistant viscose fibre can be produced by using a solid pigment flame retardant. Fibre of this type will be referred to as FR viscose. The pigment is finely ground and mixed with the spinning solution prior to extrusion of the fibre. The result is a dispersion of the insoluble particulate additive in the fibre. The strength of the fibre is reduced in proportion to the amount of additive included. All of the cellulose in the fibre contains some of the additive and the additive cannot be removed by washing or normal fabric

dyeing or finishing processes. Hence the result of the process is an inherently flame resistant fibre. A well-known fibre of this kind is Visil®, which contains silica pigment flame retardant.

- 5 A further improvement can be achieved by incorporating the solid pigment flame retardant in the spinning solution used to produce modal fibre. The modal process is a modified viscose process designed to produce a fibre with a higher strength and higher wet modulus than normal viscose. The resultant fibre containing the flame retardant pigment is inherently flame resistant. It is
10 stronger than fibre produced by the viscose process and gives fabrics with higher strength and better stability. Fibre of this type will be referred to for the purposes of this invention as "FR Modal" but note that the properties of the fibre do not conform to the BISFA (INTERNATIONAL BUREAU FOR THE STANDARDISATION OF MAN-MADE FIBRES) definition of modal fibre.
- 15 Proven flame retardant pigments for this kind of fibres are organic phosphorous compounds and a preferred pigment is Exolit® (2'-oxybis[5,5-dimethyl-1,3,2-dioxaphosphorinan]2,2'disulfide).

FR Modal is used in 100% form in only a few applications in the field of
20 apparel such as metallised fabrics or fabrics which are mixtures of two or more yarns. On its own its performance is inadequate in a number of respects compared to other products.

In the same way Lyocell fibres can be made flame resistant. Due to the
25 different manufacturing conditions usually different pigments are suitable. Fibre of this type will be referred to as Lyocell FR.

An alternative approach to producing an FR fibre is to modify the polymer from which the fibre is made so that it is inherently flame resistant but can still
30 be formed into a fibre. There are many examples of such fibres but the leading ones being used in personal protective clothing are meta-aramid, para-aramid, Polybenzimidazole (PBI), FR polyester and modacrylic.

Flame resistant fibres can often be used on their own to make fabrics which function well. They can also be used in blends with each other and with non flame resistant fibres to produce fabrics. Such blend fabrics can have properties which are a combination of the properties of the component fibres.

5

There are many flame resistant fabrics available in the market. The most widely used in personal protective clothing are (blend ratios are given in %w/w): Flame resistant treated 100% cotton; Flame resistant treated cotton / polyamide blend (typ 85/15); Flame resistant treated polyester / cotton blend (typ 50/50); Modacrylic / cotton blend (typ 55/45); Modacrylic / cotton / aramid blend (typ 25/25/50); Modacrylic / lyocell / aramid blend (typ 25/25/50); 100% meta-aramid; Meta-aramid / para-aramid blend (typ 80/20); Meta-aramid / para-aramid/Anti static blend (typ 93/5/2); Meta-aramid / FR Modal blend (typ 70/30). Meta-aramid / FR Modal blend (typ 50/50; Meta-aramid / FR Modal blend (typ 35/65)).

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Each of these fabrics has its merits and deficiencies, as can be seen from Table 2 (see Example 2). The fabric selection process used by garment makers and specifiers is based on a judgement of the overall performance and the required level based on risk analysis. None of the fabrics provides all of the criteria of an ideal fabric listed in Table 2.

20

In a lecture given by Klaus Bender, Gunther Schäch, Sergiö Rosa and Rene Sigrist of EMS-CHEMIE AG at the Manmade Fiber Congress, Dornbirn 2012, nonwoven blends have been evaluated and introduced, which are containing NEXYLON® FR, a flame resistant polyamide fibre.

25

FR treated cotton and cotton blend fabrics give poor to medium performance, fair comfort, relatively easy processing and are the most affordable. Modacrylic blends give fair performance but poor comfort and cost more. aramid fabrics give good performance and washing performance but are not comfortable and are expensive. None of the fabrics currently available are rated as good for metal splash or for electric arc. Only the meta-aramid/FR Modal fabric is rated as good for break open behaviour.

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Adding FR Modal to an aramid fabric improves its overall performance and reduces the cost.

- 5 Each of the currently available fabrics has deficiencies in one or more respects. No single fabric has given good all-round performance, protection, comfort, processability and care properties at a reasonable cost. This is the target of the invention.

10 Objective

The objective of this invention is to produce a fabric for use in FR upholstery textiles and personal protective clothing which resolves the deficiencies of the prior art described above. It should show excellent performance in terms of
15 safety of the user, especially in respect of metal splash protection, electric arc protection and break open behaviour. It should also be at lower cost and with better comfort and aesthetic properties than current products to ensure that garments made from it have all of the required performance for the intended applications.

20

Current products in the market perform well in protecting the user, but they are expensive, which means their use is limited. They are made from, at least in part, fibres with poor comfort and aesthetic properties and they can be difficult to produce because of poor dyeability. Currently used fabrics
25 especially for the molten metal industry are stiff and heavy (fabric weights ranging from 330 to 600g/m²). For electrical utilities, insulation against electric arc as well as improved break open performance after electric arc exposure are important safety requirements. There was a need for a fabric which will deliver:

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- Protection
 - Inherently flame resistant for the life of the product
 - Fabrics providing maximum protection against liquid metal splash
 - Improved break open after electric arc exposure

- Good break open behaviour after flame exposure;
- Cool to the touch immediately after exposure to flame
- Very good insulation against heat and flame
- Mechanical Performance and Durability:
 - Suitable tear resistance.
 - Low Pilling
 - Excellent abrasion properties.
- Physiological Performance:
 - Good thermal properties giving more efficient cooling of the user,
 - Improved physiological performance of the user
- Comfort:
 - High and rapid moisture absorption
 - Good short-term water absorption capacity
 - Cool touch
- Processability
 - Fabric can be piece dyed
 - Wide range of colors achievable including high-vis colors
 - Fabric printable using vat or reactive dye systems
- Washing Performance
 - Stable to washing
 - Low washing shrinkage
- Environment / Sustainability
 - Fibres which are ÖKOTEX Standard 100
 - Fibres which are highly sustainable

Description

The product of the invention is a flame resistant fabric for use in FR upholstery fabrics or personal protective clothing which provides a high level of protection from flames and other sources of heat such as molten metal splash and electric arc, which is made from a yarn which is an intimate blend of FR cellulosic fibres with flame resistant polyamide fibres.

The blend ratio of the yarn is preferably:

from 50 to 90% FR cellulosic fibres,

from 50 to 10% FR polyamide fibres

It is surprising that a fabric with this fibre content can give such exceptional performance. It is generally believed by those skilled in the art that a fabric will have better flammability performance and give better protection the higher the content of aramid fibre. The fabric of the invention contains a high percentage of FR cellulosic fibre and yet performs better than currently available fabrics made using a high percentage of aramid fibre.

10 Anti static properties of the fabric can be achieved by adding 1 to 5% antistatic staple fibre to the blend, or by creating an antistatic grid by including in the fabric yarns consisting of the ground yarn twisted with antistatic continuous filament yarns. All fibres used in the blend can be dope dyed (spun dyed) fibres.

15 The FR cellulosic fibre of the yarn is a cellulosic fibre that has been made flame resistant by addition of an FR agent during or after fibre production.

The FR cellulosic fibres of the yarn are chosen from the group consisting of FR Modal, FR viscose and FR Lyocell. More specifically the FR cellulosic fibres of the yarn are FR Modal fibres. Fibres can be dope dyed (spun dyed) or dyed in flock, tops, yarn or fabric.

20 The FR polyamide fibres are chosen from the group consisting of polyamideA 6 and polyamide 6.6; preferred is an high-tenacity FR polyamide 6.6. fibre Fibres can be dope dyed (spun dyed) or stock dyed as staple fibre or top dyed.

25 More specifically the product of the invention is a fabric consisting of a yarn, which is a blend of FR Modal, and a high tenacity FR polyamide 6.6. The fabric may be woven or knitted.

Surprisingly it was found that a part of the FR cellulosic fibres in the fabric can be replaced by FR treated cotton fibres, where the FR agent is applied by grafting polymerization technology in the fiber stage. This technology provides for very durable FR properties of the treated cotton. Such a technology was developed by and is available from the company Kurabo. Up to about 50 % of the FR cellulosic fibre component in the fabric can be such "FR grafted cotton" fibres while maintaining good and durable FR performance. Therefore one embodiment of the invention is a fabric wherein from 0 to 50 % of the FR cellulosic fibres are FR grafted cotton fibres.

- 10 The woven fabric has a warp and weft composed of the yarn according to the invention.

The fabric has exceptional flammability and protective performance. It will not burn, it does not break open when exposed to a flame and continues to provide a barrier to flame. Furthermore, the fabric provides a high level of molten iron, copper, magnesium, lead, brass, zinc and aluminium ("metal splash") protection even at a low fabric weight, as well as superior electric arc protection.

Each of the fibres in the blend may be dope dyed (i. e. spun dyed). This will produce a fabric with very high colour fastness. Only very expensive Aramids have been available as dope dyed fibres so far.

The exceptional flammability and protective performance of the fabric of the invention has previously only been possible with significantly heavier, much more expensive fabrics such as PBI, 100% aramid or Lenzing FR/meta-aramid, as well as heavy Modacrylic - or flame resistant treated cotton blends and inorganic based fibres.

All of this is achieved with a fabric that has better protection and lower production cost than other fabrics with similar performance and the fabric is much more comfortable because of the high proportion of cellulosic fibres.

The yarn is produced from staple fibre by spinning the yarn using conventional techniques such as ring spinning, open end spinning, vortex spinning, worsted spinning, semi-worsted spinning or any of the variations on these used in the yarn spinning industry. The staple length of the fibres for the primary yarn may
5 be between 35 mm up to 160 mm. The staple length will need to be appropriate to the spinning system selected.

The use of fibres with a staple length of between 75 and 90 mm provides for a high durability of even lightweight fabrics with a low pilling and high tenacity,
10 tear strength and abrasion resistance. At the same time the yarns according to the invention and also the fabrics made of these yarns have a more plain, less hairy appearance.

The linear density (= titre) of the fibres and filaments used in the fabric will be
15 chosen to fit with the intended application. Generally it will be in the range commonly used for such textile applications. The linear density will depend on the yarn spinning system used for the yarn.

During the preparatory processes prior to spinning the FR Modal fibre and the
20 FR polyamide fibres are blended together in the required proportions. The yarn according to the invention is an intimate blend of the three fibres with each of the fibres well dispersed throughout the final yarn. This blending can be done during opening of the fibres, during carding or during drawing of the sliver.

25 The blend ratio of the yarn according to the invention in an especially preferred embodiment is 70 % FR Modal and 30 % FR polyamide 6.6 fibres.

Anti static properties of the fabric can be added by blending 1 to 5% antistatic
30 fibre in or by creating an anti static grid in the fabric using yarns that are made by twisting the ground yarn (according to the invention) with antistatic continuous filament yarns.

Optional a proportion of para-aramid fibre in the yarn may be up to 30%, but the cost of the fabric increases with increasing para-aramid content with no appreciable increase in performance against the applicable standards.

One or more of the individual fibre components in the fabric are dope dyed, stock dyed or dyed tops or can be dyed in the yarn or fabric. The high temperature resistant polymer fibres can be either dope dyed or dyed in flock or tops state. By using 100% dope dyed fibres the fabric colour fastness will be improved while at the same time a cost saving on fabric dyeing can be achieved.

The fabric weight, construction and weave of the woven fabric are selected to deliver a fabric of the style and properties required for the application. E.g. the fabric construction may be a plain weave, twill, hopsack, satin, sateen or any other weave which is appropriate to a protective clothing application. For knitted fabrics a plain jersey, pique or any other suitable fabric construction is possible. The fabric may be a lightweight (i. e. a weight per unit area of 100 to 150 g/m²) plain weave for shirting applications. It may be a medium weight (i. e. a weight per unit area of 150 to 230 g/m²) twill weave for trousers. It may also be a heavyweight (i. e. a weight per unit area of 230 to 450 g/m²) twill weave for jackets and other outerwear. For upholstery use the weight per unit area usually is at least 350 g/m². The basic principle of the invention can be incorporated in a wide variety of fabrics. It will work regardless of the weave or construction, provided the correct blends and arrangements of yarns are used. Only exceptionally lightweight fabrics (less than 100 g/m²) would not show the benefits of the invention.

The fabric of the invention may also be produced using a nonwoven fabric production method. Clearly for a nonwoven process a yarn is not required but all what was said above about the nature, properties and treatment of the yarn fibres as well as for the blend ratios applies for the composition of such nonwovens as well. The fibre components are blended together and made into a nonwoven fabric without first spinning a yarn. An example of such a fabric is a needlefelt fabric where the individual fibre components are mixed together in a blending device and then carded, crosslaid and needled to give a

fabric. Such a fabric is of use e. g. as an insulating liner in a garment or could be used to make simple garments such as aprons.

Use of the invention

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The product of this invention is intended to be used as upholstery fabric for public transportation seating such as for example aircraft, train, cruise ship, bus, car seats or one of the primary components of clothing for personal protection in situations where there is a risk of exposure to flame, electric arc
10 or liquid metal splash. The fabric is used to make garments that cover the body of the user to protect the skin from exposure to flames or to other sources of heat such as metal splash and electric arc that would cause injury.

15

Garments are usually made by assembling cut shaped pieces of fabric by sewing them together. The product of this invention may be the sole fabric used in making a garment or may be one component of a garment; the other components consisting of fabrics of different design and purpose. It may also be combined with other fabrics by laminating prior to cutting the shaped pieces for garment assembly.

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The product of this invention may be used as a layer of fabric on the inside of a garment. It may be used as a layer on the outside of a garment or it may be used as an internal component between two or more other fabrics. It may also be used to provide more than one layer in the garment. For example it
25 could be used as the inner layer of the garment and as the outer layer of the garment with a third layer of a flame resistant wadding between the inner and outer layers. The product of this invention can also be used in the form of a laminate of the fabric of the invention with layers of other materials laminated together with the fabric. E.g. the fabric may serve as a carrier of a coating.

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The fabric of the invention may be used for the production of all types of garments where protection from flames is a primary purpose. It can be used for jackets, coats, trousers, shirts, polos, sweaters and jumpers, sweatshirts, T-shirts, socks, aprons, gloves and gauntlets, hoods for head protection, other

headwear and any other garment that may be worn for the purpose of protecting the wearer from flame and similar hazards. The fabric may also be used in other articles which are intended to provide protection of people or property from exposure to flame such as shoe and boot components, welding screens, fire curtains, tents, sleeping bags, tarpaulins and any other similar articles made in whole or in part from fabric.

Coloured fabrics for the intended applications are preferably achieved by using spun dyed fibres, by piece dyeing or by printing, but in general all dyeing techniques are applicable. A big advantage of the fabrics according to this invention compared to fabrics made of a blend of FR modal and FR polyester is the good dyeability in every stage of the textile chain, up to the piece dyeing.

Example 1

A twill weave fabric was woven from the following components:

- Yarn: A Nm 45/2 worsted spun yarn in which 70% of the fibre was 3.3 dtex Lenzing FR® (1/3 with 75 mm and 2/3 with 90 mm staple length), 30% of the fibre was high tenacity FR PA6.6 (Nexylon® FR) fiber. Lenzing FR® is an FR modal fibre available from Lenzing AG, Austria, which is produced according to a modal process (see AT-A 1371/2009) and which contains Exolit® as an incorporated FR pigment. Nexylon® FR is available from EMS Chemie Switzerland, is produced according to a polyamide production process and contains Exolit® as an incorporated FR pigment. The two fibre components were blended together in drafting of the slivers during preparatory processing.

The fabric warp count was 30 threads per cm. The weft count was 26 threads per cm.

The resulting fabric had a mass per unit area of 260 g/m²

Flame protection:

The resulting fabric could not be ignited in normal atmospheric conditions. On exposure to flame directed at the surface of the fabric, the fabric charred but maintained its structure and continued to act as a barrier to flame. No holes were formed in the fabric. The fabric remained soft and flexible without any break open after flame exposure according to EN ISO 15025 procedure A (surface ignition)

Afterflame and afterglow of the fabric when tested according to EN ISO 15025 procedure A were 0 seconds in the warp direction and 0 seconds in the weft direction.

Protective garments – jackets and trousers - were assembled from the fabric and evaluated as follows.

15 **Testing with an instrumented manikin**

According to ISO 13506.3: Protective clothing against heat and flame — Test method for complete garments — Prediction of burn injury using an instrumented manikin.

20 This test method characterizes the thermal protection provided by garments, based on the measurement of heat transfer to a full-size manikin exposed to a laboratory simulation of a fire with controlled heat flux density, duration and flame distribution. The heat transfer measurements can also be used to calculate the predicted skin burn injury resulting from the exposure. Garments made from the fabric according to the invention were compared with garments made from a 100% aramid fabric.

The garment made from the fabric of the invention showed less burns in comparison with 100% Aramid garments.

30 Surprisingly, the fabric of the invention does not shrink during the flame exposure. In fact the opposite occurs - some parts of the garment increased in dimensions. The 100% Aramid garment show significant flame shrinkage.

In the visual evaluation of the test garments it can clearly be seen that the garment made from the fabric of the invention is creating a kind of extra protection cushion when exposed to flame.

5 **Metal splash protection:**

The fabric of the invention was tested according to ISO 9185 and classification according to EN ISO 11612. Despite of it's relatively low fabric weight of 260 g/m² the result was excellent for Aluminium as well as for molten Iron Splash.

- 10 This test assesses the ability of the fabric to withstand a certain quantity of molten metal and how the metal interacts with the fabric. The best performing materials retain their structure and the metal does not adhere to the surface. Damage done to the fabric is minimized.

15 **Electric Arc protection:**

The fabric of the invention was tested according to EN ISO IEC 61482 1-2, 4kA and 7kA. The fabric passed with excellent values the required Stoll criteria for 4kA, and exhibited no break open of the fabric in a single layer, when tested to 7kA. The Stoll curve is a curve of thermal energy and time

- 20 produced from data on human tissue tolerance to heat and used to predict the onset of second-degree burn injury (cited from EN ISO IEC 61482 1-2)..

Mechanical Performance testing:

The tear test results tested according to ISO 13937-2 were as follows

- 25 compared to some of the other products currently used in personal protective clothing in table 1:

Table 1 – Fabric Performance Results

Fabric	Fabric weight (g/m ²)	Warp tear strength	Weft tear strength	Heat penetration coefficient Alambeta	Short time Water vapour absorption [Fi]	Colour Fastness
Fabric of the invention	260	42	39	180	16,0	5
Modacrylic / cotton	260	25	25	126	4.3	4
FR treated cotton	340	28	29	139	9.1	3
Aramid	260	51	49	109	2.3	3-4

The fabric of the invention has a higher tear strength compared with most of the other materials on the market.

5

Comfort testing: Results according to Table 1

Alambeta - Heat penetration coefficient:

The fabric was tested for its comfort properties. The Alambeta test measures the rate of transmission of body heat through the fabric. Fabrics with a high heat penetration coefficient feel cooler and this makes them more comfortable to wear. Referring to the results of Table 1 the fabric of the invention shows the highest heat penetration coefficient, resulting in the coolest fabric touch.

15 Short time water vapor absorption Fi:

The fabric was tested for short term water vapour absorption (Fi) according to EN ISO 31092 using the human skin model apparatus. A high water vapour absorbency indicates the fabric is capable of positively managing the moisture in its environment. This helps to keep the body dry and cool. Referring to the results of Table 1 the fabric of the invention shows the highest short time water vapor absorption, resulting in the best wearing comfort.

This can help to avoid the risk of heat stress and heat stroke and will improve the physiological performance of the wearer.

25 **Colour fastness testing:**

Due to the usage of 100% spundyed fibres, or quality dyeing procedures high colour fastness can be achieved, as colours never wash or wear out.

The fabric of example 1 according to the invention was assessed subjectively and compared to commercially available fabrics used for Personal Protective Clothing. The results are given in Table 2, last column. In this table the scoring system is 1 to 3: 1 = poor, 3 = excellent.

In every parameter judged, the fabric of example 1 was given the highest possible score. No other fabric assessed achieved the same high level on assessment.

Example 2

A twill weave fabric was woven from the following components:

- Yarn: A Nm 45/2 worsted spun yarn in which 40% of the fibre was 1,7 dtex 40mm Lenzing FR®, 40% of FR treated Cotton fiber (Kurabo FR-treatment was applied by grafting polymerisation technology in fiber stage) and 20% high tenacity FR PA6.6 (Nexylon® FR) fiber. The three fibre components were blended together in fiber stage.

The fabric warp count was 33 threads per cm. The weft count was 27 threads per cm.

The resulting fabric had a mass per unit area of 265 g/m²

**Table 2 – Properties of commonly used Personal Protective Clothing
Fabrics compared to example 1**

	FR cotton	FR cotton/PA	FR poly/cotton	MAC/cotton	MAC/cotton /aramid	MAC/lyocell/ aramid	100% meta-aramid	Meta-aramid/para- aramid	Meta-aramid/FR	FR Modal/High tenacity FR PA 6.6.
Protection										
Inherently FR	1	1	1	2	2	2	3	3	3	3
break open behaviour	1	1	1	2	2	2	1	2	3	3
insulation	2	2	2	2	2	2	3	3	2	3
Electric Arc Protection	2	2	2	2	2	2	1	1	2	3
Metal Splash Protection Iron	1	1	1	1	1	1	1	1	1	3
Mechanical Performance Durability:										
tear resistance.	1	1	2	1	2	2	3	3	3	3
Pilling	2	2	2	1	1	2	2	2	3	3
abrasion properties	1	2	2	1	1	1	3	3	3	3
Physiological Performance:										
thermal properties	2	2	2	2	2	2	1	1	3	3
user performance	2	2	2	1	1	1	2	2	3	3
Comfort:										
moisture absorption	3	2	2	2	1	1	1	1	2	3
Cool touch	2	2	1	1	1	2	1	1	2	3
Processability										
piece dyeable	3	3	3	2	2	2	1	1	2	3
colour fastness	1	1	1	1	2	2	1	3	2	3
Colour range	3	3	3	3	3	2	1	1	2	3
Fabric printable	3	3	3	2	2	2	1	1	2	3
Washing Performance										
Stable to washing	1	1	2	1	2	2	3	3	3	3
Low washing shrinkage	1	1	2	2	2	3	3	3	3	3
Environment / Sustainability										
ÖKOTEX Standard 100	1	1	1	1	1	1	2	2	2	3
sustainability	1	1	1	1	1	1	1	1	2	3
Affordability	3	3	3	2	2	2	1	1	2	3

5 MAC = Modacrylic

Claims

1. A flame resistant fabric for use in FR upholstery fabrics or personal protective clothing which provides a high level of protection from flames and other sources of heat such as molten metal splash and electric arc, characterized in that it is made from an intimate blend of FR cellulosic fibres with FR polyamide fibers.
2. Fabric according to claim 1, wherein the intimate blend is in the form of a yarn.
3. Fabric according to claim 1, wherein the blend ratio is preferably
 - from 50 to 90% FR cellulosic fibres,
 - from 50 to 10% FR polyamide fibres
4. Fabric according to claim 1, wherein the FR cellulosic fibres are cellulosic fibres that have been made flame resistant by addition of an FR agent during or after fibre production.
5. Fabric according to claim 1, wherein the FR cellulosic fibres are chosen from the group consisting of FR Modal, FR viscose and FR Lyocell.
6. Fabric according to claim 1, wherein the FR cellulosic fibres are FR Modal fibres.
7. Fabric according to claim 1, wherein from 0 to 50 % of the FR cellulosic fibres are FR grafted cotton fibres.
8. Fabric according to claim 1, wherein the FR cellulosic fibres 1 can be a blend of different FR cellulosic fibres out of the group of FR Modal, FR Viscose, FR Lyocell and FR grafted cotton.
9. Fabric according to claim 1, wherein the FR polyamide fibers are chosen from the group containing polyamide 6 and polyamide 6.6.

10. Fabric according to claim 1 which has been made antistatic by the addition of 1% to 5% of an antistatic staple fibre to the blend.
11. Fabric according to claim 1 which has been made antistatic by incorporating a grid pattern of yarns consisting of the ground yarn twisted with antistatic continuous filament yarn.
12. Fabric according to claim 1 wherein one or more of the individual fibre components has been dope dyed, or is stock dyed staple fibre or dyed tops, yarn or fabric.
13. Fabric according to Claims 1 to 11 which is produced by weaving or knitting.
14. Use of the fabric according to claim 1 as a layer of fabric on the inside of a garment, as a layer on the outside of a garment, as an internal component between two or more other fabrics, to provide more than one layer in the garment, as the inner layer of the garment and as the outer layer of the garment with a third layer of a flame resistant wadding between the inner and outer layers, in the form of a laminate of the fabric of the invention with layers of other materials laminated together with the fabric, in particular as a carrier of a coating.
15. Use of the fabric according to claim 1 for the production of all types of garments where protection from flames is a primary purpose, chosen from the group containing jackets, coats, trousers, shirts, polos, sweaters and jumpers, sweatshirts, T-shirts, socks, aprons, gloves and gauntlets, hoods for head protection, other headwear and any other garment that may be worn for the purpose of protecting the wearer from flame and similar hazards, other articles which are intended to provide protection of people or property from exposure to flame such as shoe and boot components, welding screens, fire curtains, tents, sleeping bags, tarpaulins and any other similar articles made in whole or in part from fabric.

INTERNATIONAL SEARCH REPORT

International application No
PCT/AT2013/000208

A. CLASSIFICATION OF SUBJECT MATTER
INV. D02G3/44
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
D02G D03D D01F A41D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

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X	US 2006/035555 A1 (NARAYANAN VASANTHAKUMAR [US] ET AL) 16 February 2006 (2006-02-16) paragraph [0043]; claims 1,6,15	1-5,9, 12,14,15
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No
PCT/AT2013/000208

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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X	US 2012/156486 A1 (BISJAK CLEMENS [AT] ET AL) 21 June 2012 (2012-06-21) paragraph [0001] - paragraph [0002] paragraph [0023] - paragraph [0025] paragraph [0049] paragraph [0094] - paragraph [0098] -----	1,2,4,5, 12-15
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