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(54) Title: FLAME RESISTANT FABRIC FOR PROTECTIVE CLOTHING

(57) Abstract: The fabric of the invention is a flame resistant fabric for use in 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 contains a first fibre component which is a flame resistant fibre and a second fibre component which is silk, and it may contain a third fibre component.

Flame Resistant Fabric for Protective Clothing

Field of application

A new flame resistant fabric has been invented that uses the properties of known flame resistant fibres combined with non-flame resistant natural fibres to produce a fabric with exceptional resistance to flame, superior heat protective properties, surprising physical properties and enhanced comfort to the user compared to other flame resistant fabrics.

"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 is also used to describe fabrics which exhibit a reduced rate of burning but may not offer any protection to the user from flames.

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 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.

Other professions where protection from flame is required include motorsport, police and security personnel, military personnel, workers in the gas and petro-chemical and the electrical utility industries.

Protective clothing for molten metal splash protection is used by welders and 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 persons, who use 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, higher sweat rate 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 firefighters and industrial workers. Especially in the application field of motor sports colors do play a major role for team differentiation and recognition. Therefore it is highly desirable that fabrics used for these applications can be dyed and printed easily to a wide range of colours and give good fastness performance.

This invention is a flame resistant fabric suitable for use in garments intended to protect people involved in motor sports, Fire Fighters, workers in the petro-chemical, 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,

Prior Art

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 firefighter's clothing historically.

Fabrics for protection against molten metal splash as used in the metal industry including welding applications, are often extremely heavy and stiff. Fabric weights ranging from 330 to 600g/m^2. They are made from materials such as flame resistant treated cotton.

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 first flame resistant man made cellulosic 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.

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 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 as FR Modal but note that the properties of the fibre do not conform to the BISFA definition of modal fibre. Proven flame retardant pigments for this kind of fibres are organic phosphorous compounds and a preferred pigment is Exolit® 5060 (2'-oxybis[5,5-dimethyl-1,3,2-dioxaphosphorinane]2,2'disulfide).

FR Modal is used in 100% form in only a few applications in the field of 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 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 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.

There are many flame resistant fabrics available in the market. The most widely used in personal protective clothing for motor sports are: Flame resistant finished 100% cotton; Flame resistant finished cotton / polyamide blend (typ 85/15); Flame resistant finished polyester / cotton blend (typ 50/50); Modacrylic / cotton blend (typ 55/45), 100% meta-aramid; Meta-aramid / para-aramid blend (typ 75/25); Meta-aramid / para-aramid/Anti static blend (typ 93/5/2);

Each of these fabrics has its merits and deficiencies, as can be seen from Table 2 (see Example 3). The fabric selection process used by garment makers and specifiers is based on a judgement of the overall performance and the required level of protection of the wearer based on risk analysis and requirements of relevant standards.

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. Furthermore, aramid fabrics are difficult to dye with poor colour, light and rubbing fastness properties. 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.

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.

Objective

The objective of this invention is to produce a fabric for use in personal protective clothing which resolves the deficiencies of the prior art described above. It should show excellent performance in terms of safety of the user,

especially in respect of heat and flame protection. It should also have 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.

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 they can be difficult to produce because of poor dyeability.

Currently used fabrics especially for the molten metal industry are stiff and heavy (fabric weights ranging from 330 to 600g/m^2). 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:

- Protection
  - Inherently flame resistant for the life of the product
  - Extremely lightweight fabrics providing maximum protection against liquid metal splash
  - After flame exposure; the fabric remains soft
  - Cool to the touch immediately after exposure to flame
  - Very good insulation against heat and flame
- Mechanical Performance and Durability:
  - High tear resistance.
  - Low Pilling
  - Suitable 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/management

- Good short-term water vapour absorption capacity
- Cool touch

- Processability
  - Fabric can be piece dyed
  - Very high colour fastness
  - Wide range of colours achievable
  - Fabric printable using vat, reactive or any other suitable dye systems or digital printing
- Washing Performance
  - Stable to washing
  - Suitable for dry cleaning
  - Low washing shrinkage
- Environment / Sustainability
  - Fibres which are ÖKOTEX Standard 100
  - Fibres which are highly sustainable

Description

These problems were solved by a flame resistant fabric for use in personal protective clothing which provides a high level of protection from flames and other sources of heat and which is characterized in that it contains a first fibre component which is a flame resistant fibre and a second fibre component which is silk.

To enable a most accurate description of the invention the term "fibre" has to be understood as either "staple fibre" or "filament". Therefore the flame resistant fibres according to the invention can be either staple fibres or filaments.

Silk is naturally flammable despite its flammability is low. Usually the flammability of a fibre increases with decreasing diameter. Therefore it was surprising that the very fine silk shows such an exceptional flame resistance performance as can be seen from the examples. The silk described and used in this invention was not pre-treated in any way to make it flame resistant.

In a preferred embodiment of the invention the flame resistant fibres are inherently flame resistant fibres. More preferably the flame resistant fibres are flame resistant cellulosic fibres. The flame resistant cellulosic fibres are chosen from the group consisting of FR Modal, FR viscose, FR Lyocell fibers and blends thereof. The FR cellulosic fibre is a cellulosic fibre that has been made flame resistant by addition of an FR agent during or after fibre production. More specifically the FR cellulosic fibres of the yarn are FR Modal fibres.

Also preferred are embodiments wherein the flame resistant fibres are chosen from the group consisting of para-aramid, meta-aramid, aromatic PES, PBI, Modacryl and blends of these fibres. Preferably the high temperature resistant polymer fibres are para-aramid or meta-aramid fibres.

The silk can be in the form of either staple fibres or filament. While silk originally is produced as endless fibres and therefore would usually be in filament form, silk staple fibres are also available which are chopped filaments.

According to a preferred embodiment of the invention the fabric additionally contains a third fibre component which is a polymer fibre.

Preferably the polymer fibre is a flame resistant synthetic polymer fibre, more preferably chosen from the group consisting of para-aramid, meta-aramid, aromatic PES, PBI, PVA, Modacryl and blends of these fibres.

Also preferably the polymer fibre can be a non-FR cellulosic fibre, chosen from the group consisting of cotton, viscose, modal, lyocell, hemp, linen, jute, ramie and sisal.

Also preferably the polymer fibre can be a non-FR synthetic fibre, chosen from the group consisting of polyamides (PA).

The construction can consist of a yarn which is an intimate blend containing the first fibre component and the second fibre component.

In another preferred embodiment the yarn additionally contains the third fibre component.

The blend ratio of the yarn is preferably:

- 40 to 60% FR cellulosic fibres,
- 3 to 10 % flame resistant synthetic polymer fibres and
- 40 to 60% silk.

In the context of this invention "%" always means "weight-%". For example, one suitable specific blend ratio is 45 % FR Modal, 5% flame resistant synthetic polymer fibres and 50% silk.

It is surprising that a fabric with this fibre composition can give such exceptional performance. It is generally believed by those skilled in the art that a fabric will have better non-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 silk, yet performs better than currently available fabrics made using a high percentage or even 100% of aramid fibre.

In addition to embodiments of the inventive fabric construction which contain only one type of yarn another preferred embodiment is a flame resistant fabric, characterized in that its construction contains a first yarn consisting of the first fibre component and a second yarn which is 100% silk filament.

Another preferred embodiment of the fabric according to the invention is characterized in that its construction contains a first yarn which is an intimate blend of the first fibre component staple fibre and the third fibre component staple fibre and a second yarn which is 100% silk filament.

Another preferred embodiment of the fabric according to the invention is characterized in that its construction contains a first yarn which is 100% first fibre component filament and a second yarn which is 100% silk filament.

The fabric according to the invention preferably has a silk content of 10 to 50 weight-%. More preferably the blend ratio is in the range of 10 to 50 weight-% flame resistant cellulosic fibres, 10 to 30 weight-% flame resistant polymer fibres and 10 to 50 weight-% silk staple fibres.

In the embodiments of this invention one or more of the individual fibre components can be dope dyed, or stock dyed staple fibre or dyed tops, yarn or fabric. Flame resistant polymer fibres can be either dope dyed or dyed in flock or tops state.

The fabric according to the invention can be produced by weaving or knitting technology. It can also be produced by a non woven fabric production method.

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 a ground yarn twisted with antistatic continuous filament yarns.

More specifically the product of the invention is a fabric consisting of a yarn, which is a blend of FR Modal, and a para-aramid or meta-aramid or a blend of the two aramids and silk. The fabric may be woven, knitted or produced with non-woven technologies.

The woven fabric has a warp and weft composed of the blend yarn. The materials can also be introduced separately in the fabric by means of different warp and weft yarns. For instance the warp yarn can consist of a FR Modal / para-aramid blend and the weft can be a silk staple fiber or filament yarn.

Even though the fabric includes a percentage of silk, 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 protection even at a low fabric weight, as well as superior electric arc protection.

The exceptional flammability and protective performance of the fabric of the invention has previously only been possible with fabrics such as 100%

aramid, heavy modacrylic - or flame resistant treated cotton blends and inorganic based fibres.

All of this is achieved with a fabric that has a lower fabric weight, better protection, higher colour fastness than other fabrics with similar performance and the fabric is much more comfortable because of the high proportion of cellulosic and silk fibres.

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

The linear density (= titre) of the fibres and filaments used in the fabric will be 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.

For a preferred embodiment of blend yarn according to the invention, during the preparatory processes prior to spinning the FR Modal fibre, the para-aramid fibre and the silk fibres are blended together in the required proportions. The yarn 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.

The blend ratio of the yarn according to the invention is preferably
45 % FR Modal, 5% Para Aramid and 50% silk fibres
or
50 % FR Modal and 50% silk fibres.

Further possible options for preferred blends include but are not limited to the following:

45 % Modacryl, 5% Para Aramid, 50% silk fibres.

or

50% Modacryl, 50% silk fibres.

or

50% Modacryl, 10% Linen, 40% silk fibres

or

50 % FR Modal and 50% Meta Aramid fiber in warp, 100% Silk filament in weft

or

50 % Modacryl and 50% Meta Aramid fiber in warp, 100% Silk filament in weft

or

80% Modacryl and 20% Lyocell in warp, 100% Silk filament in weft

or

100% Aramid Filament in warp and 100% Silk filament in weft.

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

The 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.

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 90 to 150 g/m^2) plain weave for shirting applications, racing suits, flight suits, lining fabrics, etc.. It may be a medium weight (i. e. a weight per unit area of 150 to 230 g/m^2) twill weave for trousers. It may also be a heavyweight (i. e. a

weight per unit area of 230 to 400 g/m^2) twill weave for jackets and other outerwear. The basic principle of the invention can be incorporated in a wide variety of fabrics. 400 g/m^2 is especially necessary in the case of molten metal splash. It will work regardless of the weave or construction, provided the correct blends and arrangements of yarns are used.

The fabric of the invention may also be produced using a nonwoven fabric production method. 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 needle felt fabric where the individual fibre components are mixed together in a blending device and then carded, cross laid and needled to give a fabric. Such a fabric is of use as an insulating liner in a garment or could be used to make simple garments such as aprons. For durability improvement also a woven or laid grid yarn construction can be introduced in scrim form. Other suitable technical possibilities for such fabrics are spunlace water jet entanglement nonwoven fabrics.

Use of the invention

The product of this invention is intended to be used as one of the primary components of clothing for personal protection in situations where there is a risk of exposure to flame, electric arc, liquid metal splash and heat. The fabric is used to make garments, that cover the body of the user to protect the skin from exposure to flames or other sources of heat, electric arc and liquid metal splash that would cause injury.

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.

The product of this invention may be used as a layer of fabric on the inside of a garment (innermost lining fabric) 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 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 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. One specific use is woven fabrics for race wear, i. e. in Formula 1 automobile racing. 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 partly spun dyed fibres, by piece dyeing or by printing, but in general all dyeing techniques are applicable.

Example 1

A plain weave fabric was woven from the following components:
Yarn: A Nm 70/2 worsted spun yarn in which 5% of the fibre was longstaple para-aramid fiber (staple fiber type), 45% of the fibre was 2.2 dtex Lenzing FR® (1/3 with 75 mm and 2/3 with 90 mm staple length), 50% of the fibre was Mulberry Silk average length 70/75 mm 11-12,5 microns . 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 FR pigment. The three fibre components were blended together

in drafting of the slivers during preparatory processing. The fabric warp count was 28 threads per cm. The weft count was 26 threads per cm. The resulting fabric had a mass per unit area of 120g/m^2

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. Furthermore no heat shrinkage of the fabric was observed when the flame was directed at the fabric surface and during the whole flaming time of 10 seconds.

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.

Multi layer protective coveralls were assembled from the fabric and evaluated; results are summarized in Table 2.

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.

This test method characterizes the thermal protection provided by garments, based on the measurement of heat transfer to a full-size manikin fitted with heat sensors and connected to a recording device when 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 of the invention were compared with garments made

from a 100% aramid fabric. FR underwear has been used under the coverall during the testing.

Burn prediction:

Degree of burns/Total Burns(%)	1st	2nd	3rd
Fabric of the invention:	5	5.4	0
100% aramid:	5,3	10,1	12,3

Dimensional Change after flame exposure:

Location: (Shrinkage%)	Fabric of Invention	100% aramid
Coverall length	+1	-6%
Coverall width	+0,0	-4,0
Arm length	+1,2	-5,0

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

After the flame exposure the garments were removed from the manikin to measure the size and shrinkage of the garment. Parts of the 100% aramid garments were too brittle to measure - the jacket upper arm and the trouser thigh. The fabric of the invention remained intact. No severe damage was observed. The fabric remained flexible and did not break open during flame exposure

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 showed significant flame shrinkage.

In the visual evaluation of the test garments, it can clearly be seen, that when exposed to flame the garment made from the fabric of the invention is creating better protection as it also shrinks by far less than the comparative aramid garment.

Mechanical Performance testing:

The tear test results tested according to ISO 13937-2 for the fabric of the invention are compared to some of the other products currently used in personal protective clothing in table 1.

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

Comfort testing: Results according to Table 1

The fabric was tested for its comfort and physiological properties using the Alambeta test - Heat penetration coefficient: 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.

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

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.

Example 2:

A plain weave fabric was woven from the following components:

Warp Yarn: A Nm 70/2 worsted spun yarn in which 50% of the fibre was longstaple meta Aramd fiber (fiber type), 49% of the fibre was 2.2 dtex

Lenzing FR® (1/3 with 75 mm and 2/3 with 90 mm staple length), 1% of the fibre was anti static 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 FR pigment.

Weft yarn: Silk filament tram 20/22 deniers 8 ply with European twist S250 Tpm, degummed and not loaded

The yarn components were used as the warp and weft to produce a woven fabric.

The fabric of example 1 and 2 were assessed subjectively and compared to commercially available fabrics used for Personal Protective Clothing. The results are given in Table 1. In every parameter judged, the fabric of example 1 and 2 was given the highest possible score. No other fabric assessed achieved this level on assessment.

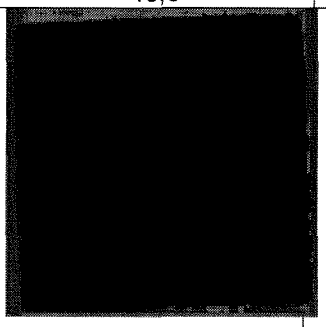
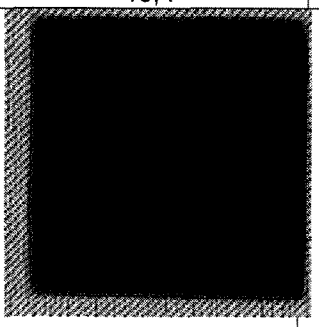
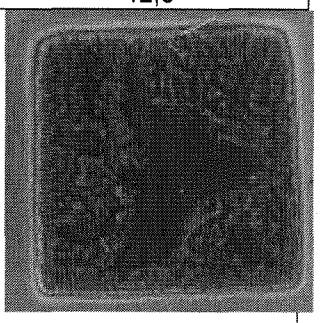
Table 1 – Fabric Performance Results

Fabric	Fabric weight (g/m2)	Warp tensile strength	Weft tensile strength	Warp tear strength	Weft tear strength	Heat penetration coefficient Alambeta	Short time Water vapour absorption [Fi]	Air Permeability l/m²/sec	Colour Fastness to light
Example 1	120	477	599	27	21	164	6,31	518	5
Example 2	110	528	789	32	33	177	7,17	1300	5
Modacrylic / cotton	150	450	399	13	14	129	3,99	386	4
FR treated cotton	160	410	387	8	9	133	5,1	301	4
Aramid	120	523	756	26	21	120	3,94	370	2-3

The fabrics from example 1 and 2 have been also tested in a full sandwich composite as it is used for motor sport protective garments. Table 2 shows the result in comparison with a 100% meta-aramid composite - the current bench mark for woven race wear fabrics. Each of the three full sandwich composites tested had the same thermal insulation layer and lining taken from the same lots of fabric. Only the outershell fabric was varied.

The fabrics of invention, example 1 and example 2 show superior protection performance though flammable silk fiber is used. The 100% aramid fabric showed significant hole formation, where as fabric from example 1 and example 2 did not break open during test.

Table 2 Fabric compound comparison results:

Compound Construction	Example 1	Example 2	
Outershell	**50% Lenzing FR® 50% Silk intimate blend**	**Warp: 50% Lenzing FR® 50% Meta Aramid Weft: 100% Silk Filament**	**100% Meta- Aramid**
Thermal Insulation	100% FR Synthetic fiber	100% FR Synthetic fiber	100% FR Synthetic fiber
Lining	100% Aramid knit	100% Aramid knit	100% Aramid knit
Total compound weight gsm	341	348	353
Pretreatment	15 washes acc. EN ISO 6330, 60°C + Tumbler	15 washes acc. EN ISO 6330, 60°C + Tumbler	15 washes acc. EN ISO 6330, 60°C + Tumbler
FR Performance according to EN ISO 15025 - surface ignition	0 sec. Afterflame 0 sec. Afterglow no holeformation	0 sec. Afterflame 0 sec. Afterglow no holeformation	1 sec. Afterflame 0 sec. Afterglow no holeformation
Heat Transfer Flame according to EN 367 HTI 24 sec.	13,3	13,4	12,5
Fabric Specimen after Heat Transfer Flame	 No break open	 No break open	 Significant hole formation
Comfort Test Data			
Air permeability EN ISO 9237 l/m²*s @ 2mbar	518	1300	370
Rct Body Heat transfer resistance ISO 11092 m²K/W	0,149	0,153	0,154
Ret Water vapor transfer resistance ISO 11092 m²Pa/W	11,12	11,03	11,59
Moisture Transfer index imt ISO 11092	0,75	0,83	0,8
Heat Transfer Coefficient Alambeta	164	177	120
Short time water vapor absorption Fi ISO 11092 g/m²	6,31	7,17	3,94

Example 3

A twill weave fabric was woven from the following components:
Yarn: A Nm 38/2 spun yarn in which 50% of the fibre was 2,2 dtex 51mm Lenzing FR®, 40% Mulberry Silk average length 50mm 11-12,5 microns staple fiber and 10% of the fibre was high tenacity PA6. 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 Exolith® as an incorporated FR pigment. The three fibre components were blended together in drafting of the slivers during preparatory processing. The resulting fabric had a mass per unit area of 360 g/m^2

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 after flame exposure according to EN ISO 15025 procedure A (surface ignition). Furthermore no heat shrinkage of the fabric was observed when the flame was directed at the fabric surface and during the whole flaming time of 10 seconds.

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.

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 360 g/m^2 the result was on the highest protection level which can be achieved: E3 (Iron Splash). For comparison: A typical fabric already used for iron metal splash protection has a fabric weight of 400 g/m^2 and only shows a protection level E1.

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. The fabric was also tested against codeletter D (Liquid Aluminium splash) and achieved also the highest ranking for aluminium metal splash protection D3.

Further more the fabric was subjected to the following other metal splash: Cryolite (Aluminum Bath), Brass, Lead, Zink, Steel, Copper, Magnesium, Gold and Silver.
It also performed outstandingly well, with no metal sticking on the fabric, no break open of the fabric, no damage on the skin simulant, which has been used straight under the fabric.

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 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 compared to some of the other products currently used in personal protective clothing in table 3:

Table 3 – Fabric Performance Results

Fabric	Fabric weight (g/m^2)	Warp tear strength	Weft tear strength
Fabric of the invention	360	73	68
Modacrylic / cotton	310	30	29
FR treated cotton	340	28	29

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

Similar blends with PVA fiber instead or in addition to PA have been developed and tested showing also remarkable results for molten metal splash and electric arc protection.

Claims

What we claim is:

1. A flame resistant fabric for use in personal protective clothing which provides a high level of protection from flames and other sources of heat, characterized in that it contains a first fibre component which is a flame resistant fibre and a second fibre component which is silk.

2. A flame resistant fabric according to claim 1, wherein the flame resistant fibres are inherently flame resistant fibres.

3. A flame resistant fabric according to claim 1, wherein the flame resistant fibres are flame resistant cellulosic fibres.

4. A flame resistant fabric according to claim 3, wherein the flame resistant cellulosic fibres are chosen from the group consisting of FR Modal, FR viscose, FR Lyocell fibers and blends thereof.

5. A flame resistant fabric according to claim 1, wherein the flame resistant fibres are chosen from the group consisting of para-aramid, meta-aramid, aromatic PES, PBI, PVA, Modacryl and blends of these fibres.

6. A flame resistant fabric according to claim 1, wherein the flame resistant fibres are either staple fibres or filaments.

7. A flame resistant fabric according to claim 1, wherein the silk is in the form of either staple fibres or filament.

8. A flame resistant fabric according to claim 1, wherein the fabric additionally contains a third fibre component which is a polymer fibre.

9. A flame resistant fabric according to claim 8, wherein the polymer fibre is a flame resistant synthetic polymer fibre, preferably chosen from the group consisting of para-aramid, meta-aramid, aromatic PES, PBI, Modacryl and blends of these fibres.

10. Fabric according to claim 8, wherein the polymer fibre is a non-FR cellulosic fibre, chosen from the group consisting of cotton, viscose, modal, lyocell, hemp, linen, jute, ramie and sisal.

11. A flame resistant fabric according to claim 1, characterized in that its construction consists of a yarn which is an intimate blend containing the first fibre component and the second fibre component.

12. A flame resistant fabric according to claim 11, characterized in that the yarn additionally contains the third fibre component.

13. A flame resistant fabric according to claim 1, characterized in that its construction contains a first yarn consisting of the first fibre component and a second yarn which is 100% silk filament.

14. A flame resistant fabric according to claim 1, characterized in that its construction contains a first yarn which is an intimate blend of the first fibre component staple fibre and the third fibre component staple fibre and a second yarn which is 100% silk filament.

15. A flame resistant fabric according to claim 1, characterized in that its construction contains a first yarn which is 100% first fibre component filament and a second yarn which is 100% silk filament.

16. Fabric according to claim 1, characterized by a silk content of 10 to 50 weight-%.

17. Fabric according to claim 8, wherein the blend ratio is in the range of 10 to 50 weight-% flame resistant cellulosic fibres, 10 to 30 weight-% flame resistant polymer fibres and 10 to 50 weight-% silk staple fibres.

18. Fabric according to claim 1, which has been made antistatic by the addition of 1% to 5% of an antistatic staple fibre.

19. Fabric according to claim 1, which has been made antistatic by incorporating a grid pattern of yarns consisting of a ground yarn twisted with anti static continuous filament yarn.

20. 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 [Flame resistant polymer fibres can be either dope dyed or dyed in flock or tops state].

21. Fabric according to Claims 1, produced by weaving or knitting technology.

22. Fabric according to Claims 1, produced by a non woven fabric production method.

INTERNATIONAL SEARCH REPORT

International application No
PCT/AT2013/000106

A. CLASSIFICATION OF SUBJECT MATTER
INV. A41D31/00
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)
A41D D03D D02G

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2007/117052 A1 (HWANG DUCK YEUL [KR]) 18 October 2007 (2007-10-18) paragraphs [0025] - [0031] -----	1-12,16, 17,20-22
X	US 2001/009832 A1 (SHAFFER DONALD E [US] ET AL) 26 July 2001 (2001-07-26) claims 1,5-7 -----	1,2,5-9, 14-16, 18,20,21
X	US 3 913 309 A (CHIAROTTO NEREO) 21 October 1975 (1975-10-21) examples 1,3 -----	1,2,6-8, 11-13, 16,20-22
A	US 2007/077839 A1 (MCKINNON BOB [US] ET AL) 5 April 2007 (2007-04-05) claims 1-3,5,6 -----	1,21
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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	Date of mailing of the international search report
23 October 2013	29/10/2013

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/AT2013/000106

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 4 950 540 A (MCCULLOUGH JR FRANCIS P [US] ET AL) 21 August 1990 (1990-08-21) claims 1,3,5,6	1

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Information on patent family members

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