

Applications of Standarized High-Visibility Textiles for Protective Apparels

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Abstract

High-visibility clothing is a type of personal protective equipment (PPE) worn that has highly reflective properties or a colour that is easily discernible from any back ground. Occupational wearers of clothing with high-visibility features include railway and highway workers, airport workers or other places where workers are near moving vehicles or in dark areas. The high-visibility colours are yellow, orange or red. For visibility clothing there are defined areas of fluorescent back ground fabrics and retro-reflective materials. High-visibility textiles are fabrics with a colour that is discernible in any environment. Workers' visibility is enhanced by high colour contrast between clothing and the work environment against which it is seen. High-visibility vest is worn by construction persons, traffic police and road safety persons for their safety. A variety of styles for various end uses for performance textiles are available. Reflective fabrics are exceptional for a variety of outdoor activities.

Keywords: *Fluorescent colours, Safety Vest, Tear Resistance, Colour Contrast, Luminance Factor, Retro-reflective Colour, Jerkin.*

INTRODUCTION

Experimental use of **high-visibility clothing began in 1964** on the **Scottish**

Region of British Railways. Fluorescent orange jackets, known as “fire flies”, were issued to track workers on **the Pollok**

Shields to Eglin to street electrified section of Glasgow, they were later tried in other areas, such as **Edinburgh, Aberdeen and Inverness [01]**. The train drivers operating in those areas were asked their opinion as to the effectiveness of the jackets. Following trial, high-visibility clothing was issued to engineering and other staff working on the **electrified lines of BR's London Midland region in 1965**. It was thought to be more important due to the higher speeds of the **newly electrified WCML route from Euston to Manchester, Liverpool and Birmingham**. The first version was worn as a jerkin and was visible at half a mile in normal weather conditions. Since then, features of high-visibility clothing such as **EN 510 quick release standard and EN 471 high-visibility standard**, have improved effectiveness and contributed to improved safety for rail workers.

High-visibility products fall within the jurisdiction of the Personal Protective Equipment **(PPE), directive (89/686/EEC)** and are intended to signal the wearers' presence visually in different light conditions and make the wearer stand out from the surrounding environment **[02]**. High-visibility products are worn in many different settings to provide conspicuous to people working in areas

where needs to be seen easily. **Examples of this are motorways, roads, railways, docks, construction sites and also by emergency workers**, and security staff. High-visibility products are also worn by school children cyclists, motor cyclists and horse riders for non-professional or leisure activities.

High-visibility safety apparel (HVSA) is the clothing that workers can wear to improve how well other people „see“ them. Most often, **high-visibility clothing is worn to alert drivers** and others vehicle operators of a worker's presence, especially in low light and dark conditions. High-visibility head wear can also be **worn to increase the visibility of the wearer in situations** where part or all the wearer's body could be obscured **[03]**.

Some of the toughest and most visible fabrics known as reflective cloths are exceptional for a variety of outdoor activities. **The Super Glo Reflective Polyester from Seattle Fabric Inc [04]** is suitable to spot gear in incremental weather or starry nights. According to the company **100% polyester fabric** is perfect for use in items where high-visibility is required. **An aluminium or fluorescent orange colour coating** is applied to be followed by glass reflective beads. This

fabric is also UV resistant for all outdoor needs. This high-visibility cloth fabric was made for covers, motor cycle covers, outdoor clothing, safety vests, bags and much more.

Many organic substances are characterised by fluorescent ability. The application of fluorescent dyes involves various differential fields. Recently, the applications of fluorescent dyes in **medical diagnostic and biochemical investigations** have been developed extremely dynamically. Fluorescent dyes have also been **used for construction of lasers, photoelectric cells and solar batteries**. The application of fluorescent dyes in medium flow control, as well as for testing material defects and equipment damage has well known for many years. But one of the major applications fields where fluorescent dyes have long been **used for the dyeing of flat materials, especially textiles**. The use of fluorescent dyes **causes a significant increase in colour brightness** which makes the dyed materials more easily perceptible or more accurately have increased visibility [05].

Technical fabrics for high-visibility garments (EN471) used in areas where it's necessary to have **good visibility for both short and long distance**. The **high-visibility colours are in Yellow and**

Orange and in other range of contrast colours. Besides, these one **can also combine with retro-reflective brands** to obtain a better detection in dark areas. **Marina Textil** also offers the possibility of providing some of its technical fabrics of other categories in high-visibility [06].

Performance Textiles have **designed Hi-Visibility ANSI/ISEA 107-2015** compliant fabrics since the inception of the ANSI Standards. **Glen Guard [07]**, have variety of styles for many end uses, such as **FR-T-shirts, Fr-Safety vests, Rain wear vests** for everyday use. They also have developed fabrics for utility workers that meet very **stringent requirements for FR, ARC flash and Anti-static**. They have both woven and knit fabrics in yellow/green and safety orange.

According to **Fabrics India [08]**, high-visibility fabrics are used in uniforms for safety workers at construction and road sites. Fluorescent high-visibility fabrics **(120-135 GSM)** are produced with **58-60 inches in width in orange/yellow colour in knitted pattern** for use in safety garments.

Hi Vis Work Apparels are built to withstand whatever the workday brings- **jackets, sweat shirts, rainwear and**

more. ANSI compliant high-visibility clothing includes shirts, jackets, pants, head wear, women's clothing and a wide range of other items for all seasons [09].

The Reflective Apparel factory manufacturers [10] are making a complete line of high-visibility safety apparels to meet the requirements of ANSI 107-2010. VEA (Visibility Enhanced Apparel) the registered trade mark, assures not only a highly visible garment but a comfortable and durable one as well.

Coop man International's 1 Range of fabrics offers unrivalled standards of performance for high-visibility clothing. They give superior protection to workers operating in low-light and/or potentially hazardous conditions. They are available in superior luminosity and brightness of the three available colours-High-visibility Yellow; High-visibility-Orange; and High-visibility Red [11].

Now ANSI 107 is the universal standards of Excellence in performance and Geh Ring Tricot is the one textile organization have played the vital role in the committee to create the protection [12].

High-visibility "HI-VIZ" safety yellow polyester twill fabric 62 inches by the

yard, is fluorescent twill for safety vests for areas that must be seen or the fabric will glow in the dark as suggested [13].

High-visibility colours refer to fluorescent colours or neon colours that can be seen easily even in low-light conditions. By measuring the chromaticity, co-ordinates brightness and colour difference, the test verifies whether the claimed colour complies with the fluorescent colour requirements. High-visibility textiles are fabrics with a colour that is easily discernible in any environment or has highly reflective properties. High-visibility clothing can serve as a distinctive sign to indicate the presence of the wearer and are widely used for the purposes of public safety, emergency services, personal safety applications and other professional uses. Intertek provides a total solution for the various visibility-related tests to assure the product quality and safety [14].

APPLICATION AREAS OF HIGH-VISIBILITY CLOTHING

Experimental use of high-visibility clothing began in 1964 on the Scottish Region of British Railways. Train drivers operating on their areas were asked to express their opinion as to the effectiveness of the jackets used by them in the form of fluorescent orange colours.

Moreover, high-visibility clothing was issued to **engineering and other staff working on the electrified lines of BR's London Midland Region in 1965**. The **First version was worn as a Jerkin and was visible at Half-a-Mile in normal weather conditions**.

The Hurt Report found that very few motorcyclists involved in collisions wore high-visibility clothing and that just over half of the collisions studied, **nearly 23rd** of those involving another vehicle were due to the motorist unintentionally **violating the motorcyclists' right of way**. This dominant culpability of the driver of the other vehicle emphasises the **special need for high contrast** conspicuous for the motorcycle and the driver.

Traffic risks to the cyclists are similar to those faced by motorcyclists with the main differences being the bicycling speeds are typically lower and the bicycle wears less protective gear. Almost **all drivers agreed that cyclists need to wear reflective clothing in low lighting environments**, where as less than 3/4th of the cyclists agreed and less than 1/2 claimed that they always did so. **A Canadian report stated** that a decrease in the odds of a collision with a motor vehicle when wearing light coloured clothing in day light but an

increase in the odds of a collisions for the cyclists using fluorescents clothing at night.

A randomized controlled trial was conducted in **Denmark in 2012-13** and the study collected **data from 6793 regular cyclists for a year**. The results suggested that conspicuous **enhancing jackets can reduce by 47% of the risk of collisions with other road users that cause injury and 55% for those collisions involving a motor vehicle**.

REFLECTIVE FABRICS

Super Glo Reflective Polyester fabric is made of 100% polyester for use in items where high-visibility is required. **An aluminium or fluorescent orange colour** coating is applied to be followed by glass reflective beads. This fabric is UV resistant perfect for all outdoor needs. This high-visibility cloth fabric was made for covers, motorcycle covers, outdoor clothing, safety vests and much more as reported [04]. **For maximum visibility** we might consider wearing an outfit that is completely **made from some form of reflective materials** no matter from what angle we are being approached, the driver will be **able to see the opponent**. In this respect, if we want to be **quite so reflective**, we **need to wear a shirt,**

jacket or vest that features high-visibility cloth. For those who work on the highways and byways, they have one of the riskiest occupations in the world dealing with the hundreds of passing them by everyday while they are on the jobs. Most road construction workers now **wear a variety of clothing made from high-visibility from simple vests to complete outfits** to help drivers see them in the dark or foul weather. Other users of reflective cloth include use in military and civil services. **Fire-fighters" clothing is also one from reflective materials** such as stripes and patches attached.

Technical fabrics for **high-visibility garments (EN 471)** in areas where it's necessary must at to have **good visibility for both short and long distance.** The high-visibility colours are yellow and orange, and other range of contrast colours are recommended by **Marina [06].** Beside these ones can also be combined with retro-reflective bands to obtain a better detection in dark areas. **Marina Textil** has special fabrics for other areas also. **High-visibility (EN 471) fabrics are with an excellent durability, good contrast and excellent colour fastness against solar light and sweat.**

Since the inception of the **ANSI Standards Performance Textiles** has designed and produced **Hi-visibility ANSI/ISEA 107 2015** compliant fabrics in the **trade name of HI-VIS FABRICS [07].** They have both woven and knit fabrics available in yellow/green safety orange.

Fabrics India have fluorescent high-visibility fabrics of the types (12-135 gsm) and (60-75 gsm), which are made according to international standards. These are used in industries and institutions for safety purpose of the workers [08]. The main feature of the fabric is that it is made with **superior cotton, nylon, polyester or blend.** They are high-tear resistance and adhesive binding resistance. These are available in **fluorescent and reflective colours.** These are also **used by construction persons, traffic police and road safety persons for their safety.** The high-visibility vest comes in high-visibility clothing that makes the wearer visible even in the darkest hour of night in the head lamps light of vehicles.

Hi-VIS clothes are a complete high-visibility outfit of clothing items. According to the **Company, ANSI compliant high-visibility clothing includes shirts, sweat shirts, jackets,**

pants, rainwear, headwear, women's clothing, gloves and a wide range of other items for all seasons [09]. Items can be combined to transform ANSI 107 class 2 safety vest into an ANSI 107 class 3 outfit or by selecting HI-VIS clothing that may help to stand out while near a roadway for work recreation.

Koop man International in the name of Coop man's Luminas range of fabric offer unrivalled standards of performance for high-visibility clothing [11]. They give superior protection to workers operating in the low-light and/or potentially hazardous conditions, due to the super luminosity and brightness of three available colours: high-visibility yellow, orange and red. All the Coop man's Luminas fabrics are compliant to the ISO-20471 Standards for high-visibility clothing and all are certified for skin friendliness by OEKO-TEX. The fabrics are available on the basis of weight and blends. The additional protection can be obtained from Dura Clean for soil-release finish and water and oil repellent finish from Hydrofoil fabrics. Fully accredited high-visibility yellow versions of a number of multifunctional and dedicated flame retardant fabrics for multi-risks areas or EN 1149-3 for anti-static and EN 13034 type 6 for

protection against liquid chemicals are available.

For a long time practice, Geh Ring Tricot was one of the suppliers for the use of high-visibility fabrics. Presently, ANSI-107 is the universal standard of excellence in performance and Geh Ring Tricot is proud to have played the role as the one textile mill vested in ANSI to create this protection [12]. Currently Geh Ring Tricot is actively developing many new constructions for a range of market needs of future interests.

High-visibility „Hi-Vis“ safety yellow polyester twill fabric 62 inch by yard by Burlington Industries have the quality parameter for use by the users. High-visibility safety fluorescent yellow twill fabric 62 inch by the yard, great for safety vests or for areas that must be seen. Fluorescent yellow is a colour name which does not imply that the fabric will glow in the dark. It is about 12.75 oz/yd, machine washable polyester fabric [13].

The Reflective Apparel factory manufacturers a complete line of high-visibility safety apparel to meet the requirement of ANSI 107-2010 VEAR (Visibility Enhanced Apparel) is the trade mark of RAF and assures that these

are not only high-visible garment but comfortable and durable one as well [10].

DYEING OF HIGH-VISIBILITY POLYESTER TEXTILE PRODUCTS

The application of fluorescent dyes involves in various fields. Recently the application of **fluorescent dyes in medical diagnostic and biochemical investigations** has developed extremely dynamically. Fluorescent dyes have also **been used for the construction of lasers, photoelectric cells and solar batteries**. For many years, the application of **fluorescent dyes in medium flow control as well as testing material defects and equivalent damage** has been well known. Again, the application of **fluorescent dyes has long been used in dyeing of flat materials**, especially the textiles [05]. The use of fluorescent dyes causes a **significant increase in colour brightness**, which makes the dyed materials more easily perceptible or more accurately have increased visibility. This intensified perceptibility of materials dyed with fluorescent dyes is an advantage in preparing **coloured advertisements, information descriptions, roads and traffic signs** and to a great extent for manufacturing sports clothing and clothing for special services such as fire brigades and the police. The problem of fluorescent

dyes used in dyeing textiles materials has often been described.

The Institute of Dyes and Organic Products in Zgierz, Poland which includes in its structures an accredited laboratory for research into materials of high-visibility types, carried out tests of **disperse dyes offered on the Polish market** and used for dyeing polyester fibres and textile fabrics which should **fulfill the requirements of EN 471:1994 standards**. It should be emphasised that “WARNING” clothing of high-visibility is manufactured in only three colours, **yellow, orange and red**. From the description of many disperse dyes in **Colour Index** as well as in the **Manufacturers Table-I**, it is found that practical application for dyeing fabrics are intended to meet the demands of **EN 471:1994 Standards**. As an example, the **Disperse Yellow 184:1** dye of this group which is most easily available and popular in the market has a chemical structure which has not been described till date. On the contrary, the **Disperse dye 184**, which is known with its structure has been **eliminated** from the market. A **chromo gram of fluorescent dyes** approachable on the market is presented together with the structural formulae have been officially published. The chromo gram was carried

out at the Institute of Dyes and Organic Products.

The estimation of the fluorescent dyes offered on the Polish market was carried out with the authors based on the colour analysis of dyes carried out with the use of the individual dyes and the relation of the results obtained to **the requirements of the EN 471:1 1994 Standards** for the products designed for the high-visibility warning clothing. The basic parameter which determines the products' usability in accordance with the standards mentioned is the **colour characterised by the chromaticity co-ordinates** which **determine the chrome saturation and hue and the luminance factor**. The **luminance factor** for fluorescent materials is **the sum of two components**, i.e., **the reflective luminance factor and the fluorescent luminance factor**.

It is concluded that the **yellow fluorescent dyes tested** when applied alone, **do not guarantee the manufacturers of the polyester knitted fabrics dyed for high-visibility products will meet the requirements of the EN 471:1994 standards for yellow colour**. Dyes whose hue after illumination shifts in the **direction of red achieve a colour of chromaticity parameters** which is more

similar to the requirements of the standards, despite their low light fastness. An analysis of the investigation carried out to state that **the requirements of the EN 471:1994 standards chromaticity of the fluorescent yellow colours force the manufacturers of the textile fabrics to apply tinting with the use of non-fluorescent dyes**.

HIGH-VISIBILITY SAFETY APPAREL

High-Visibility Safety Apparel (**HVSA**) is the clothing (e.g. vests, bibs or coveralls) that workers wear can wear to improve how well other people „see“ them (their visibility). Most often, high-visibility clothing is worn to alert drivers and other vehicle operators of workers presence, especially in low light and dark conditions. High-visibility head wear can also be worn to increase the visibility of the wearer in situations where part or all of the wearer's body **could be obscured (e.g, leaves/trees, traffic barriers, construction materials, etc)**. Requirements for high-visibility safety clothing for Canadian workers are found in the **CSA Standards Z 96-15 High-Visibility Safety apparel**. In the **United States, it is ANSI / ISEA 107-2015**, American National Standards for the High-

Visibility Safety Apparel and Accessories [03].

High-visibility safety Apparel (HVSA) is needed if people work when there is low light and poor visibility, especially if people are working around **moving vehicles like, cars, trucks, or other machinery travelling under their own power**. High-visibility items allow people to be seen by the drivers of those vehicles sooner and more readily. This fact increases the safety at work. The human eye responds best to large, contrasting, bright or moving objects. Workers visibility is enhanced by high colour contrast between clothing and the work environment against which it is seen **CSA Standards recommended that a hazard assessment be carried out on each job** to evaluate the work place site for known or potential hazards a worker can encounter while performing a job or task. This assessment helps determine the risk to workers of being hit by moving vehicles and environmental conditions under which work is performed.

Fluorescent materials take a portion of invisible ultra violet light from the sunlight and through special pigments and sends it back to the viewer as more visible light. This material only functions

where there is a source of natural sunlight. **Retro-reflective material is created to return light in the direction of the light source.** This property will let a driver to see the light of the light being reflected from the retro-reflective material on a person's garment.

Large bright garments are more visible than small ones. Stripes of colours that contrast with the back ground material are to provide good visibility. When back ground material is bright coloured or fluorescent material, it is intended to be highly visible. For safety and best performance, garments should be fitted to the person. The apparel should be comfortable to wear. Garments should be selected and worn so that no other clothing or equipment covers the high-visibility materials. **CSA lists provide three classes of garment based on body coverage.** Each class covers the torso (waist to neck) and/ or limbs according to the minimum body coverage areas specified for each other. **Following are the details of the classes of garments:**

Class 1 provides the lowest recognized coverage and good visibility.

Class 2 provides moderate body coverage and superior visibility.

Class 3 provides the greatest body coverage and visibility under poor light conditions and at great distance. When Risk factor comes into play, the following arrangement may be done to wear the garments.

Low Risk Class 2, Class 1, may be worn by the workers directing vehicle operators or service stations, workers retrieving shopping carts in parking areas, etc.

Medium Risk Class 2, Class 3, based on jobs like, roadway constructions, utility workers, survey crews, forestry workers, etc.

High Risk Class 2 for day time, Class 3 for low light for situations under jobs like, roadway workers, utility workers, emergency responders, flagging crews, etc. For the workers, as with any personal protective equipment, **workers should be given appropriate training in the use and in the equipment.**

REQUIREMENTS FOR THE HIGH-VISIBILITY CLOTHING

In **Europe**, presently to harmonize the standards, there are **two standards are available for Visibility Clothing and one for Accessories. Published standards are available in U.K for visibility clothing,**

which are used by the railway workers. In U.K the standards are published by the **Rail Safety and Standards Board Limited. Defined standards for fluorescent and retro-reflective clothing** are mentioned in the published standards. The possibilities in changing the visibility at 360 degree are also available. The visibility clothing for both the types provides enhancement in visibility during day time as well as poor light in dark conditions.

The Standards EN ISO 20471:2013 High-Visibility Clothing specifies the requirements for the clothing under the available situations of light faced by the wearer in any conditions. During day time fluorescent high-visibility material is used, which provides a high level contrasts between the product and the environment under which it is worn. This specific **standard suggests** the performance requirements for the **colour, the retro-reflection, minimum areas and the placement of both the fluorescent and retro-reflective materials [02]. Three colour, namely the fluorescent Yellow, Red and Orange-red are specified in the Standards.** The other requirements related to the standards are colour fastness, dimensional stability, strength, the water vapour resistance of the fluorescent and

non-fluorescent materials. Performance requirements for the colour, retro-reflection for minimum areas and the placement on the materials are also provided by the standards. **EN 1150, allows design flexibility** for the clothing, like the **retro-reflective material does not have to be in tape form**. It can be of any shapes of the material provided it is evenly distributed around the body parts. Some **others colours are also recommended** for use, like **fluorescent green, yellow-green, yellow, yellow-orange, orange, orange-red, red and pink**. The important thing is that the area of the fluorescent back ground portion of the fabric and the retro-reflective materials are dependent on the size of the wearer.

EN 471 was first issued in 1994 and was revised in 2003. There was an additional **amended made in 2007**. When the standards last mandatory review, it was decided that a **further revision was needed**. It would also become a **International Standards (ISO)**. **ISO 20471 was ISSUED IN 2013**. As on **EN ISO**, it became **harmonized in September 2013**. An ensemble of garment can be classified together, i.e, **jacket plus trouser**. This must be indicated on the making and user information. Back ground material must

encircle all relevant parts of the body with a minimum width of 50 mm. Two or more bands are allowed on legs, sleeves and in most cases the torso. These bands can all be used for the calculation of minimum areas. Sleeves covering s view of torso band must have a sleeve band or bands. **The back ground fabrics must now meet the chromaticity and luminance** after the maximum number of cleaning cycles.

TESTS FOR HIGH-VISIBILITY TEXTILES

High-visibility textile testing have been described for **total solution for chromaticity of Neon colours, Hunter Orange and Retro-reflective materials by the authors [14]**. The chromaticity of high-visibility colours refer to fluorescent colours or neon colours that can be easily detected, even in low-light conditions. By measuring **the chromaticity coordinates, brightness and colour difference**, the test verifies whether the claimed colour complies with the fluorescent colour requirements. Scope of the test is by colour comparison of textiles, chromaticity of neon colours and luminance factors with the testing **standards of ANSI/ISEA 107/207; AS/NZS 1906; CSA Z96-15; ISO 20471; GB/T20653; BS EN 1150; and GO/RT 3279**. is for chromaticity of high-visibility day time tests (**Cal 21**).

Hunter Orange or Blaze Orange are safety colours used in Hunting Clothing

designed for the wearers so as to avoid accidently suiting each other. The International Hunter Education Association (IHEA) sets the **licensing requirements for such clothing in U.S.** The **test evaluates** the colour in accordance with the **procedures defined in ASTM E 1164 with polychromatic illumination D65 and 45/0 geometry and the 2-degree standards observer.** All textile products such as hats, vests, and garments using Hunter Orange are within the scope of these tests. **Retro-reflective materials test (Cal 25)** is for clothing designed for the high-visibility for the wearers. The test procedures and requirements are based on high-visibility clothing and accessories. It measures the coefficient of retro-reflection of retro-reflective materials that do not qualify for Personal protective equipment. **Materials such as fabric, tape, coating, yarn, weaving or embroidery garments with retro-reflective materials and other retro-reflective removable or mounted accessories attached to a garment** comes under the scope of this testing method.

CONCLUSIONS

Occupational wearers of clothing with high-visibility features include railway and

high-way workers, airport workers or other places where workers are near moving vehicles or in dark areas. The other uses of reflective fabrics include making a huge variety of patches for different colours including military and civil service uses. The high-visibility colours are yellow and orange and in other range of contrast colours. Fluorescent high-visibility fabrics in the form of fluorescent and reflective colours are used for uniforms and safety purposes. ANSI compliant high-visibility clothing includes shirts, sweaters, jackets, pants, rainwear, headwear, women's clothing, gloves and a wide range of other items for all seasons. The superior luminosity and brightness of the three available colours such as high-visibility yellow, orange and red give superior protection to the workers operating in low-light or potentially hazardous conditions. The application of fluorescent dyes involves various different fields. Combined performance retro-reflective materials are also fluorescent materials. A total solution for various visibility related test to be performed for product's quality and safety for use.

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