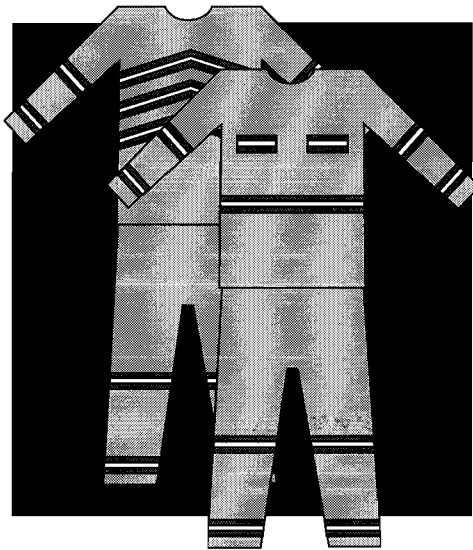


TECHNICAL
ASSISTANCE REPORT

**DEVELOPMENT
OF A SAFETY SERVICE PATROL
UNIFORM STANDARD**



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<p>Abstract</p> <p>The Virginia Department of Transportation's (VDOT) Safety Service Patrollers (SSP) use different color uniforms depending on their geographic location. Red jumpsuits are used in the Northern Virginia District, orange jumpsuits are used in the Fredericksburg District and by the Tidewater Tunnel Patrollers, and white shirts and blue pants with a flagger's vest are used in the Suffolk District.</p> <p>The purpose of this research was to identify and evaluate various colors and configurations of retroreflective materials for use on the SSP uniform in an effort to maximize employee safety. This study was to recommend a color, or colors; a pattern of retroreflective material; and the type of uniform that should be used as VDOT's standard SSP uniform. The scope of the project was limited to the use of existing materials and colors readily available from vendors.</p> <p>The uniforms selected for testing were evaluated under controlled conditions in the field. This evaluation consisted of photographing the existing SSP uniforms and the two prototypes on a closed portion of roadway with little to no external lighting. Photographs were taken of each uniform under daytime and nighttime conditions. A videotape was used to capture how the uniforms appear while a driver drives toward them during nighttime conditions under low and high beams. The videotape was also used to capture the ergonomic movements of the uniforms and how well the retroreflective tape depicted the actual movements as humans. In addition to photographing and videotaping the uniforms, the researcher made photometric measurements under daytime and nighttime conditions and laboratory colormetric measurements of each type uniform.</p> <p>The report concludes that fluorescent colors enhance the daytime conspicuity of highway worker's clothing. The literature indicates that fluorescent orange and fluorescent strong yellow-green are the two best colors for use on high-visibility clothing. Of the garments studied in the daytime portion of this research, the fluorescent strong yellow-green garment was determined to be the most visible. The addition of circumferential retroreflective bands on the limbs and major hinge points (knees and elbows) provides for enhanced recognition as a person during nighttime viewing.</p>				

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

The Virginia Department of Transportation's (VDOT) Safety Service Patrollers (SSP) use different color uniforms depending on their geographic location. Red jumpsuits are used in the Northern Virginia District, orange jumpsuits are used in the Fredericksburg District and by the Tidewater Tunnel Patrollers, and white shirts and blue pants with a flagger's vest are used in the Suffolk District.

The purpose of this research was to identify and evaluate various colors and configurations of retroreflective materials for use on the SSP uniform in an effort to maximize employee safety. This study was to recommend a color, or colors; a pattern of retroreflective material; and the type of uniform that should be used as VDOT's standard SSP uniform. The scope of the project was limited to the use of existing materials and colors readily available from vendors.

The uniforms selected for testing were evaluated under controlled conditions in the field. This evaluation consisted of photographing the existing SSP uniforms and the two prototypes on a closed portion of roadway with little to no external lighting. Photographs were taken of each uniform under daytime and nighttime conditions. A videotape was used to capture how the uniforms appear while a driver drives toward them during nighttime conditions under low and high beams. The videotape was also used to capture the ergonomic movements of the uniforms and how well the retroreflective tape depicted the actual movements as humans. In addition to photographing and videotaping the uniforms, the researcher made photometric measurements under daytime and nighttime conditions and laboratory colorimetric measurements of each type uniform.

The report concludes that fluorescent colors enhance the daytime conspicuity of highway worker's clothing. The literature indicates that fluorescent orange and fluorescent strong yellow-green are the two best colors for use on high-visibility clothing. Of the garments studied in the daytime portion of this research, the fluorescent strong yellow-green garment was determined to be the most visible. The addition of circumferential retroreflective bands on the limbs and major hinge points (knees and elbows) provides for enhanced recognition as a person during nighttime viewing.

TECHNICAL ASSISTANCE REPORT

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BACKGROUND AND PROBLEM STATEMENT

The Virginia Department of Transportation's (VDOT) Safety Service Patrollers (SSP) use different color uniforms depending on their geographic location. Red jumpsuits are used in the Northern Virginia District, orange jumpsuits are used in the Fredericksburg District and by the Tidewater Tunnel Patrollers, and white shirts and blue pants with a flagger's vest are used in the Suffolk District.

For daytime work, the *Manual on Uniform Traffic Control Devices* (MUTCD) requires flaggers to have a vest, shirt, or jacket that is orange, yellow, strong yellow-green, or a fluorescent version of these colors. For nighttime work, similar outside garments must be retroreflective. This retroreflective material must be orange, yellow, white, silver, strong yellow-green, or a fluorescent version of these colors and must be visible at a minimum distance of 1,000 feet. In addition, the retroreflective clothing must be designed to clearly identify the wearer as a person and be visible through the full range of body motions.¹

An October 1995 memorandum from an Occupational Safety and Health Administration (OSHA) regional administrator cited two federal regulations that require the wearing of a high-visibility garment.²⁻⁴ This memorandum further stated that the use of high-visibility garments should be encouraged strongly when employees are working in areas where mobile equipment is operated. The memorandum also provided general guidelines relative to these garments, including the recommended color and material and the use of retroreflective materials for nighttime visibility.

Reaction times and perceptions from the motoring public are also of concern. The reaction times for different colors vary significantly depending on lighting conditions, especially during periods of dawn, dusk, haze, or fog. The public's perception of colors varies as well. The public perceives red to mean prohibition or immediate danger (e.g., fire); yellow (in contrast with black) to mean warning; and green to mean rescue services, safety exit, etc. Green is also used to indicate all forms of rescue equipment and first aid.

This information was presented to VDOT's Maintenance Program Leadership Group (MPLG), and the group identified the need to provide uniformity in the SSP program regardless of geographic location. The MPLG requested the Seaboard Incident Management (SIM) Committee to convene a task group to identify a color, or set of contrasting colors, for specific use in the SSP uniform. In addition, the SIM Committee dedicated a limited amount of funds for

this task group to develop prototypes of different color uniforms and evaluate their effectiveness. Therefore, there is a need to establish an SSP uniform that meets and/or exceeds federal standards and maximizes employee safety under a variety of environmental conditions.

PURPOSE AND SCOPE

The purpose of this research was to identify and evaluate various colors and configurations of retroreflective materials for use on the SSP uniform in an effort to maximize employee safety. This study was to recommend a color, or colors; a pattern of retroreflective material; and the type of uniform that should be used as VDOT's standard SSP uniform. The scope of the project was limited to the use of existing materials and colors readily available from vendors.

METHODS

The researcher conducted several tasks to accomplish the objectives of the study

1. *Review the Literature.* A literature review was conducted to ascertain the pertinent information regarding uniform colors for highway workers and SSP personnel. This review was also used to identify current standards, allowable colors for uniforms for individuals working in traffic, any recommended retroreflective patterns and placement, etc.
2. *Survey of the Practices of Other States.* States identified in the literature review as having investigated or implemented unique uniform colors for highway workers and/or SSPs were contacted for more information. This information was to be used to aid VDOT in developing a prototype uniform
3. *Select Color(s) and Material.* Based on the results of Tasks 1 and 2, the task group identified the best color(s) and retroreflective material, and its placement, for use on the SSP uniform.
4. *Develop Prototype Uniforms.* Once the task group identified the color(s) and the placement of retroreflective material, the uniform specifications were sent to a garment manufacturer for construction of the prototype uniforms.
5. *Evaluate the Uniforms.* The uniforms selected for testing were evaluated under controlled conditions in the field. This evaluation consisted of photographing the existing SSP uniforms and the two prototypes on a closed portion of roadway with little to no external lighting. Photographs were taken of each uniform under daytime and nighttime conditions. A videotape was used to capture how the uniforms appear while a driver drives toward them during nighttime conditions under low and high

beams. The videotape was also used to capture the ergonomic movements of the uniforms and how well the retroreflective tape depicted the actual movements as humans. In addition to photographing and videotaping the uniforms, the researcher made photometric measurements under daytime and nighttime conditions and laboratory colorimetric measurements of each type uniform.

6. *Develop Uniform Standards.* Based on the findings of the tasks, a prototype uniform specification was developed.

RESULTS

Literature Review

Federal Regulations

OSHA has a limited number of standards that directly relate to worker clothing. Two are specific to individuals working in vehicular and mobile traffic. One standard specifically states: “Exposure to vehicular traffic. Employees exposed to public vehicular traffic shall be provided with, and shall wear, warning vests or other suitable garments marked with or made of reflective or high visibility material.”⁴

The other OSHA standard relates to flaggers. It states that these individuals should be provided with and wear a red or orange warning garment while flagging. Warning garments worn at night must be made of reflectorized material.³ This standard also refers the reader to Part VI of the MUTCD.

In addition to these two standards, an October 13, 1995, memorandum from an OSHA regional administrator provides guidance on the appropriate color and design of high-visibility garments.² The general guidelines for using such garments on days when visibility is good recommend the use of fluorescent strong yellow-green, fluorescent pink, fluorescent green, fluorescent orange, or fluorescent red garments. These garments will provide a high degree of conspicuity. The memorandum also states that recent studies have indicated that fluorescent strong yellow-green garments tend to be the most noticeable. Additionally, applying a contrasting high-visibility color to high-visibility garments will further increase the conspicuity of employees in the daytime.² The memorandum also states that such garments, preferably with retroreflective materials applied to them, should be worn when visibility is limited due to weather, dawn, dusk, or night. The garments should be a different color than any high-visibility warning materials on barricades or any other non-human objects in the area.

As mentioned in an OSHA standard, the MUTCD has clothing requirements for highway workers and flaggers. Part 6D-2 of the MUTCD states that workers exposed to traffic should be attired in bright, highly visible clothing similar to that worn by flaggers. The MUTCD requirement for flaggers is to have a vest, shirt, or jacket that is orange, yellow, strong yellow-

green, or a fluorescent version of these colors for daytime work. For nighttime work, similar outside garments are required to be retroreflective. This retroreflective material must be orange, yellow, white, silver, strong yellow-green, or a fluorescent version of these colors and must be visible at a minimum distance of 1,000 feet. In addition, the retroreflective clothing must be designed to clearly identify the wearer as a person and be visible through a full range of body motions.¹

Fluorescence

Although federal regulations allow and encourage the use of fluorescent material on clothing, it is beneficial to understand why fluorescent colors are brighter than non-fluorescent colors. *Fluorescence* can be defined as the phenomenon in which light energy of a relatively short wavelength is converted into visible light energy of a longer wavelength. That is, fluorescent colors are brighter than ordinary colors because they can convert light energy that is normally absorbed and wasted to visible light, which, in turn, reinforces the color in intensity.⁵ Hence, visibility is greater in daylight conditions. Fluorescent colors also have exceptional visibility at dawn and dusk and in conditions of limited visibility, such as fog and haze. The reason is that the longer wavelengths of light cannot penetrate haze, so non-fluorescent colors undergo a general darkening or graying effect. However, fluorescent surfaces convert the shorter wavelengths into longer wavelengths, reinforcing the fluorescent color. This makes the color appear not only more brilliant but also more visible, especially on hazy days.⁵

There is, however, a downside to the use of fluorescent colors. The energy conversion process taking place in fluorescent pigments has a limited life. Therefore, the useful life of fluorescent colors is a direct function of the amount of solar radiation incident to the target surface.⁶ That is, the more sunlight fluorescent colors are exposed to, the shorter their useful life. This seems to be true especially in conditions where more shorter wavelengths (violet and blue parts of the spectrum) are being converted to longer wavelengths.

Previous Color Studies

In a 1963 study, Hanson and Dickson found that fluorescent yellow-orange targets were detected and recognized at distances from 6 to 29 percent greater than the distances at which the conventionally pigmented targets were recognized.⁶ In fact, the only target to have a consistently high detection range on all backgrounds investigated was the fluorescent yellow-orange. This is of no real surprise since eye sensitivity peaks about the yellow-green region and decreases toward the red and blue regions, as shown in Figure 1.

In another study published in 1994, Zwalen and Vel investigated daytime conspicuity in terms of peripheral vision detection and recognition of fluorescent color targets versus non-fluorescent color targets against different backgrounds.⁷ This study used 10 color targets, 6 non-fluorescent and 4 fluorescent, that were tested against different non-uniform multicolored

backgrounds. These backgrounds were used to depict either the typical city background, fall foliage, or spring foliage.

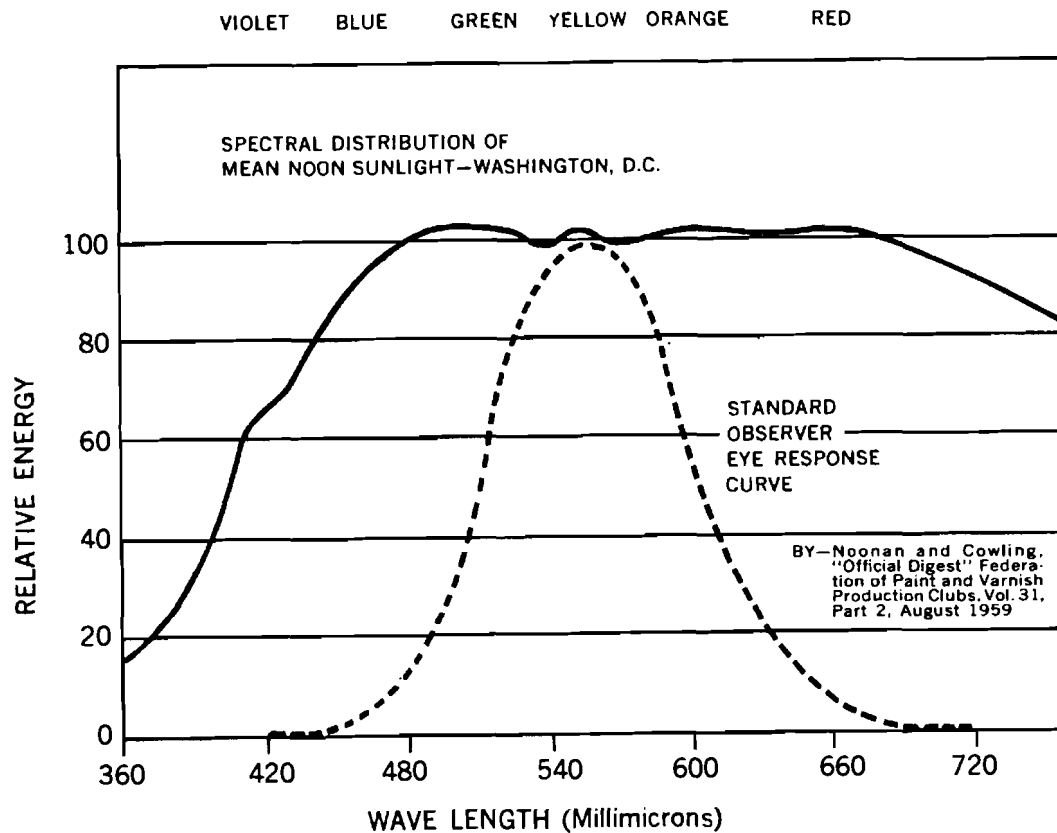


Figure 1. Sensitivity Response of Average Human Eye⁶

The study concluded that there is a significant difference in the ease and successful detection of fluorescent colors and non-fluorescent colors. The study also found that fluorescent yellow is the best color if one wants the highest peripheral detection performance against the three backgrounds. However, fluorescent orange is the best color if one wants the highest correct peripheral recognition performance against the three backgrounds.

The study recommended that individuals responsible for the design of traffic control devices and personal equipment consider the superior visual conspicuity properties of fluorescent colors (especially fluorescent yellow and fluorescent orange) and incorporate these colors into their designs when the highest possible daytime target conspicuity is necessary and required.

High-Visibility Clothing Research

Several studies have investigated high-visibility clothing for flaggers, but very few have investigated the requirements for individuals who require full body visibility rather than simply upper body coverage in the case of a vest. The findings of many of these studies, however, are essential to the development of an SSP uniform.

The Michigan Department of Transportation studied the development of a flaggers' vest that will provide maximum protection under daytime and nighttime conditions. The research developed a variety of colored vests with different configurations of retroreflective material on each. The study concluded that a basic fluorescent orange vest was not bright enough, even on a cloudless day, to be seen when a flagger is standing in front of an orange construction vehicle. The study went on to note that the "addition of a fluorescent yellow pattern greatly enhances the conspicuity of the vest."⁸

The Michigan study also developed a proposed retroreflective pattern for use on the vest. It consists of an inverted chevron underneath a chevron. The chevrons are constructed of 2-inch-wide retroreflective material. The chevron pattern was selected to provide retroreflective material for each corner of an individual's trunk, thereby providing drivers with a more humanistic pattern for easier identification. In addition to the chevrons, two 4-inch by 2-inch rectangles on each side of the vest, both front and back, provide a pattern that delineates the sides of the individual.

Minnesota has also been investigating and refining flaggers' safety vests. In 1990, the Minnesota Department of Transportation conducted a survey of colored safety vests at the Minnesota State Fair. MnDOT used four different fluorescent color safety vests that were placed on mannequins and voted on by fair attendees. The attendees were asked to determine which vest was the most visible. Fluorescent yellow was selected as the most visible by 45.5 percent of the voters, followed by fluorescent green (21.2 percent), then fluorescent orange (17.5 percent), and finally fluorescent pink, with 15.8 percent of the votes. It is also interesting to note that of the 119 individuals who identified themselves as being color blind, 97 percent chose fluorescent yellow as the most visible.⁹

A more recent study, *High Visibility Clothing for Daytime Use in Work Zones*,¹⁰ investigated 11 colors: 8 fluorescent, 2 non-fluorescent, and 1 semi-fluorescent. Subjects were asked to indicate the point at which they were able to detect the clothing in four different work zone situations. The study concluded that the fluorescent red-orange vest was the most conspicuous. The study did note that motorists may have become accustomed to seeing workers in orange vests and, therefore, associated an orange object with safety clothing.

The study recommended that agencies seeking an alternative to fluorescent red-orange vests should consider fluorescent yellow-green vests. This color appears to work well in work zones, and other research has identified it as performing well in low light and hazy conditions.

The University of Michigan Transportation Research Institute conducted a study to investigate the effects of retroreflective material positioning to increase nighttime recognition of pedestrians.¹¹ The study found that when retroreflective markings were attached to the limbs, the recognition distances were significantly longer than when the retroreflective markings were attached to the torso.

Summary

As is evident from the federal requirements and past research, the use of fluorescent colors to enhance the conspicuity of highway workers is a viable option. The increased visibility of fluorescent colors is especially evident when they are viewed under low light, haze, and fog situations. The research has also shown that fluorescent orange and fluorescent yellow-green are the two best colors for use on high-visibility clothing. If the main purpose of an agency is to provide garments that are readily detectable, they should choose fluorescent yellow-green. If the agency wants a garment that is readily recognizable, they should choose fluorescent orange. However, some research has noted that recognition of fluorescent orange might be due in a large part to motorists being accustomed to seeing highway workers wearing orange vests. In most of the research, however, fluorescent yellow-green has been noted as being a superior color because of its ability to be easily detected, and it has been stated that this color should be used as an alternative to the standard fluorescent orange.

Evaluation of the Uniforms

Colorimetric Measurements

Colorimetric measurements were made on the red, orange, and strong yellow-green uniforms by VDOT's Materials Division. Suffolk's garment, the vest, was not tested. Five measurements were taken of a 9-inch by 9-inch area on various parts of each garment and then averaged. Table 1 shows the results. (The x and y values are supplied to provide readers with the color coordinates of the respective garments.)

Table 1. Colorimetric Measurements (2°, Illuminant C)

Garment	x	y	Y
Red	0.5928	0.3263	12.06
Orange	0.5764	0.3589	24.25
Strong yellow-green	0.3653	0.5078	110.45

Note that the strong yellow-green Y value is more than 9 times greater than the red and more than 4.5 times greater than the orange Y value. In essence, this means that the strong yellow-green garment appears 9 times brighter than the red and 4.5 times brighter than the

orange garment. This can be attributed to the fact that the strong yellow-green garment is fluorescent and the red and orange garments are not.

Photometric Measurements

Photometric measurements (luminance) were made of the red, orange, and the strong yellow-green garments under daytime and nighttime conditions. VDOT’s standard highway worker’s vest was also measured under the same conditions. These photometric measurements were made with a 1° Minolta luminance meter at a distance of 30 feet from the object.

Daytime conditions were mostly sunny with light winds and high temperatures near 60 degrees Fahrenheit. Nighttime conditions were clear with a low of 45 degrees Fahrenheit. The objects, during the nighttime evaluation, were illuminated using a 1997 Ford Taurus sedan. The object was placed directly in front of the vehicle, and measurements were made under low-beam and high-beam conditions. Appendix A contains the full measurements, and Table 2 shows a summary of the averaged results.

Table 2. Photometric Measurements (cd/m²)

Garment	Condition	Average (cd/m²)
Strong yellow-green	Daytime	15,960
Red	Daytime	2,186
Orange	Daytime	2,708
Strong yellow-green	Night (low beam)	8.42
Red	Night (low beam)	1.32
Orange	Night (low beam)	2.64
Strong yellow-green	Night (high beam)	50.06
Red	Night (high beam)	12.02
Orange	Night (high beam)	23.74
Vest with white shirt	Day	16,900
Vest with blue shirt	Day	6,300
	Night (low beam)	0.7
	Night (high beam)	8.0

Photographs

Photographs were taken in an attempt to capture the appearance of the three uniforms under daytime and nighttime condition at varying distances. The photographs were used to show the variation in resulting visibility from each of the garments depending on the level of lighting. It is important to remember that daytime visibility of the garment depends on its color, whereas

nighttime visibility of the garment depends on the retroreflective material and its placement on the garment. Appendix B contains a subset of daytime photographs, and Appendix C contains a subset of the nighttime photographs.

As the photographs in Appendix B depict, the strong yellow-green garment appears to be the most conspicuous. The orange garment is next, and the red garment is last, even at a distance of 885 feet from the objects. This ranking of conspicuity for the three garments (strong yellow-green, orange, and red) is valid for each distance photographed (885, 500, 200, and 100 feet), which is clearly evident from the photographs.

The nighttime photographs in Appendix C depict how the uniforms might appear to oncoming motorists. At 885 feet, none of the uniforms tested can be distinguished as human silhouettes. Take note to the retroreflective delineators on the right shoulder and the uniforms at the end of the photograph. At this distance, a clear distinction between a delineator and a human target cannot be made. However, at 500 feet, the silhouettes appear to resemble human forms. At 500, 200, and 100 feet, the strong yellow-green garment appears to be the most conspicuous of the three garments. This can be primarily attributable to the fact that this garment has two circumferential retroreflective bands on each leg and arm, whereas the other two garments do not have any bands on the legs and only one band on each arm.

Videotape

The author used videotape to capture the appearance of a driver dynamically driving toward the garments at night under low and high beams. First, the garments faced forward and then the backs of the garments faced the oncoming vehicle. Videotape was also used to capture the ergonomic movements of an individual wearing these garments (red, orange, strong yellow-green Prototype I, and strong yellow-green Prototype II) and performing typical SSP tasks. These tasks included asking motorists if they require assistance, inspecting the engine compartment, changing a tire, looking in the trunk of the stranded vehicle, and walking to and from the vehicle. The videotape was then used to ascertain how the uniforms would look when viewed from the side as if the person was walking across a street.

The scenes in which the vehicle was driven toward the uniforms simply indicated that the addition of reflective material makes the object more visible. This was true with low beams and high beams and for the fronts and backs of the garments. Those garments with the leg bands and armbands were considerably more visible than those without them.

Videotape was also used to capture the movements of an SSP performing routine tasks in each uniform. The red and orange garments were equally visible. This is because both garments had almost the same pattern of retroreflective material. It should be noted that with no retroreflective material on the legs other than the stripe down the outside of the leg, the lower half of the body is not visible when a person is walking toward and away from the stranded vehicle. Only the two armbands and the two chest pockets are visible when the person is facing

traffic. The chevron design on the back does provide significantly greater visibility than the front of the garment, but the lower half of the body remains relatively invisible.

In contrast to the red and orange garments, the two prototype garments remain visible for the full range of motions evaluated. This again is due to the circumferential bands placed on the legs and arms. The addition of the retroreflective band around the abdomen also allows the garment to be visible a full 360 degrees. The second prototype garment had stripes down the outside legs and arms in addition to the material on the first prototype. These additional stripes produced only an incremental increase in visibility over Prototype I.

Finally, when each garment was demonstrated on a person walking across the street, the red and orange garments had similar levels of visibility, but both lacked the clear distinction of a person. The two prototype garments, however, clearly depicted a person walking due to the placement of the circumferential bands on the legs and arms and at the major hinge points. Again, the second prototype garment with the stripes provided only a slight increase in visibility and detectability as a person.

Limitations of the Research

Although the research identified a new uniform color and a configuration of reflective material, the research did not take into account several issues that must be addressed on the operational level before successful implementation can be realized. These issues include identifying a durable and fade-resistant fabric and the costs associated with implementing use of the uniforms.

The uniforms that will be used for VDOT deployment will be of a higher quality material than that used in the prototypes, similar to that material being used today. The prototype garments were selected because they were the only ones available at the time and the researcher was able to experiment with various configurations of retroreflective material to support the concept.

Another issue that was not addressed is that of fading. Fading of a fluorescent garment will reduce its ability to be seen. Since fading is inevitable with a fluorescent garment, the rate at which the garment fades should be investigated. The threshold of when the garment should be replaced because of fading needs to be examined. There will be a point at which the garment fades and becomes ineffective.

The costs of implementing the use of a new garment were not investigated. This is primarily because a durable, colorfast garment in the fluorescent yellow-green color did not exist at the time this research was conducted. Since the garment did not exist, the life-cycle costs attributable to normal wear and fading could not be analyzed.

CONCLUSIONS

- Fluorescent colors enhance the daytime conspicuity of highway worker's clothing.
- The literature indicates that fluorescent orange and fluorescent strong yellow-green are the two best colors for use on high-visibility clothing.
- Of the garments studied in the daytime portion of this research, the fluorescent strong yellow-green garment was determined to be the most visible.
- The addition of circumferential retroreflective bands on the limbs and major hinge points (knees and elbows) provides for enhanced recognition as a person during nighttime viewing.

RECOMMENDATIONS

1. VDOT's SSP garment should be a fluorescent yellow-green material that is durable and fade resistant. The configuration of reflective material should be, at a minimum, the same as that shown in Figure 2.
2. VDOT's SSP and Employee Safety and Health Division should collaborate to develop the final design of the garment.
3. A pilot study should be undertaken by the operating SSP groups to address some, if not all, of the limitations of this study. The findings of this pilot study should be provided to the MPLG and the Employee Safety and Health Division of VDOT for final decision making regarding implementation.
4. VDOT's Employee Safety and Health Division should continuously monitor the SSP's work functions and as these functions change should re-evaluate the placement of the retroreflective material on the uniform.

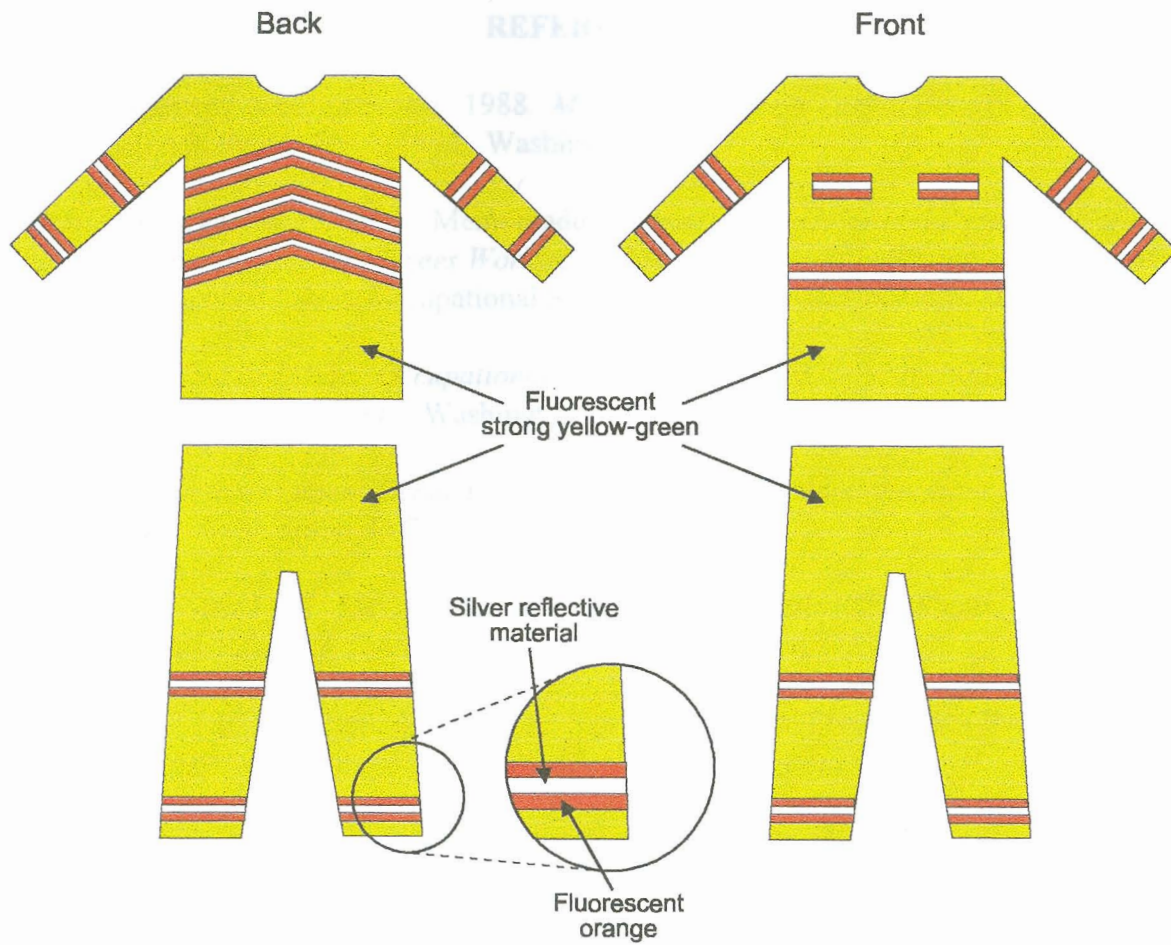


Figure 2. Recommended Safety Service Patrol Uniform Design

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Appendix A

Photometric Measurements
Safety Service Patrol Uniforms
(cd/m²)

Color	Condition	Right Arm	% Diff	Left Arm	% Diff	Abdomen	% Diff	Right Leg	% Diff	Left Leg	% Diff	Low	High	Average	% Diff.
Yellow	Day	15500	549%	12000	458%	16100	659%	21200	834%	15000	650%	12000	21200	15960	630%
Red	Day	2390		2150		2120		2270		2000		2000	2390	2186	
Orange	Day	3500	46%	2680	25%	3300	56%	2200	-3%	1860	-7%	1860	3500	2708	23%
Yellow	Night (Low Beam)	2.2	340%	2.6	333%	2.6	271%	17.3	565%	17.4	691%	2.2	17.4	8.42	440%
Red	Night (Low Beam)	0.5		0.6		0.7		2.6		2.2		0.5	2.6	1.32	
Orange	Night (Low Beam)	1	100%	1.1	83%	1.3	86%	5.4	108%	4.4	100%	1	5.4	2.64	95%
Yellow	Night (High Beam)	30.6	314%	36.2	376%	39.9	324%	76.1	314%	67.5	290%	30.6	76.1	50.06	324%
Red	Night (High Beam)	7.4		7.6		9.4		18.4		17.3		7.4	18.4	12.02	
Orange	Night (High Beam)	14.5	96%	14.5	91%	23.2	147%	33.7	83%	32.8	90%	14.5	33.7	23.74	101%
Vest w/white	Day	16900													
Vest w/blue	Day	6300													
	Night (High Beam)	8													
	Night (Low Beam)	0.7													

NOTES: All measurements taken 30 feet away from object.
A Minolta 1° luminance was used to take photometric measurements.
Day conditions: mostly sunny, light winds, high around 60° F.
Night conditions: clear, no wind, low around 45° F.

Appendix B

Appendix C



Orange, Strong Yellow-Green, Red Uniforms at 200 feet (Front)



Orange, Strong Yellow-Green, Red Uniforms at 200 feet (Back)



Orange, Strong Yellow-Green, Red Uniforms at 100 feet (Front)



Orange, Strong Yellow-Green, Red Uniforms at 100 feet (Back)

Appendix C



Orange, Strong Yellow-Green, Red Uniforms at 885 feet – front side (Low Beam)



Orange, Strong Yellow-Green, Red Uniforms at 885 feet – front side (High Beam)



Orange, Strong Yellow-Green, Red Uniforms at 500 feet – front side (Low Beam)



Orange, Strong Yellow-Green, Red Uniforms at 500 feet – front side (High Beam)



Orange, Strong Yellow-Green, Red Uniforms at 200 feet – front side (Low Beam)



Orange, Strong Yellow-Green, Red Uniforms at 200 feet – front side (High Beam)



Orange, Strong Yellow-Green, Red Uniforms at 200 feet - backside (Low Beam)



Orange, Strong Yellow-Green, Red Uniforms at 200 feet - backside (High Beam)



Orange, Strong Yellow-Green, Red Uniforms at 100 feet – front side (Low Beam)



Orange, Strong Yellow-Green, Red Uniforms at 100 feet – front side (High Beam)



Orange, Strong Yellow-Green, Red Uniforms at 100 feet - backside (Low Beam)



Orange, Strong Yellow-Green, Red Uniforms at 100 feet - backside (High Beam)