Safety clothing for work on the road

Institute for Road Safety Research SWOV

Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV

P.O.Box 3071, Deernsstraat 1, Voorburg, the Netherlands

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Foreword

If those who have to work along and on the road are made more readily discernible, there will be less risk of them being run over. That is why special safety clothing was introduced for them some time ago. This clothing is now obtainable in a wide variety of colours, styles and materials.
However, it was not known what form of safety clothing was the most suitable for the circumstances in which it was most frequently worn, viz. in the daytime and at dusk. What was quite certain, though, was that many users greatly dislike wearing a number of the current types of safety clothing: they fell that they are thrust into a sort of jester's garb. These considerations led the Netherlands Ministry of Transport and Waterways to request the Institute for Road Safety Research SWOV to carry out tests to determine the visibility of this clothing for road users and its accep'ability for the wearers, and to supply recommendations regarding any improvements deemed desirable.
SWOV adopted a method by which the investigation of different aspects of the question were contracted out to other institutes. The work of these institutes was then co-ordinated by SWOV's Human Factors Department.
The Institute for Perception RVO-TNO, Soesterberg, carried out research into the conspiousness of the colours and styles of the clothing. The Fibre Research Institute TNO, Delft and the Plastics and Rubber Research Institute TNO, Delft, tested the materials used. On the basis of the results obtained KEMA (N.V. tot Keuring van Electrotechnische Materialen), Arnhem, then drew up recommendations for inspection standards which safety clothing should meet.
The results of the research and tests carried out were such as to warrant encouraging the textile industry to develop a new fabric which, dyed in the correct colour with the right degree of brightness, would meet the requirements regarding protection against rain and cold while at the same time allowing heat and moisture resulting from exertion to escape.
NITHO (Netherlands Institute for Applied Home Economics Research), Wageningen, which has already acquired experience with working clothes, is carrying out this development work on the basis of the now concluded tests. According to information received from NITHO, it is possible that material for safety clothing meeting the requirements as laid down in this report will become available. Up till now the new fabric has not been develloped yet due to a lack of sufficient commercial possibilities.
SWOV is grateful to these institutes for their co-operation in this research. A description of the work done by them is included in the Annex to this report.

The Central Police Traffic Committee (CPVC) has in the meanwhile issued country-wide recommendations to the effect that the largest group of users, the schoolchildren detailed for crossing duty, should be provided with fluorescent orange safety clothing in place of the white or yellow coats used up to the present. It may be assumed that the fluorescent orange clothing as recommended will be progressively introduced in different municipalities. This clothing is now obtainable from the Netherlands Road Safety Association (Verbond voor Veilig Verkeer).
The white patrol cars used by the Highway Section of the State Police have since had fluorescent orange markings added.

The report has been written by D. J. Griep, Human Factors Department SWOV.

E. Asmussen
Director Institute for Road Safety Research SWOV

1. Introduction and analysis of the problem

The research to determine the most suitable safety clothing for work on the road has been based on the requirements which can be set for several groups of users, viz. roadmen employed by State and Provincial public works departments, local authority and contractors' personnel working on the roads, police officers, schoolchildren on crossing duty and personnel of the Royal Dutch Touring Club ANWB (Signposting division).
Besides these there are also others who have to work on the road too, such as customs officers, Ministry of Agriculture & Fisheries inspectors and State Traffic Inspectorate staff, garage personnel, towing services and ambulance staff and road patrols.
These groups, however, rarely or never use safety clothing as referred to in this report. Although not originally intended as safety clothing in this sense, the yellow coats worn by the road patrols nevertheless have a similar function, especially when the patrols have to direct traffic at the scene of an accident when waiting for the police to arrive. These yellow coats have accordingly been classed under safety clothing where considered necessary.

1.1. Situation in which the clothing is to be used

The requirements to be met the clothing can be determined according to the situation in which it will be used. Two categories of users can be distinguished. (A more detailed description of these two categories is given in Section 1 of the Annex).

1.1.1. A 'road group'

a. *Function:* inspection and maintenance of roads.
b. *Composition:* public works department and contractors' employees, ANWB Signposting division personnel and roadmen.
c. *Where and under what circumstances:* chiefly outside built-up areas. In daytime (red and white) signs on the road are often used as a form of visual protection. After sundown normal roadside lighting or special lighting is used for illumination.
An exception is formed by roadmen who are responsible for inspection of the road and are constantly moving about; these men often have to work without protective equipment as referred to above.

1.1.2. A 'traffic group'

a. *Function:* control and directing of traffic.
b. *Composition:* police, schoolchildren on crossing duty, and also roadmen and road patrols who take over traffic control duties at the scenes of accidents before the police arrive.
c. *Where and under what circumstances:* inside built-up areas (police, school crossings) and outside (police, roadmen). Frequently have to work without any other protection than their safety clothing under both day and night conditions.
Schoolchildren on road crossing duty almost always work in daylight. Their visibility is increased somewhat by the red and white 'baton' shaped something like a tabletennis bat which they hold. The visibility of police officers is sometime increased by the equipment they use when directing traffic, such as stop signs, baton and so on. The visibility of police on traffic duty at fixed points is occasionally improved by increasing the lighting at such points. Use is also made of spotlights shining on policemen on point duty.

The clothing for the 'traffic group' must be able to meet exacting requirements regarding the visibility of this group, since as a rule no other adequate or universally applicable means are employed or feasible to make them stand out.
In addition drivers can rarely know when and where they are likely to encounter 'pedestrians' of this category on or near the carriageway. This is particularly the case when accidents occur outside built-up areas and other drivers suddenly find someone directing the traffic, either form the side of the road out on the carriageway. This can result in situations fraught with danger.

Besides its visibility another aspect is also found to be of importance as regards the clothing worn by police and roadmen, viz. the extent to which the wearer considers it suitable for his work and function.
For the 'road group', what could be termed the 'wearability' of safety clothing plays the biggest role (besides its visibility). It should permit full freedom of movement and also allow heat and moisture resulting from exertion to escape without discomfort to the wearer.

1.2. Visual requirements

1.2.1. Visibility

It is accordingly evident that conditions of a widely varying nature have to be taken into account when considering the visibility of safety clothing. These relate to:
a. the colour and brightness of the locations concerned inside and outside built-up areas, factors determining these being the road itself, traffic at the point in question, clarity of the sky, greenery, trees, etc. (the latter again varying with the season);
b. atmospheric conditions, e.g. rain, mist and snow, and their effect on colour and brightness contrasts;
c. the lighting, natural and otherwise, which varies from daylight to dusk and night, and its effect on colour and brightness contrasts;
d. the traffic on busy and less busy roads and streets, which may sometimes distract drivers; the lights of oncoming traffic may also glare others on occasions too;
e. safety clothing worn should moreover stand out sufficiently to be spotted by persons with defective vision, e.g. drivers who are colour-blind.

Visibility distance is the greatest distance at which the presence of an object can be spotted. It is determined by the physiological properties of the eye and depends on physical quantities, particularly the luminance level, the contrast in brightness, the size of the object, etc.
If safety clothing is to fulfill its function it must of course be easily visible.
Depending on the situations in which it will be worn, factors which will determine whether or not clothing is seen are:
a. size and shape;
b. the contrast in brightness and colour with the surroundings;
c. contrasts in colour, brightness and shape on the surface of the actual clothing.

Good visibility in this sense is of course necessary, but not sufficient. In traffic conditions it is even not impossible for an easily visible colour, for instance white, to be relatively inconspicuous, even when the brightness of different colours, such as white and yellow, is the same.
To visibility as referred to here can be added: conspicuousness, recognizability and localization.

1.2.2. Conspicuousness

Conspicuousness—the extent to which an object stands out—is a psychological quantity, dependent on the subject's primary task (e.g. driving for a driver).
Besides straightforward visibility, safety clothing also has to be made conspicuous by differing in colour and form from objects a driver normally expects to see. In present-day traffic conditions, where drivers frequently have to be alert and react to the unexpected quickly, conspicuousness is of primary importance. This is particularly so because wearers of safety clothing may be working at places where and times when drivers do not expect to encounter them.

1.2.3. Recognizability

The recognizability distance is the distance at which an object can be identified within the visibility distance.
It is important that persons authorized to undertake traffic-directing duties—such as police officers, and schoolchildren on crossing duty, and also under certain circumstances roadmen and road patrols—should be readily recognized. For these to be recognized by road users they must of course be both visible and conspicuous, although this in itself is not sufficient: the fact that the wearer of safety clothing is empowered to direct traffic in such cases must also be known.
Inadequate recognizability, in so far as influenced by clothing, can be specified as follows:
a. the extent to which police officers and children on crossing duty are confused on account of their safety clothing with other persons not authorized to direct traffic;
b. the confusion caused between persons authorized to direct traffic on account of the clothing.

The confusion named under a. can be prevented by creating clothing of specific brightness and colour for persons who may control traffic, basing the design etc. adopted on the primary requirements of visibility and conspicuousness.
It is reasonable to state that the visibility of the traffic controller will not be endangered by any confusion named under b. Any lack of clear distinction between the clothing worn by different traffic control officers does not in fact present any real problem as far as their personal safety is concerned. In so far as it is considered necessary for specific categories of traffic controllers to be separately recognizable for the exercise of their functions, this can be ensured by means which will not detract from the requirements of visibility and conspicuousness. Clothing of different cut or the addition of insignia to indicate function can be used to obtain some form of distinction between different categories. This particular subject falls outside the scope of this study, however.

1.2.4. Localization

Localization can be defined as the distance at which and the time in which the position and the change in position of an object with respect to its surroundings can be determined.
The localization of the wearer of safety clothing is largely determined by circumstances other than the clothing and will not therefore be considered further.

1.3. Wearability

The wearability of safety clothing is determined by:
a. the extent to which heat and moisture resulting from exertion can escape;
b. the protection afforded against the weather;
c. its attractiveness, which may be defined as the degree to which the clothing is adapted to the task and work of the users.

Not counting the dimensions of the article of clothing concerned, the properties named under a. and b. are usually chiefly determined by the nature and density of the material and, if applicable, the characteristics of the form of impregnation employed.
The property named under c. is affected by the stiffness of the material (freedom of movement) and by its colour and brightness, but also by the style and design of the clothing.

1.4. Durability

The economic aspects do not depend on the nature and quality of the material only, but also on the durability of the aspects of the clothing which are essential for visibility, such as its colour and brightness.

2. The clothing used at present

The materials used for safety clothing usually consist of synthetic material such as vinyl polymer, synthetic rubber and the like. A wide range of colours are in use. The police generally wear white. Police officers responsible for traffic control often have white sleeveless jackets with a 'V' of reflectorized material on the front and back. White clothing is also used by a considerable minority of schoolchildren on crossing duty. Road workers, the majority of children on crossing duty and some roadmen wear yellow. ANWB Signposting staff are issued with orange clothing and a number of roadmen with orange or red. Sometimes a chevron in white, grey, black or red is also stamped or stitched on to the clothing. In a number of cases this chevron is added in reflectorized material, and occasionally in fluorescent material. Blue and green are two colours which are avoided owing to their lack of contrast with the natural surroundings (air and greenery). Yellow, red and orange stand out better. Clothing in these colours can be supplied in fluorescent types.
The safety clothing worn may be a form of sleeveless jacket or overalls, but full-length coats are also worn. Separate sleeves and leggings are also sometimes included. The fastenings employed are buttons or press-studs, or elastic or non-elastic tapes or 'Velcro'-type fastenings.

2.1. Clothing of the 'road group'

Users in the 'road group' have objections to the present materials, largely because the synthetic materials as mentioned above tend to retain heat and moisture resulting from exertion. This group also complains about the unsuitability of the clothing, particularly about how it bulges out when they stoop, other consequences of the stiffness of the materials, and the lack of pockets. The contrasts obtained by means of chevrons and certain styles of jackets are not considered acceptable in most cases either; the majority of those wearing such clothing in the 'road group' feel they are dressed up in 'clowns' rig-outs'.

2.2. Clothing of the 'traffic group'

The 'traffic group' is also found to have objections about the design of their safety clothing in particular. Municipal police have no complaints about their present clothing, a full-length white coat in synthetic rubber based material without chevron markings, or in specific cases a sleeveless jacket. What they would object to, apparently, would be any changes in colour for aesthetic reasons or because it was thought that road users might confuse them with other persons authorized to direct traffic. The question whether this could have a detrimental effect on the exercise of their duties by the police does not fall within the scope of this study, which is concerned with the safety aspects only. It can be noted, however, that in view of the frequency of white or nearly white clothing among road users the recognizability of white safety clothing cannot be termed optimal. From the safety aspect, it can be stated that white safety clothing is relatively poorly conspicuous (see 5.1.).

3. The studies carried out

3.1. Colours

a. Determination of the most conspicuous colour under the conditions as occurring in practice.
b. Determination of the conspicuousness of contrasts incorporated in the clothing.
c. Determination of the minimum colour surface required facing the oncoming driver.
d. Determination of the most conspicuous colour for persons with defective colour vision.
e. Comparison of reflectorized and fluorescent material as regards conspicuousness.

None of the many experiments already carried out concerning colour detection has been designed to determine colours which stand out well against roadside backgrounds. In most cases the colours tested have been tried out against a grey background. Considerable effort has been put into determining the most conspicuous colouring for aircraft. A listing of the experimental work done with this object in view has been compiled by Siegel and Federman (1965).

3.2. Materials

a. The determination of the properties of the materials used up to the present for clothing for persons who have to work on or by the road, such as composition, stiffness, durability, light fastness, reflective power and strength.
b. The development of a material which combines the desirable properties of synthetic fibres as regards strength, brightness and colour with adequate heat and moisture conductivity, while still providing good protection against the weather.

4. Research contracts

Specialized research institutes carried out sections of the work.

4.1. Institute for Perception RVO-TNO, Soesterberg

Determination of the conspicuousness of materials available from manufacturers for safety clothing for work on the road, depending on:

a. colours;
b. dimensions;
c. contrast in the clothing itself;
d. shapes (chevrons);
e. defective colour vision.

This part of the work had to be done under conditions as obtaining when the clothing is in use.

4.2. Fibre Research Institute TNO, Delft

Investigation of existing clothing to determine:

a. light fastness;
b. reflective power after six month' use (simulated);
c. opacity.

4.3. Plastics and Rubber Research Institute TNO, Delft

Investigation of existing clothing with respect to:

a. stiffness;
b. composition;
c. effect of ageing on the stiffness;
d. resistance to tearing.

4.4. NITHO (Netherlands Institute for Applied Home Economics Research), Wageningen

Development of material which meets the following requirements:

a. reflective power and colour, as specified in the tests carried out by the Institute for Perception RVO/TNO, Soesterberg;
b. conduction of heat and moisture resulting from exertion;
c. protection against weather.

5. Results of the studies

5.1. Conspicuousness

The most relevant factor was found to be conspicuousness (see 1.2.2.).

5.1.1. Colours

The colours tested were white, yellow, fluorescent orange, fluorescent red and fluorescent yellow, with grey as standard reference colour. According to information from the Paint Research Institute TNO, Delft, fluorescent white does not retain its colour and properties very long. In addition fairly marked variations in colour occur and its fluorescent capacity is relatively low. Fluorescent white was not therefore selected for testing here.
The colours mentioned above were selected on the basis of results of earlier studies on the conspicuousness of colours which had revealed that fluorescent red, orange, yellow and blue usually stand out better than equivalent non-fluorescent colours. Of the fluorescent colours orange is the relatively most conspicuous (Siegel and Federman, 1965). White was included in the study because the clothing used by the police is as a rule white and about a third of the schoolchildren on crossing duty are also issued with white coats. Yellow was included because it is used for the clothing issued to the majority of children who do crossing duty and to road patrols.

5.1.2. Laboratory and field experiments

Using seven sets of circumstances representative for roadside conditions, samples of clothing were tested in the laboratory, the driving task being partially simulated. These laboratory experiments were then followed by a field experiment as a means of checking the findings. (See Michon, Eernst and Koutstaal, 1969).

The results of these laboratory and field experiments are as follows:
a. Of the colours tried out fluorescent orange was found to be by far the most preferable for use in daylight as regards conspicuousness. Under all the sets of circumstances included this colour proved to be better, even for persons with defective colour vision.
b. Grey and white were found to be definitely the least conspicuous in daytime. After grey, white is the least conspicuous colour. Yellow is better than white and grey, but still nowhere near as effective as fluorescent orange. Fluorescent red is not so good as fluorescent orange.
The results of the field experiment correspond with those of tests carried out to find the most conspicuous colour for aircraft.
c. Contrasts, e.g. by means of chevrons, could not be demonstrated to have any effect.
This is also in line with the results of the studies listed by Siegel and Federman, which indicated that unbroken coloured areas were more effective than broken ones. A contrast achieved by means of e.g. a chevron could be effective in darkness, however, if reflectorized material were used.
d. For use in darkness reflectorized material is preferable to fluorescent.
When caught by vehicle headlights the amont of light reflected in the direction of oncoming drivers is ten times higher in the case of reflectorized material; it will consequently stand out better too. White, which is the least visible in daylight or at dusk, has the highest reflective power in darkness when lights shine on it. To the fluorescent orange clothing could be added white reflectorized material in order to make it stand out sufficiently when used in darkness as well (See 7.1. and 7.3., however).

5.2. Material research

On the basis of a listing of the materials which manufacturers could supply for safety clothing, fourteen samples were tested as regards composition, stiffness, opacity, light fastness, reflective power, tear resistance and durability.
On the grounds of the results obtained regarding light fastness and reflective power manufacturers have endeavoured to improve different materials. In order to check the results of these efforts, eight materials were tested. Nothing new was brought to light. Reports on the tests by the Fibre Research Institute TNO and the Plastics and Rubber Research Institute TNO have been included in Section 2 of the Annex.

a. One of the findings is that the present fluorescent orange—and hence the most conspicuous—clothing is relatively not very lightfast and consequently fades quickly.
By way of notes to the test reports included in Section 2 of the Annex it should be stated that at a light fastness value of 3 serious discolouration occurs after no more than about 20 sun-hours; for a light fastness value of 5 after about 200 sun-hours and for a light fastness value of 7 after about 1000 sun-hours. Pronounced fading has a detrimental effect on conspicuousness and spoils the appearance of the article concerned. So far no process is known by means of which light fastness can be improved. Manufacturers can achieve a light fastness of 5–6 (according to the determination as given in the Annex) for fluorescent orange clothing. It is recommended to adopt this value as the minimum requirement. The reflective power is more important for conspicuousness than the colour, however. It could be said that faded fluorescent orange clothing is preferable to non-faded articles in other colours.
b. The reflective power (0 for black, 10 for absolute white) is not in general detrimentally affected by the fading, as is shown by the report in the Annex. After 500 hours illumination in the Xenon test the reflective power remains in general the same as it was originally or even higher. The lighting time used in the Xenon test corresponds to roughly six months' use, on the basis of about four hours' sunshine per working day.
c. The synthetic materials used for the clothing are as a rule polyvinyl chloride plasticized by means of a plasticizer, or a copolymer of vinyl chloride and vinyl acetyl.
With one exception the materials tested were found to possess a degree of stiffness such that after a 24-hour folding test at 0°C a permanent crease generally remained, although without any little cracks developing.
The likelihood of the material used at present for safety clothing becoming harder and brittler after a fairly short time (as indicated by the degree of volatility of the plasticizer) is fairly slight. This did not prove to be the case with one of the materials tested, however. A reduction in the amount of plasticizer (according to the measurements) of no more than 2.5% wt. after twelve hours at 100°C seems to be advised.
d. The opacity of all the materials tested seems to be adequate (0.85 to 0.99).
e. With regard to the tear resistance of warp and woof, quite marked differences were found between the materials (from 1.3 to 13 kg). Recommendations for minimum and maximum values can only be given of the nature of the work to be done, the possible chance of being dragged along by traffic (low tear resistance desirable), economic considerations (cost of replacement), and the type of fastening used are taken into account.
In view of the work they have to do, stronger clothing appears to be needed for the 'road group' than for the 'traffic group'. Those in the 'road group' are also less likely to be run into owing to the warning signs and other safety measures taken to protect them.
A minimum tear resistance for warp and woof of 1.5 kg (determinated by the single strip method) seems to be recommended for clothing to be used by both groups.

6. Conclusions

6.1. Colour

Fluorescent orange is by far the most preferable colour for safety clothing to be worn by persons working on the road, both by day and in the dusk.
White is not to be recommended. Yellow, although it stands out better than white, is by no means as effective as fluorescent orange. No improvement is gained by making the yellow fluorescent. In fact fluorescent yellow is even less readily spotted than ordinary bright yellow.
Fluorescent red is not so eye-catching as fluorescent orange.
The light fastness of all the colours tested is poor.

6.2. Material

Conduction of heat and moisture, flexibility and light fastness are aspects which are apparently critical for the materials used at present for safety clothing to be worn on the road. Excessive heat and moisture retention and stiffness are drawbacks of these materials which are felt particularly by the 'road group', which is made up of persons who do relatively heavy physical work.
These drawbacks are less important for those in the 'traffic group', who are employed in supervisory functions and on the directing of traffic. The present materials (PVC or synthetic rubber) coloured fluorescent orange could therefore be considered satisfactory for this group. Complaints about physical discomfort when wearing the clothing in hot weather are also to be expected from this group of users, however.
A different material than at present obtainable from manufacturers would accordingly be desirable for this group too.

6.3. Solution

To be suitable for safety clothing materials should satisfy two requirements:
a. They must be available in a fluorescent orange possessing an acceptable degree of light fastness.
b. They must provide protection against rain and cold, but should not retain heat and moisture (water vapour).

Woven or knitted textiles made from fine yarns which have been dyed fluorescent orange and made water-repellent can meet these requirements. From contacts with manufacturers by NITHO at the request of SWOV, it has been learned that polyacryl nitril fibre could be used as base material for adequately light fast fluorescent orange fabrics. The only difficulty is that polyacryl nitril fabrics in poplin or gabardine versions are not yet being manufactured. Discussions are now under way with manufacturers in order to obtain a fabric of this type which is also sufficiently waterproof. (A report on the work done by NITHO has been included in Section 3 of the Annex.)

7. Evaluation of results

7.1. Clothing for the 'traffic group'

The materials now available for safety clothing for work on the road (synthetic fibres) can be considered satisfactory for those whose functions do not, as a rule, involve heavy physical exertion, in particular police officers, schoolchildren on crossing duty and roadmen. These materials should, however, be in fluorescent orange, in order to make the clothing stand out in daylight and at dusk. (Section 4 of the Annex gives (test) specifications for this type of material). For use during the hours of darkness on unlit roads, reflectorized material is preferable to fluorescent material. This material could for instance be applied in strips on the front and back of the clothing. A chevron is not necessary for visibility, while the wearers tend to dislike 'sergeants' stripes' on their clothing. They object to reflectorized material around their ankles too, and this was also found to be unnecessary for helping oncoming drivers to see them. At the visibility distances involved the wearer is in fact outside the beam of low-beam headlights and consequently only receives the scattered light from an approaching vehicle's low-beam headlights. In such cases the intensity of the light falling on the ankles is virtually the same as that on for instance the upper part ot the body. In order to recognize and distinguish between the various groups of wearers of reflectorized material for safety clothing at night, different shapes could be applied.

7.2. Clothing for the 'road group'

For persons whose work usually entails relatively heavy physical exertion such as public works department and contractors' personnel, staff of the ANWB Signposting division and sometimes roadmen belonging to public works departments as well, the material used for the clothing now obtainable is not satisfactory.
For clothing for this group a fabric is required which does not retain heat and moisture resulting from exertion but is also sufficiently waterproof. Such a fabric has to be suitable for dyeing fluorescent orange, as described under 5.2.
In so far as persons in this category also operate in the dark on unlit roads—as may be the case in particular for roadmen and also road patrols—it is desirable that reflectorized material should be applied on their clothing as under 5.1.d and 7.1.d.
Fabrics meeting these requirements are not yet obtainable from manufacturers. NITHO is at present investigating what can be done in this respect and considers the chance of success reasonably good. An interim solution could be to make the clothing partly in fluorescent orange plastic and partly in water-repellent textile material. At least 1500 sq. cm fluorescent orange material seems necessary to be visible on the surface facing oncoming traffic.
The material could be fastened to the ordinary working clothes by means of press-studs, a zip or by sewing on.
It should be borne in mind, however, that this solution is not a fundamental one and will not be a very practical one either.

7.3. Style and design

The design of the clothing should be such that it will no longer be regarded as bothersome special safety gear but as a reasonably attractive outfit of practical utility for the wearer's work or function.

Possible designs could be for example a windjacket for ANWB Signposting staff, a jacket for roadmen and road patrols and a longer coat for police officers and schoolchildren on crossing duty. The distinction between functions as desired by different groups of users can be obtained by the addition of special emblems. Consideration could be given to adding such markings in reflectorized material. White reflectorized material would be preferable for this purpose owing to its high reflective power when applied in relatively small-sized pieces. Were another reflectorized material to be selected the optimal size of the insignia would have to be larger.
If a 'button-in' lining could be added for use during winter the general utility of the clothing would be enhanced.
The style and design of the clothing could be standardized per group of users. This could be done by a working group made up of representatives ot these groups, the State Clothing Commission (Rijkskledingscommissie) and industrial designers. This working group could follow the development of new materials as well, and could also determine for which groups of users reflectorized material should be added on the safety clothing worn, and the coulours and shapes which are considered the most suitable.

7.4. Test certificate

It is to be recommend that safety clothing be provided with a test certificate, which could also state for which group(s) of users the clothing is intended. This could serve to prevent clothing being purchased which does not meet the requirements laid down, while it could also provide a means of establishing the distinction between the clothing for different groups which some of them consider desirable.

Literature

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Annex to the report Safety clothing for work on the road

1. Conditions of use

1.1. Roadmen

a. *Work*. Road inspection; in case of accidents, traffic control until police arrives.
b. *Posture*. Upright.
c. *Place*. Usually cycling along roadsides, but may cross the road if an irregularity, such as a bad road surface or damage to a median barrier, is noticed.
d. *Time*. Daytime. Also at night for work against icy roads and in case of fog.

1.2. Employees of State and Provincial public works departments and personel of Royal Dutch Touring Club ANWB (Signposting division)

a. *Work*. Minor repairs to road surface. Pricking up paper and removing dirt and maintaining safety barriers. Placing signposts. Supervising contracted work. Work against icy roads. Hedge clipping.
b. *Posture*. Both upright and stooping.
c. *Place*. On the road, often along the left-hand side. Working behind barrier of red and white striped planks illuminated at night with lamps.
d. *Time*. Mostly daytime. Sometimes at night with public lighting or special work-lighting.

1.3. Contractors' workmen

a. *Work*. Road construction and repair.
b. *Posture*. Often stooping, sometimes upright, often next to road machines.
c. *Place*. Very often on left of road, with spades next to road machines, both left and right of road. Behind red and white barrier. Outside built-up area (municipal workers also in built-up area).
d. *Time*. Day and night. At night with public lighting or work-lighting.

1.4. Police officers

a. *Work*. Traffic control.
b. *Posture*. Upright.
c. *Place*. Mostly on road, both inside and outside built-up areas.
d. *Time*. Day and night.

1.5. Schoolchildren on crossing duty

a. *Work*. Stop traffic for pedestrians.
b. *Posture*. Upright.
c. *Place*. Mostly in built-up areas. Rarely outside built-up areas. Mostly at pedestrian crossings.
d. *Time*. Nearly always daytime.

1.6. Road patrols

a. *Work*. Simple repairs to motor vehicles. Sometimes traffic control pending arrival of police.
b. *Posture*. Standing, leaning over, lying.
c. *Place*. Inside built-up areas, often in road, outside built-up area mostly by side of road.
d. *Time*. Day and night.

2. Material research

by the Fibre Research Institute TNO, Delft, and the Plastics and Rubber Research Institute TNO, Delft.

Table 1

Light fastness was determined according to NEN 5230 (average humidity) with the aid of the Xenotest type 150. Light fastness is expressed in the scale of 1 to 8, 1 indicating very poor and 8 excellent.
Reflective power was measured with a Zeiss Elrepho photometer with a green (FMY) filter. Reflective power is expressed as a percentage of reflection of Mgo. In order to simulate conditions after 6 month's use, 500 hours' illumination in the Xenotest was applied.
Opacity was determined as the ratio of reflective power of a single layer ot material with black and white backgrounds respectively. Opacity is 1 for a completely opaque material and 0 for a completely transparent material.
Tear resistance was determined by the single strip method.

Table 2

Structure was not completely analyzed, only an exploratory determination was made.
Plasticizer loss was determined according for Plastics Research Institute No. 1.1.17 analysis method.

Specimen No.	Colour	Light fastness	Reflective power % 500 hours Xenotest illumination		Opacity	Tear resistance (kg)	
			before	after		warp	woof
1	Orange fluorescent	3–4	42	70	0.93	1.4	1.6
2	Grey	8					
3	Yellow	7	46	43	0.94	7.6	8.2
4	Black	8					
5	Yellow	7–8	53	53	0.94	1.9	1.3
6	Brown	3					
7	Yellow	6–7	46	43	0.85	8.1	7.7
8	White	8	82	82	0.99	1.9	2.4
9	Red	6–7 *					
10	Green-Yellow fluorescent	6					
11	White	8	86	85	0.99		
12	Yellow	2 *	52	44 *	0.92	1.7	1.4
13	Orange fluorescent	2–3	37	50	0.99		
14	Orange fluorescent	4	38	62	0.90		
15	White fluorescent	3–4					
16	Orange fluorescent	3	47	71	0.91		
17	Yellow	6–7	54	52	0.99		
18	Yellow	7–8	56	56	0.94		
19	Yellow	5 *			0.89		
20	Yellow	6 *			0.95		
21	White	8			0.94	13.0	7.2
22	Red fluorescent	5–6					
23	Yellow fluorescent	3–4					
24	Red fluorescent	5–6					
25	Orange fluorescent	5–6					
26	Yellow fluorescent	4					
27	Red fluorescent	5–6					
28	Orange fluorescent	4–5	35	50			
29	Orange fluorescent	3–4	36	66			
30	Orange fluorescent	4	39	62			

Table 1.

* These samples were darkened by illumination.

				Stiffness at low temperature after							
Specimen No.	Structure	Plasticizer loss		24 h at 0°C		24 h at —14°C		24 h at —20°C		24 h at —30°C	
		loss as % by weight after 6 h at 100°C	loss as % by weight after 12 h at 100°C	creasing test	tears	creasing test	tears	creasing test	tears	creasing test	tears
1	vinyl + plasticizer	1.3	1.9	permanent crease	none	permanent crease	none	permanent crease	none	permanent crease	none
2											
3	ditto	0.8	1.4	no crease	ditto	no crease	ditto	no crease	ditto	no crease	ditto
4											
5	ditto	1.0	1.6	permanent crease	ditto	permanent crease	ditto	permanent crease	ditto	permanent crease	ditto
6											
7	ditto	1.0	1.6	no crease	ditto	no crease	ditto	no crease	ditto	no crease	ditto
8	ditto	0.6	1.0	permanent crease	ditto	permanent crease	ditto	permanent crease	ditto	permanent crease	ditto
9											
10											
11	ditto	1.0	1.7	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto
12	ditto	1.2	2.0	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto
13	probably synth. rubber	—	—	no crease	ditto	no crease	ditto	no crease	ditto	no crease	ditto
14	vinyl + plasticizer	3.2	4.9	permanent crease	ditto	permanent crease	ditto	permanent crease	ditto	permanent crease	ditto
15											
16	ditto	0.9	1.4	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto
17	ditto	1.7	2.6	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto
18	ditto	1.1	1.7	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto
19	ditto	3.9	4.9	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto
20	ditto	1.6	2.4	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto

Table 2.

3. Material development research

By NITHO (Netherlands Institute for Applied Home Economics Research), Wageningen.

The problems were formulated as follows:
a. the clothing must be properly visible;
b. it must be wearable both summer and winter;
c. it must protect its wearer against rain;
d. it must cause no physical discomfort.

It follows from these requirements that:
a. For proper visibility, the surface of the garment must be at least 1500 sq.cm on both chest and back, according to research by the Institute for Perception RVO-TNO. The colour of the clothing should preferably be fluorescent orange. It would thus have to be dyed or provided with pigments of this colour.
b. The safety clothing is not specifically summer or winter clothing. Safety clothing with good heat-insulating properties would be unsuitable in summer (see point d.). The safety clothing must therefore be regarded as a garment worn over the normal clothing. The normal clothing must give protection against cold in winter. Single woven or knitted fabrics, made from fine yarns, worsteds or three-roller yarns, might be suitable clothing material.
c. Protection against rain can be obtained by coating the woven or knitted fabrics mentioned in b. with PVC or synthetic rubber for instance. Another possibility is to apply a permanent waterrepellent finish. This has good prospects of success, however, only if the fabric is made of close-woven fine yarns.
d. If water vapour transport (perspiration) through the safety clothing is obstructed, the wearer will feel uncomfortable. The clothing material must therefore be porous.
It follows from the foregoing that coating fabrics with a non-porous PVC or synthetic rubber gives a material unsuitable for safety clothing. Woven or knitted fabrics made of fine yarns, dyed fluorescent orange and made permanently water repellent might be suitable material for manufacturing safety clothing. The first reports by dyestuffs manufacturers on the light fastness of fluorescent dyes were not very encouraging. On the whole this type of dye proved not to be very fast. There was one exception. For dyeing polyacryl nitril fibres, new fluorescent dyestuffs with good fastness had been developed.

Contact with N.V. CIBA, Arnhem, presented new perspectives in regard to rainproofing. This firm tested a new micro-porous coating for rainwear. Tests in Switzerland with clothing waterproofed with this coating had been very promising. It was found to be rainproof and comfortable to wear. The coating must be applied on the inside of a fabric (poplin or perhaps gabardine weave), after which rainwear can be made with it. This might solve the problem of a permanently waterproof, physically comfortable safety clothing for road workers, provided it also meets the requirement of visibility.
Investigations into the possibility of dyeing mixed fabrics of polyester and cotton with this colour, utilizing the fluorescent effect of the optic whiteners used in detergents, had negative results. The only possibility was to use polyacryl nitril fibres as the basic fabric material.
Contact with manufacturers, however, has revealed that polyacryl nitril fabrics of poplin or gabardine weave, made with three-roller yarns are not included in their range of products. It is, however, possible in principle for the industry to make these.

4. Recommendations for inspection standards

Drawn up by KEMA, Arnhem in co-operation with the other institutes collaborating in the research.

4.1. Diffuse reflection, colour and opacity

4.1.1. Diffuse reflection

Diffuse reflection of a material is defined as the reflection of light whose average angle of incidence forms an angle of 45° with and towards the normal on the—flat—material.
The diffuse reflection factor of a material is defined as the ratio between the luminances towards the normal, occurring:
a. with diffuse reflection from a sample of the material attached to a black background;
b. with diffuse reflection from a flat surface, intensively smoked with magnesium oxide, of the same size and illuminated in the same way as the sample.
The diffuse reflection factor is measured with light having the same relative spectral energy distribution as CIE standard light source C (colour temperature approx. 6500°K) and must not be smaller than 0.40.

4.1.2. Colour

The colour of the material is established with the aid of three colour-co-ordinates x, y and z in the trichromatic co-ordinates system of the Commission Internationale de l'Eclairage (CIE) decided upon in 1931. The sum of the colour co-ordinates x, y and z is 1, and the colour can therefore be indicated by means of a colour point—determined by two of these co-ordinates—in a colour plane, See Figure 1.
The colour co-ordinates are determined by one of the methods customary in colorimetry from light diffusely reflected by the material. The material—which is placed against the blackest possible background—is illuminated with light having the same relative spectral energy distribution as CIE standard light source C (colour temperature approx. 6500°K). The colour co-ordinates must satisfy the following requirements:
$y < 0.176x + 0.262$ boundary towards orange
$x > -y + 0.900$ boundary towards white
$y > 0.048x + 0.301$ boundary towards red

4.1.3. Opacity

The opacity of the material is defined as the ratio between the diffuse reflection factors of the material when first placed upon a dark background (diffuse reflection factor maximum 0.03) and then on a light background (diffuse reflection factor minimum 0.90). Opacity must be at least 0.90.

4.2. Additional requirements for artificial fibres

4.2.1. Stiffness

After a 24-hour creasing test at 0°C no permanent creasing or tears.

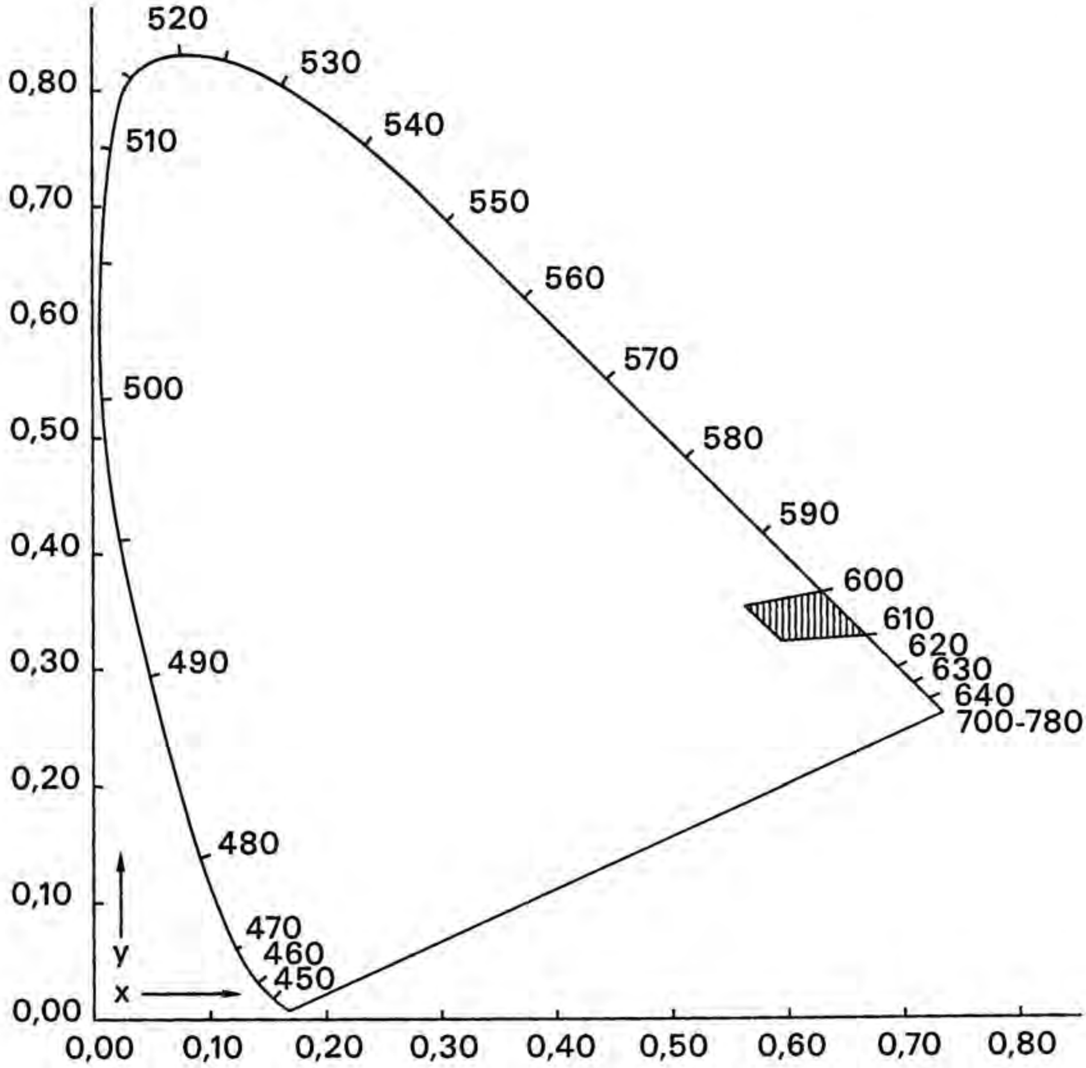

Figure 1 · CIE colour triangle with the colour-area for fluorescent orange.

4.2.2. Hardness

A plasticizer loss which, by TNO determination after 12 hours at 100°C, does not exceed 2.5 per cent by weight.

4.2.3. Tear resistance of warp and woof

Minimum 1.5 kg, determined by the single strip method.

4.2.4. Light fastness

Light fastness is determined according to NEN 5230 (fastness to light, artificial daylight), subject to assessment being made when the colour change in the specimen is equivalent to stage 3 or stage 2 of the standard grey scale. Colour change in this case means fading only. Section 2 of this Annex gives the light fastness of a number of samples. On the basis of these data a minimum value of 4–5 is recommended.

Designed by Cees van Dorland, Krommenie, The Netherlands
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