Motor Vehicle and Pedal Cycle Conspicuity

Part 3: Retro-reflective and Fluorescent Materials - Discomfort Glare of Markings

Project Number 9/33/13

Undertaken on behalf of

The Department of Environment, Transport and the Regions (DETR)

Prepared by

Sharon Cook

July 1998

Checked by .....

Table of Contents

1.0 Aim

The aim of the assessment was to determine if the application of retro-reflective material to the side and rear faces of heavy and long vehicles and their trailers could result in discomfort glare. Discomfort glare occurs when a source of high luminance, such as a vehicle headlight, is found to be painful or annoying but does not result in the loss of visual information.

Discomfort glare was assessed in this study for two types of material application:

- Contour markings only. (According to the Draft Regulation these markings, are 'a series of rectangular strips intended to be placed in such a way that it shows the contour of the vehicle to the side or rear').
- Contour markings and graphics markings. (Graphics markings are 'additional coloured markings intended to be placed within the contour marking' which are of a lower retro-reflective performance than the contour markings).

Since discomfort glare is a subjective phenomenon, it cannot be measured directly or calculated. Instead those exposed to the glare sources are required to make and report their own judgements as to the level of discomfort they are experiencing. These judgements are made using the deBoer rating scale which, despite its short comings, is the industry standard. (Refer to Appendix 1).

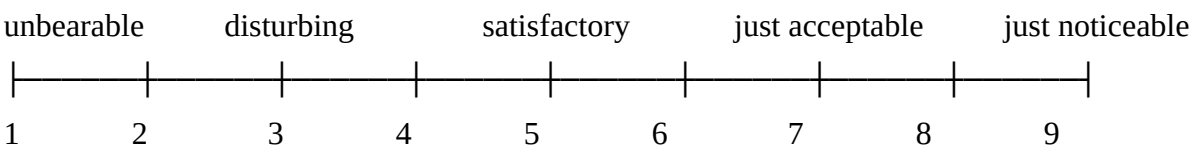


Fig.1: Illustration of the deBoer rating scale

2.0 Methodology

2.1 Variables

The study was conducted in the hours of darkness at a local test site. A rig was built to represent the side of a truck and was fitted with side marker lamps and side retro-reflectors.

The performance requirements of the contour and graphics materials used met those defined in the Draft Regulation XA (refer to Appendix 2). The main variants assessed are summarised in Table 1.

Table 1: Main variants of the Draft Regulation XA assessed

	Format	Colour
Contour	Full contour outline Dashed horizontal lines	White Yellow Fluorescent orange Fluorescent yellow Red
Graphics	2.0m² block	White

The Draft Regulation XA permits four types of contour marking format (refer to Appendix 3). However this part of the study only considered the assumed best case of a full contour outline and worst case of two horizontal dashed lines to the lower edge of the truck side or rear. (These assumptions were based on the likely photometric performance of the marking format due to the amount of material available for exposure).

A worst case scenario for discomfort glare, in which the materials would appear at their brightest, was replicated by viewing at a distance of 135m. The materials were viewed under both dipped and main beam.

2.2 Subjects / Participants

Two groups assisted in the study and their details are given below in Table 2.

Table 2: Participant details

	Group 1	Group 2
Male	14 participants 30-69 years old	10 participants 36-75 years old
Female	6 participants 22-75 years old	10 participants 35-73 years old

2.3 Procedure

Before any ratings were made, basic instruction in the use of the scale was given. The participants were told that they would be viewing truck markings as they may see them on the road. The scale was then presented to the participants who were given some time to become familiar with it. Since the deBoer scale is subject to a range effect (that is, the rated discomfort is dependent upon the range of glare stimuli with which it is likely to be associated), the scale ends were anchored for the road environment. The participants were told that markings which were considered to be so dull as to not be visible were to be rated at 9, whilst those which were comparable to an oncoming headlight on main beam were to be rated at 1. The different formats of markings were then presented in quick succession with the participants recording their first impression.

3.0 Results

3.1 General levels of discomfort glare

To obtain an overview of how the different material formats performed under different viewing conditions, an analysis has been made of their mean deBoer ratings shown in Table 3.

Table 3: Mean and standard deviation (SD) deBoer ratings for each condition

Marking format		Contour markings				Contour markings + graphics markings			
		Dipped		Main		Dipped		Main	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
White	Full contour	4.40	0.88	4.53	1.58	5.63	1.57	4.11	1.63
White	Dash line	6.25	1.29	5.89	1.45	5.68	1.80	5.37	1.54
Flu Yellow	Full contour	4.25	0.79	3.95	1.93	5.16	1.42	3.79	1.58
Flu Yellow	Dash line	6.00	1.26	6.11	1.41	5.84	1.50	5.11	1.41
Yellow	Full contour	4.45	1.28	4.21	1.81	4.63	1.64	3.84	1.57
Yellow	Dash line	6.20	1.36	6.89	1.15	5.63	1.89	5.32	1.25
Orange	Full contour	4.60	1.39	5.05	1.78	5.11	1.52	4.21	1.27
Orange	Dash line	5.60	1.27	6.32	1.38	5.47	1.31	5.21	1.36
Red	Full contour	4.70	1.13	5.11	1.70	6.05	1.61	4.89	1.49
Red	Dash line	6.05	1.54	5.84	1.95	5.79	1.18	5.26	0.99

Assuming that a mean deBoer scale rating of 3 or less would suggest that some noticeable effect of discomfort glare is perceived, it can be observed that discomfort glare was not found to be a problem in any of the above conditions. However previous research by Olson et al (1992) suggests that these values should be reduced by ½ a deBoer unit to account for the fact that longer duration exposures, of 1 and 5 minutes, are rated as more uncomfortable than shorter duration exposures of 2 seconds. If an allowance is made for this and for the standard deviation, then those conditions represented by the lighter shaded cells would fall below a deBoer rating of 3.

Consideration of the opposite end of the deBoer scale assumes that a deBoer rating of 8 or 9 is undesirable because the markings may be insufficiently bright to be noticed at all. However examination of the data in table 4 indicates that there is only one incidence of this nature which represented by the darker shaded cells in Table 3.

3.2 Effect of graphics material

An analysis was undertaken to determine if the addition of the graphics markings to the contour markings was likely to significantly increase discomfort glare ratings. Paired two sample T-tests were conducted for each of the contour markings variants in both dipped and main beam conditions. Refer to Table 4. The results indicated that with the exception of the shaded cells, the addition of graphics markings did not significantly increase the participants ratings of discomfort glare.

Table 4: T-probabilities of discomfort glare ratings for different contour markings variants with and without the graphics markings

		Dipped	Main
White	Full contour	<0.01	0.25
White	Dash line	0.26	0.21
Flu yellow	Full contour	0.02	0.63
Flu yellow	Dash line	0.72	0.06
Yellow	Full contour	0.70	0.32
Yellow	Dash line	0.29	<0.01
Orange	Full contour	0.29	0.04
Orange	Dash line	0.76	<0.01
Red	Full contour	<0.01	0.57
Red	Dash line	0.56	0.30

3.3 Effect of contour markings format

Further analysis was undertaken to determine if the full contour outline markings resulted in significantly greater discomfort glare ratings than the two horizontal dashed lines. Table 5 indicates that generally this was found to be the case in the assessment, the exceptions being shown by the shaded cells.

Table 5: T-probabilities for comparison of marking configuration

	Dipped					Main				
	White	**Flu. yellow**	**Yellow**	**Flu. red-orange**	**Red**	**White**	**Flu. yellow**	**Yellow**	**Flu. red-orange**	**Red**
No graphics	<0.01	0.17	<0.01	0.02	<0.01	0.01	<0.01	<0.01	0.04	0.03
With graphics	0.88	0.02	0.02	0.31	0.50	<0.01	<0.01	<0.01	<0.01	0.17

3.4 Effect of fluorescent markings

Analysis was undertaken to determine if the fluorescent yellow and fluorescent red-orange materials were found to result in significantly different ratings of discomfort glare than their non-fluorescent counterparts. Table 6 indicates that generally this was not the case, the exceptions in the main being related to the use of these materials as full contour markings in conjunction with the graphics block.

Table 6: T-probabilities for comparison of fluorescent and non-fluorescent markings

	Dipped				Main			
	Dashed line		Full contour		Dashed line		Full contour	
	No graphics	With graphics	No graphics	With graphics	No graphics	With graphics	No graphics	With graphics
Red v fluorescent red-orange	0.15	0.11	0.78	<0.01	0.33	0.87	0.87	0.01
Yellow v fluorescent yellow	0.46	0.45	0.30	0.03	0.03	0.53	0.23	0.79

3.5 Comparison of Draft Regulation XA requirements with ECE70

A T-test comparison of the Draft Regulation and ECE70 markings is given in Table 7 below. The ECE70 markings used in the work were a single rectangular marking and a combination of four diagonal markings. Refer to Appendix 4 for full details.

The data in the table suggests that:

- The full white contour both with and without the rectangle/diagonal was considered significantly more glaring in terms of discomfort than the rectangle/diagonal only. However this was not the case when the red dashed outline was considered in place of the full white outline.
- The addition of the rectangle/diagonal to the full white contour and the red dashed outline did not significantly increase discomfort glare.

NB. These results are only applicable to dipped beam conditions.

Table 7: T-probabilities for comparison ECE 70 and Draft Regulation XA markings

	White full outline	**Red dash line**	**White full outline with rectangle**	**Red dash line with rectangle**	**White full outline with diagonal**	**Red dash line with diagonal**
Rectangle	<0.01	0.18	<0.01	0.14		
Diagonal	<0.01	0.05			<0.01	0.20
White full outline		<0.01	0.33		0.33	
Red dash line				0.83		0.49

4.0 Summary and conclusions

4.1 Summary

Discomfort glare can be subjectively measured using the deBoer 9-point rating scale. A rating of 9 signifies that the discomfort glare is just noticeable which in the context of this work means that the truck markings are barely visible; a rating of 1 signifies that the discomfort glare is unbearable and in the context of this work would equate to truck markings which are as bright as an oncoming vehicles main beam.

General ratings

- Aside from the yellow dashed markings viewed under main beam, all markings were rated as being sufficiently bright to be visible.
- It is assumed that all forms of full contour markings viewed for more than one minute under main beam will give rise to a significant level of discomfort glare (rated from 'disturbing' to 'unbearable'). However in most instances, drivers will have the option to adjust their lights to view under dipped beam.
- Aside from the full yellow and full orange contours, all the marking formats were considered to have acceptable levels of discomfort glare under the dipped beam condition. However it should be remembered that the materials used at this phase of the work were new and so appeared at their brightest. It is likely that at any given time only a small proportion of markings will appear at these levels of brightness on the road.

Effect of the addition of graphics materials

- For most marking formats the addition of the graphics materials did not significantly increase the ratings of discomfort glare. Even in those instances when it did, it did not make the marking formats unacceptable in terms of discomfort glare.

Effect of contour marking format

- Generally, for all marking colours, the full contour markings were rated as significantly brighter (i.e. received higher ratings of discomfort glare) than the two horizontal dashed lines. When viewed under main beam this change from dashed

lines to full contour markings resulted in the markings becoming too bright for comfort; this did not occur under dipped beam.

Effect of fluorescent markings

- Fluorescent yellow and fluorescent red-orange markings were not found be brighter i.e. significantly more glaring in terms of discomfort, than their non-fluorescent counterparts. The exceptions to this were in the main related to full contour marking format applied in conjunction with the graphics block. However this did not make the fluorescent contour markings any more or less acceptable than their non-fluorescent counterparts.

Comparison of Draft Regulation XA requirements with ECE70

- The full white contour (both with and without the rectangle/diagonal) was rated significantly brighter than the rectangle/diagonal only. However this was not to the extent that the markings were considered uncomfortably bright.
- The two red horizontal dashed lines were not rated as being significantly different to the rectangle/diagonal.
- The application of the rectangle/diagonal to the full white contour and red shaded lines is unlikely to significantly increase discomfort glare.

4.2 Conclusions

- In general, all colours of contour markings assessed were rated as being sufficiently bright to be seen but not so bright to give rise to discomfort glare under dipped beam conditions.
- Full contour markings viewed under main beam for more than one minute may give rise to discomfort glare. However drivers will usually have the option to adjust their headlamps to dipped beam to counter this. Also, since these assessments used the worst case of new materials, this is less likely to be a problem once the materials have become weathered and dirtied.
- Full contour markings were rated as brighter than the two dashed line makings. However this increase in brightness is only likely to result in discomfort glare under main beam conditions - see point above.

- The addition of graphics markings to contour markings did not increase discomfort glare to unacceptable levels.
- Fluorescent markings did not give rise to unacceptable levels of discomfort glare.
- The full white contour was considered to be significantly brighter than the ECE70 rectangle and diagonal markings, but not uncomfortable so. However there was found to be no difference in brightness between the red horizontal dashed lines and the rectangle/diagonal.
- The application of the draft XA markings in conjunction with the ECE 70 markings is unlikely to result in unacceptable levels of discomfort glare.

5.0 References

Olson, P L et al (1992) Performance requirements for large truck conspicuity enhancements UMTRI-92-8.

Appendices

Appendix 1

Limitations to the deBoer rating scale

There are some limitations to the deBoer rating scale which may affect its validity and these are described below.

- The deBoer scale is Dutch in origin and there are a variety of English translations of it in use.
- It is not known if the Dutch version was designed as an interval scale and no known work has been conducted in this respect on the English versions.
- Unconventionally the small numbers of the scale are associated with the more intense stimuli.

However, despite these limitations the de Boer scale is considered to be the best measure available and, since subjects appear to use the scale according to the numbers and not the descriptors, reasonable data has been obtained from its use.

Appendix 2

Photometric specifications for Contour and Graphics Markings defined by Draft Regulation XA

1.1 Minimum values for the coefficient of Retro-reflection

Photometric specifications for retro-reflective markings of Class C:

TABLE 1

Minimum values for the Coefficient of retro-reflection R′ ($cd.m^{-2}.1\ x^{-1}$)

Observation angle α (°)	Entrance angle ß (°)			
α = 0.33° (20′)	ß1	0	0	0	0
	ß2	5	30	40	60
Colour					
yellow	300	130	75	10
white	450	200	90	16

1.2 Maximum values for the coefficient of retro-reflection

Photometric specifications for distinctive markings or graphics of Class D:

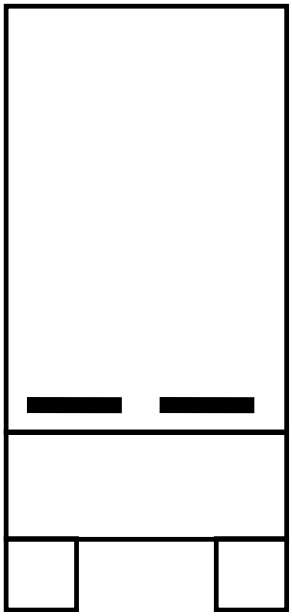
TABLE 2

Maximum values for the Coefficient of retro-reflection R′ ($cd.m^{-2}.1\ x^{-1}$)

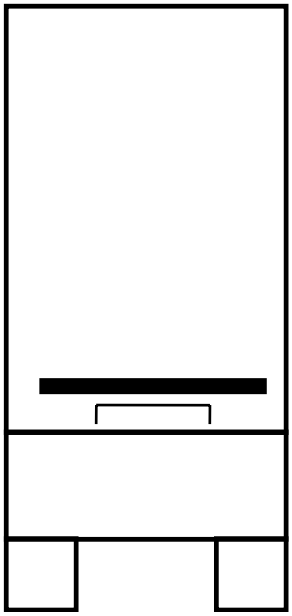
Observation angle α (°)	Entrance angle ß (°)			
α = 0.33° (20′)	ß1	0	0	0	0
	ß2	5	30	40	60
Any Colour	150	65	37	5

Appendix 3

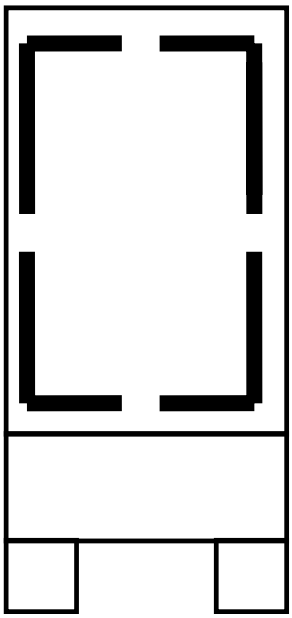
Marking formats defined by Draft Regulation XA



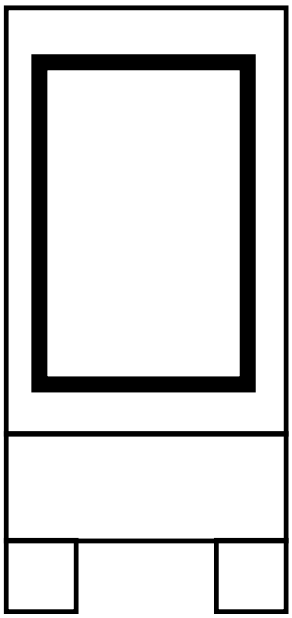
Dashed line



Full line



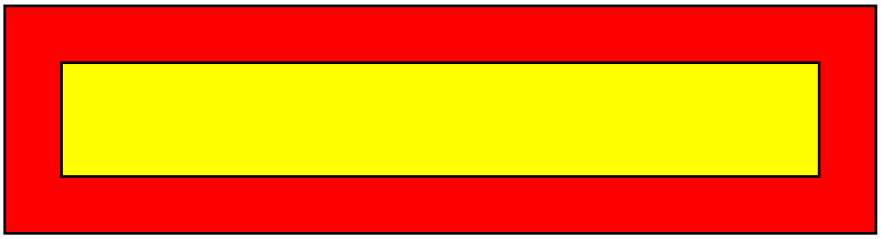
Partial contour



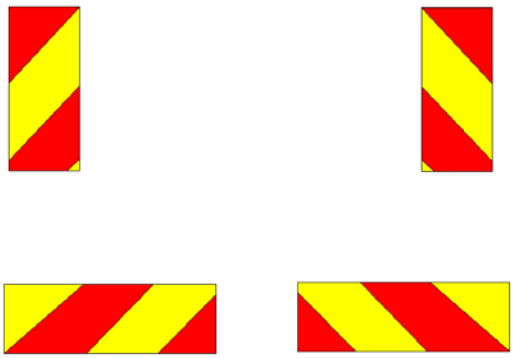
Full contour

Appendix 4

ECE70 marking formats



Rectangle - Class 4



Diagonals - Class 3

= Retro-reflective Red

= Retro-reflective Yellow