Informal Document No. 30
(48th GRE, 9-12 April) 2002
(Agenda Items 1.2 and 4.2)

# History and Scientific Back-up

Hanno Westermann
(AFS Secretary)

references:
TRANS/WP.29/GRE/2002/18 to 20



PCNA Ex. 1015
U.S. Patent No. 10,894,503

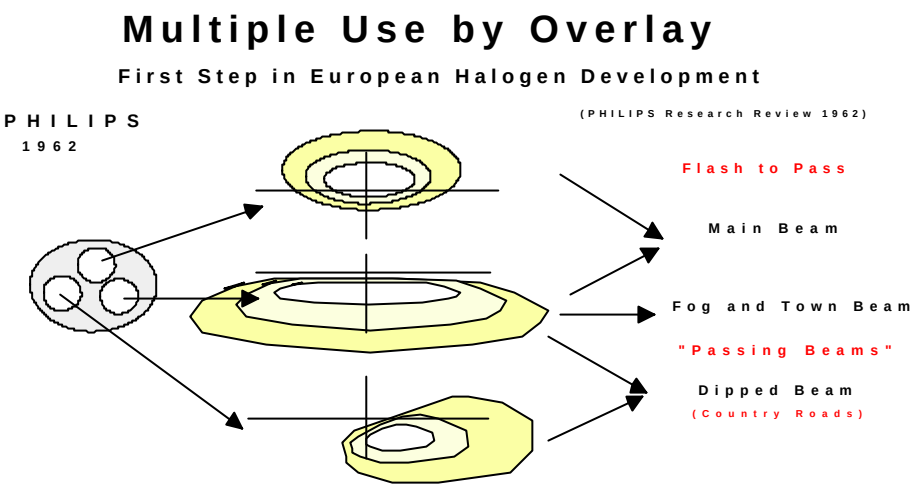
# Content


| | | page |
|---|---|---|
| 1. | The AFS Project | |
| | - Project history and desirability of headlighting improvements | 3 |
| 2. | Glare and Visibility under night time traffic conditions | 6 |
| | 2.1 Glare from headlamps on traffic roads | 6 |
| | 2.2 Influence of lateral distance of glare sources on glare | 7 |
| | 2.3 Disability glare and visibility of pedestrians on straight traffic roads | 9 |
| | 2.4 Influence of the light emitting area on discomfort glare | 11 |
| | 2.5 Glare from headlamp reflexes on wet roads | 12 |
| | 2.6 Influence of vehicle inclination changes on glare | 14 |
| | 2.6.1 .. due to vehicle loading | 14 |
| | 2.6.2 .. due to vehicle dynamics | 15 |
| | 2.7 Glare reduction and visibility improvement on illuminated roads | 16 |
| | 2.8 Glare reduction and visibility improvement in curves | 18 |
| 3. | Photometric Requirements | |
| | 3.1 Co-ordinates for headlamp photometry | 19 |
| | 3.2 Specified values in the photometric tables | 19 |
| 4. | Vehicle appearance at night | 21 |

# 1. The AFS Project

## - Project history and desirability of vehicle front lighting improvements

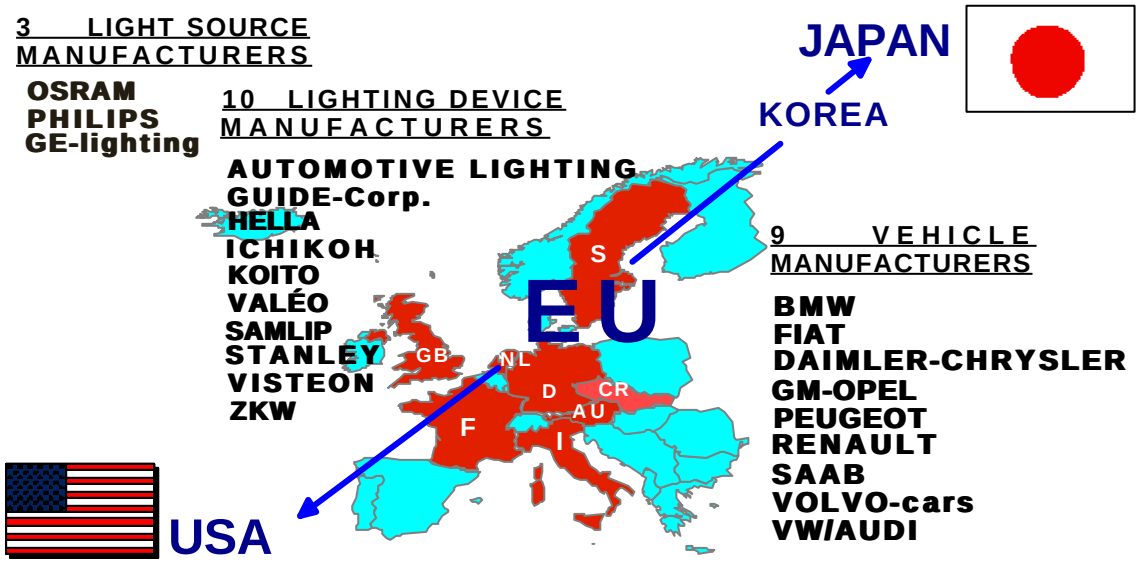
During the development within the Eureka project "VEDILIS" (Gas Discharge Light Sources) it became obvious that a single passing beam pattern can not provide an optimum lighting performance for all common road situations, particularly not in adverse weather conditions; it had to be a compromise. Already back in the 60th (see figure), attempts were made for adaptive beams, but the projects were stopped for missing technologies with respect to accuracies of light sources and reproduceability of mechanical levelling movements. However, headlamp levelling control was introduced in the 70th, be it by manual setting as a first step.



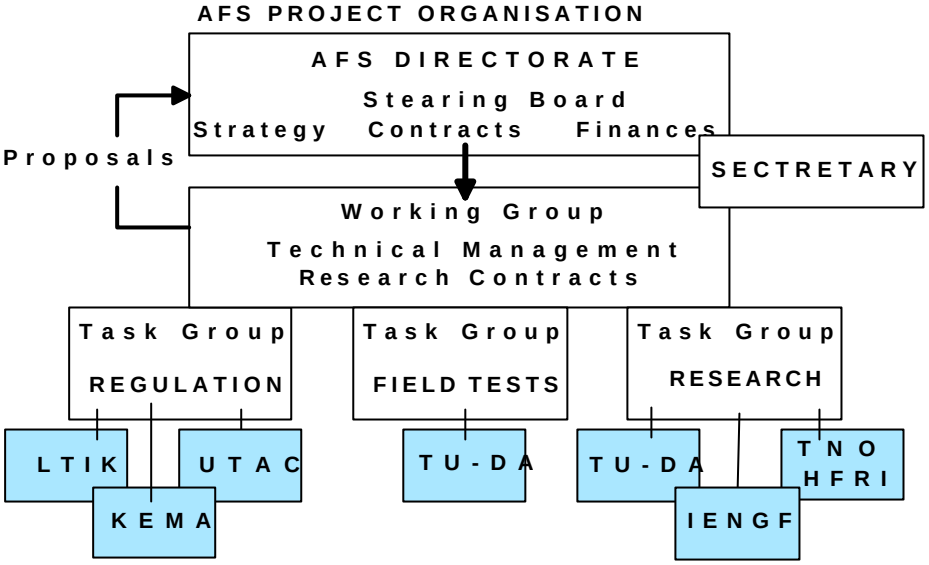

*J.J. Balder, Iodine incandescent lamps, Philips Technical Review, Vol 23, No.8/9, 1961/2*

In 1992, new technologies were available that would allow front lighting systems to adapt in lighting performance for different road and weather conditions. The partners of the VEDILIS project therefore decided to initiate a new EUREKA project "AFS" with the purpose to advance in the development of *adaptive front lighting systems* and overcome some major weaknesses of conventional passing beams.

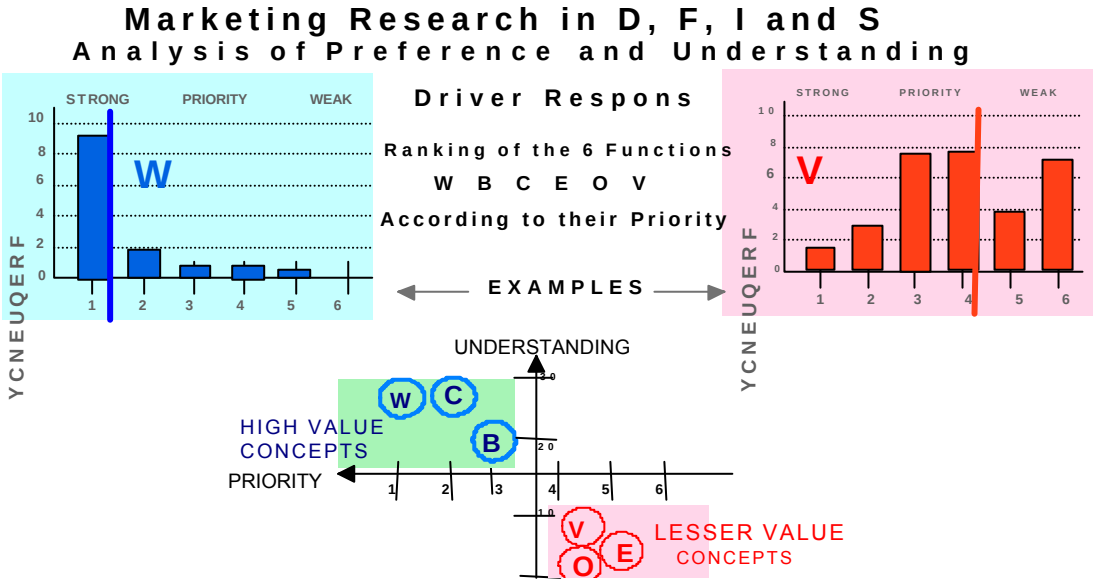
In May 1993 the Eureka project status was granted. A value analysis and feasibility study of shortcomings of conventional front lighting revealed possibilities to improve visibility and comfort for typically adverse conditions. The consortium in the project was build from light source manufacturers, headlamp manufacturers and car makers from over the world.



The project structure was set up and work could begin.




First a marketing study was made to investigate the drivers' complaints and their wishes. Enquired for the wishfulness and priority of different options, the drivers in all age groups, female and male, wearing and not wearing glasses understood easily their advantage with an improvement for wet road lighting (W), improved passing beams (C) and bend lighting (B). For the latter a cost increase such as being paid for front fog lamps or even ABS was judged acceptable. The special visual conditions on town roads with public lighting (V), on motorways (E) and for overhead signs (O) found less understanding and were, accordingly, judged of lesser value.

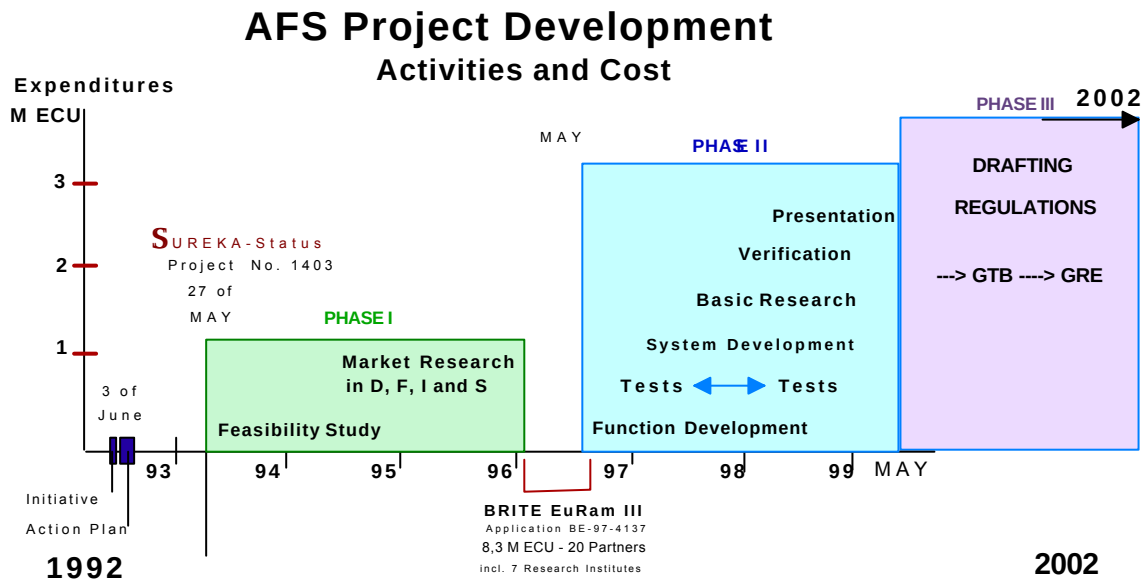



The results of the marketing study gave evidence to pursue the project and to allocate financial assets for the project. After more detail work in function development, the necessary research was specified and first prototype systems were made for field tests and to develop type approval procedures. The specified research included dynamic glare and the influence of shape, area and partition of the headlamps on glare as well as on vehicle appearance for other road users. Initially it was also planned to include road reflection research on dry and wet roads in different countries as well as statistical research on pedestrian reflection and on the statistical positions relative to the headlamps of targets such as road signs, pedestrians, rear view mirrors in the visual field.

The enormous cost involvement of such research and development (8 M €) was reason to apply for sponsorship within the framework of BRITE EuRam III - with 20 partners and 7 research institutes being involved. However, the application was denied and preference given to non automotive traffic projects. This was a loss of a year and urged to cut the research activities to a bearable budget. The research was dedicated to glare and appearance issues only and to the assistance of test houses in developing type approval procedures and the set up and evaluation of field tests.

The AFS systems were developed and designed to adapt the front lighting performance to particular environmental and traffic conditions. Such particularly differing conditions prevail on motorways, country and town roads and they prevail also in adverse weather such as fog, precipitation, wet roads and when driving on curved roads or cornering. For the special conditions in fog and cornering, special lamps are specified and regulated with adequate performances. They can be reciprocally incorporated in AFS systems. Their lighting performances, however, form no part of the AFS system requirements but of separate ECE Regulations.

The project targets (phase II) were finalised by May 1999. The results were presented and real scale test drives done at the Balocco test grounds by members of the participating industries and invited guests from national governments, GTB and GRE.




During phase III of the project, the experiences and investigations were transformed into draft regulations that were approved by GTB at their 92nd session at Kyoto in 2001 and transmitted to GRE as working document in January 2002.

During the AFS phase II a special overhead sign lighting had also been developed and tested. During discussions in GTB it was omitted from the set of requirements since modern retroreflective traffic signs are adequately visible with spread light intensities of about 100 cd. Therefore no special lights were felt necessary.

This report summarises the research aspects that let to the requirements as specified in the draft documents for

1) a new AFS Regulation (TRANS/WP.29/GRE/2002/18 and 19) and
2) amendments for mounting and operating requirements of AFS systems in ECE Regulation No. 48 (TRANS/WP.29/GRE/2002/20).

# 2. Glare and Visibility under night time traffic conditions

## 2.1 Glare from headlamps on traffic roads

Discomfort glare is the judgement of a person whether glare is unbearable, disturbing or absent. The glare sensation is directly related to stress by over-excitation of the receiver cells in the eye. Different from discomfort glare, disability glare can not be judged. It needs to be measured and tells to what extent the eye adaptation and therewith the threshold sensitivity is at a given adaptation luminance and how this threshold is increased by glare. However, this threshold difference of luminance that makes an object distinguishable from its surround gives alone no understanding of what can be seen and what not. For this purpose the luminances of the target and its surrounding must be known. These luminances depend from reflection properties of e.g. the road and a pedestrian, and from the illuminance from the headlamp on the pedestrian and on its background. For both, discomfort glare and disability glare, formulas have been established from experiments. They show that the detectable luminance threshold and the discomfort glare rating depend from the adaptation luminance ($L_{ad}$/cd/m$_2$), from the eye illuminance ($E_{eye}$/ lx) and from the glare angle ($\Theta$ / degrees) for which the exponent depends on age.

**DISABILITY GLARE**

Schmidt-Clausen/Bindels 1971

young: 1,8
aged: 2,2

$$\Delta L = L_{min} = 0{,}013 + 0{,}037 \times L_{ad} + 0{,}419\,(E_{eye} / Q^{2{,}0})$$

against a dark background

**DISCOMFORT GLARE**

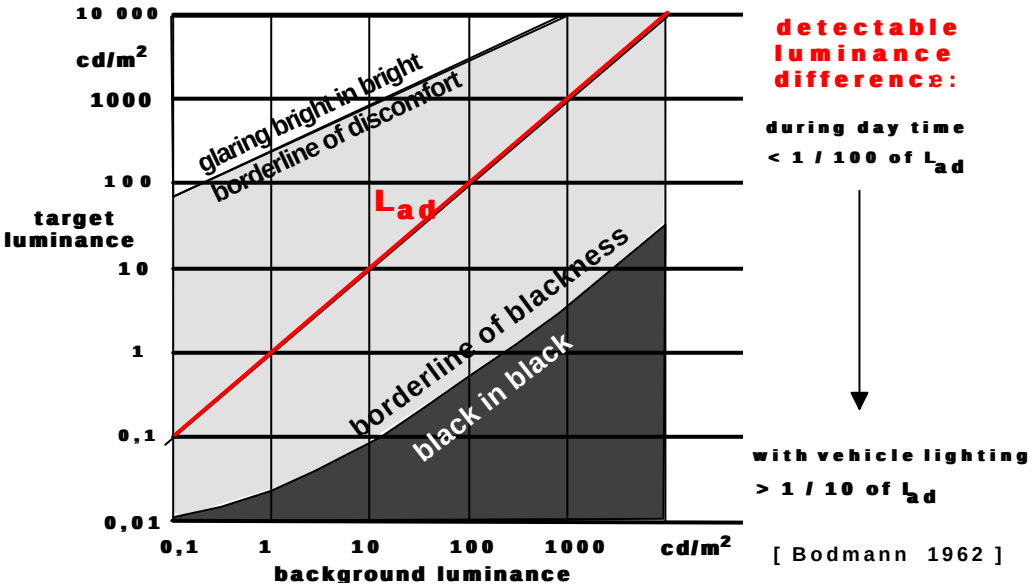
Schmidt-Clausen/Bindels 1971

$$W = 1{,}59 + 2 \log (1 + \sqrt{L_{ad}}) - 2 \log (E_{eye} / Q^{0{,}46})$$

$$E_{eye} = I/r^2 \cos Q$$

*H.J. Schmidt-Clausen, Bindels; Disability glare, J. Lichttechnik 10+12, 1971*
*H.J. Schmidt-Clausen, Bindels; Assesment of discomfort glare, J. Light.Res.Techn. 6, 1974*

Different from day time condition, where the visible luminance difference ranges at less than 1/100 of the adaptation luminance, an object must differ at least as much as 1/10 of the adaptation luminance in order to be visible under road and vehicle lighting conditions .



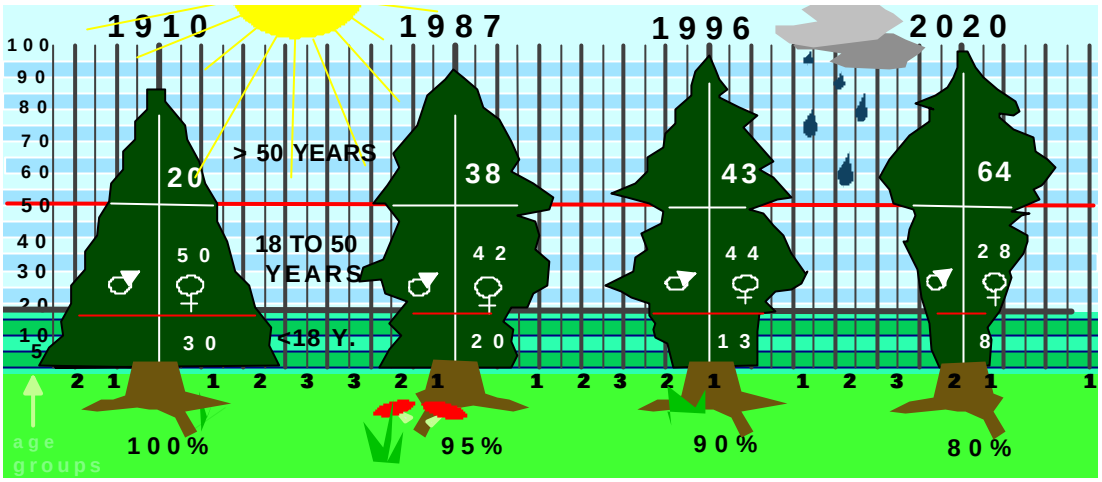

*H.W. Bodmann und Voit, Versuche zur Hellempfindung, J. Lichttechnik Nr.8, 1962*

Any glare source in the visual field, whether present during a short or long period of time, rises the adaptation luminance and therewith the discernible luminance threshold. This glare influence is due to light scatter in the eye, that - for older persons with starting cataract - is more than it is for young persons. Older persons have also less acuity and need more light for the same visual performance. Today, great concern exists with increasing glare. This has different reasons from which one is age and the greater glare sensitivity of older persons.

The statistically increasing average age of the population shows that the majority of drivers of motorised vehicles (in 2020 near to 70%) is aged over 50. Persons of that age are more

glare sensitive and also have less visual acuity. The increasing number of complaints on glare and requests to the parliament to take action against glare, underline this. Thus glare and visibility under vehicle front lighting conditions form a key issue that needs a profound understanding in order to develop effective lighting improvements.

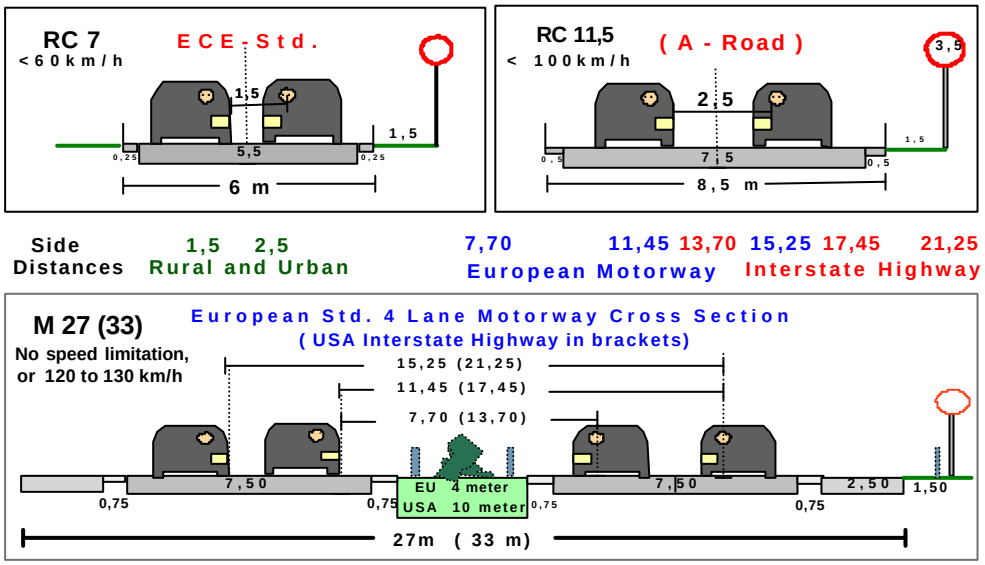
GERMANY'S LIFE TREE - EUROPE DEVELOPS SIMILARLY -




The AFS project was particularly set-up to address the needs of older drivers for improved vehicle front lighting that would compensate for their loss of acuity and take care of increased glare sensitivity due to eye cataract. In the following, therefore, the relationship of visibility and glare are addressed in more detail.

## 2.2 Influence of lateral distance of glare sources on glare

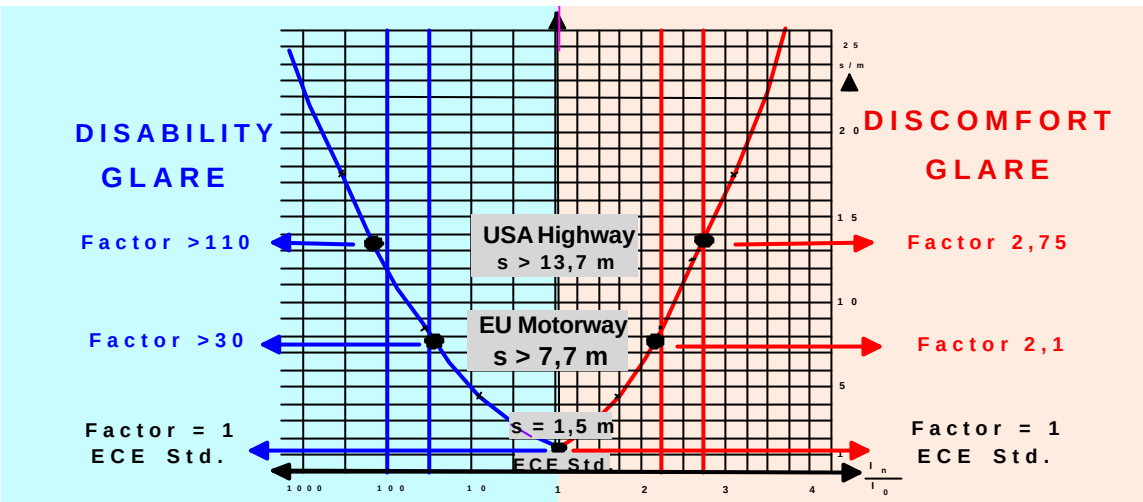
Country roads are dual carriageways where opposing traffic flows at rather short lateral distance that makes glare from headlamps and reflexes on wet roads a special item of concern. On motorways the lateral distance is much greater and reflex glare is shielded by the crash barriers. This reduces the glare effects for opposers considerably.



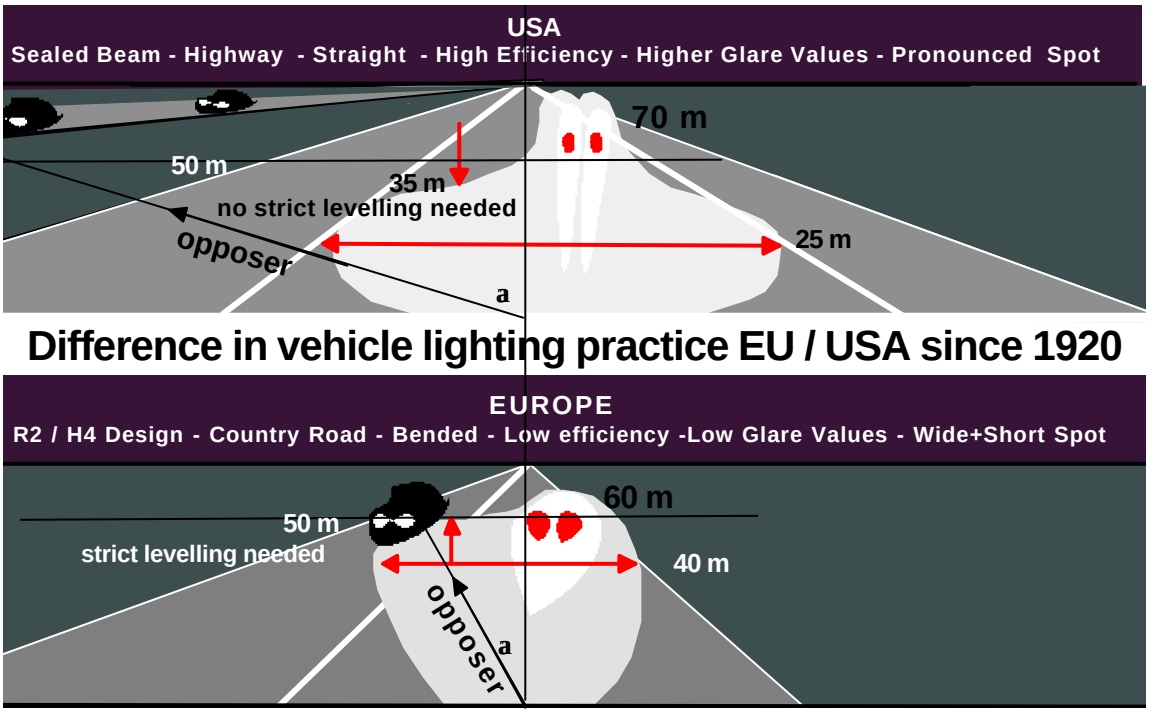

Since the lateral viewing angle under which the headlamps of opposing vehicles are seen has great influence on glare, the glare on motorways is much less than on dual carriage ways. For roads of 6 meter width (RC7) the ECE glare limitation in EB50 and for zone III was introduced in the 60th. The need of limiting glare on the rather small traffic roads had also been reason to develop shielded filament lamps "R2" in 1924 and similar halogen lamps "H4" in 1971. In the USA, at those times, most of the traffic flow concentrated already on highways

with separated lanes. Glare was not seen as important and more attention was given to a high utilisation of the luminous flux and a strong hot spot of far reach. This led at the time to sealed beam headlamps with differing photometry as compared to Europe.

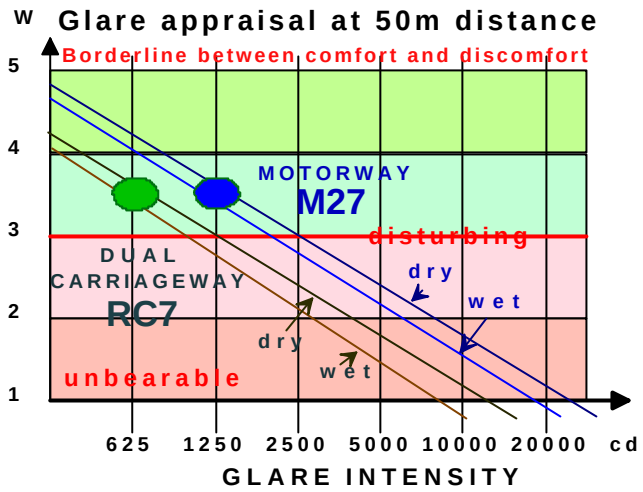
Both beam patterns are good for their intended purpose. For an equivalent level of disability and discomfort glare, the greater lateral distance and viewing angle on motorways towards opposers allows considerably higher glare intensities. The factor of increase relative to the European standard road of 6 m width, is shown in the diagram below.




On motorways the luminous intensity may increase by a factor of 30 for disability glare and a factor of two for discomfort glare. This explains the difference of passing beam photometry between the practice in Europe and in the USA.




The discomfort glare expressed numerically as glare appraisal mark (W) is shown in the diagram below for different glare intensities (cd) for two types of road (RC7 and M27), each in dry and wet condition.

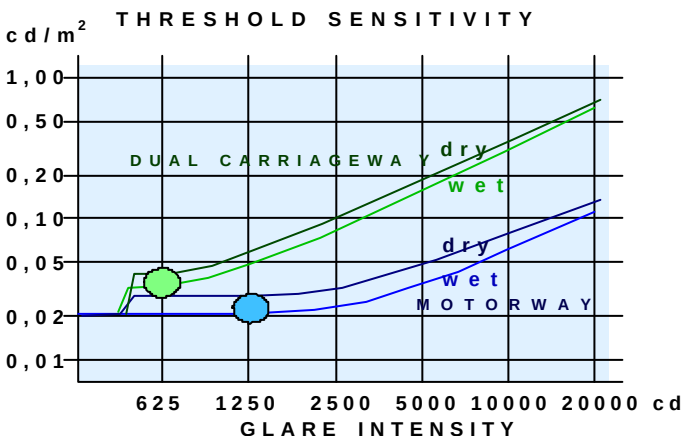



The scale of discomfort glare appraisals according to the glare formula on page 6 comprises 9 steps. A glare mark of 5 defines the borderline between comfort and discomfort (BCD). Public lighting installations are designed to have glare marks of more than 4; under vehicle lighting glare marks down to 3 are technically feasible and accepted practice. Whether the road is dry or wet has no great influence on discomfort glare. On wet roads the lower adaptation luminance (dry: ~0,3 cd/m$^2$; wet: ~0,05 cd/m$^2$)causes a slightly higher glare sensitivity. This consideration, however, does not yield reflex glare on wet roads; this influence is addressed separately under chapter 2.5 below.

The diagram shows clearly, that for typical dual carriageways of about 7 meter width, the glare intensity in zone III should not exceed 625cd (CoP-value). On motorways and for an equal glare sensation, however, the luminous intensity may rise to 1250 cd or double the value. Higher glare intensities will expectedly create complaints on dual carriageways but also on wet motorways and should be avoided. The diagram shows clearly that greater luminous intensities of 10 000 to 20 000 cd (or 16 to 32 lx@25m) towards opposing drivers lead to unbearable glare - this occures whith driving beam on when the passing beams are wrongly levelled such that they emit the high intensities from below cut-off above the horizon - reason why special attention needs to be given to proper levelling (see chapter 2.6 below).

## 2.3 Disability glare and visibility of pedestrians on straight traffic roads

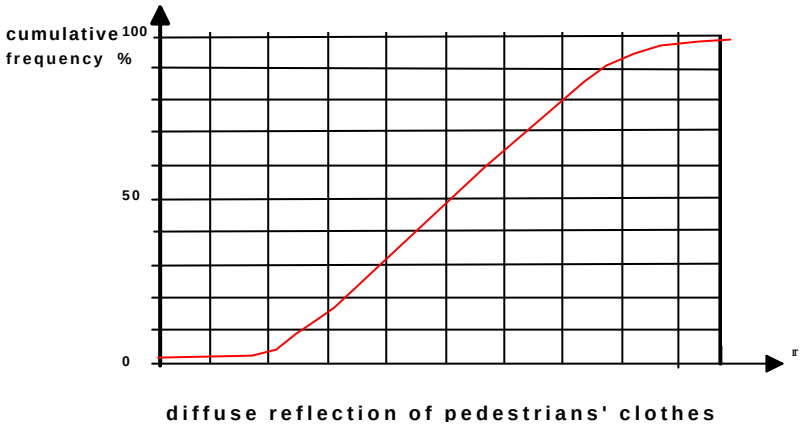
Disability glare is the reason for rising the eye adaptation (the glare light is scattered in the eye and produces a veiling luminance). This increases the threshold luminance that can be disccerned. However, the meaning of a visible threshold luminance of e.g. 0,04 cd/m$^2$ in terms of visibility fully depends on the illumination of the object and its reflection properties.



Different from discomfort glare, disability glare can not be judged. A driver experiences whether he could see a pedestrian or not, after he escaped a near accident or too late.

Due to the flat incidence of light on the road, the road luminance is rather low. On a vertical object such as pedestrians the illuminance is relatively high what makes the pedestrian light against a dark background, particularly when situated at and outside the road edges. At the kerb of a road, in order to see a pedestrian, the illuminance must be such that the detectable threshold luminance is exceeded. With the knowledge of the pedestrians' reflection, the necessary illuminance can be calculated.

Already in the 30th Waldram had introduced "Revealing Power". Revealing power means the probability in % that an object, e.g. a pedestrian, can be seen at a particular location. This probability depends from the luminance of the pedestrian, that can be calculated statistically at knowledge of the frequency distribution of the reflection factors of pedestrians' clothes. Revealing Power gives a much better understanding, of what can be seen at a given combination of glare intensity and glare source location relative to that of the illuminated object.



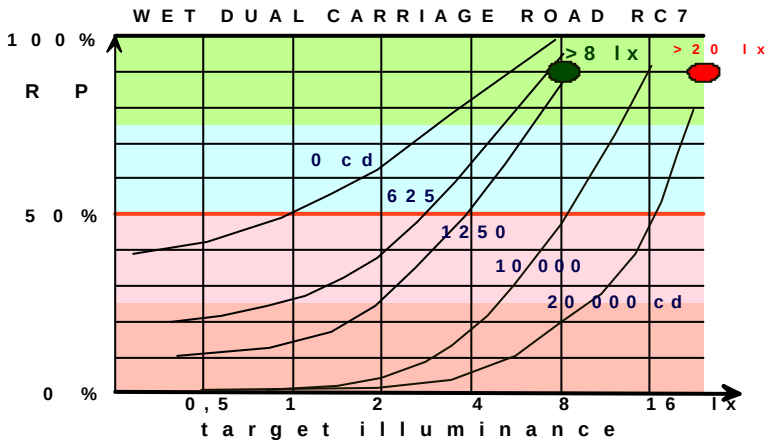

$$L = E \times r / p$$

$$r_{lim.} = \frac{D L \times p}{E}$$

when seen against black background the threshold luminance determines the percentage of pedestrians that cannot be seen; the percentage that can be seen is the remainder to 100 $

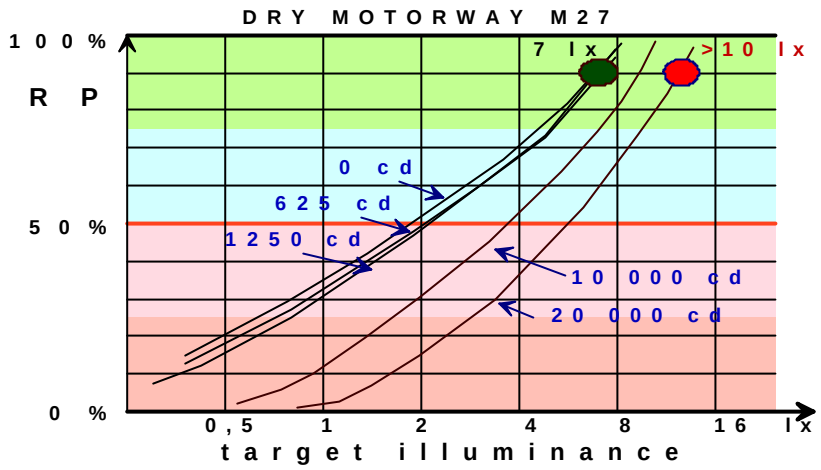
$$RP = (100 - P(r_{lim}))\%$$

The disability glare is expressed by the luminance difference that can just be distinguished. By approximation it also means the minimum luminance of an obstacle that is necessary to see it against a dark background - e.g. when positioned on the kerb of the road. Many researchers use the threshold increase, that is the ratio of threshold under glare divided by the luminance threshold without glare. But, neither the luminance threshold nor the increment gives a clear understanding of what can be seen and what not. Therefor the revealing power as described above in chapter 3 is used in the following diagram in dependency from the object illuminance for a range of glare intensities. The figures of revealing power now indicate the chance in % that e.g. a pedestrian can be seen



To get the necessary luminous intensity towards a target, the object illuminance is to be multiplied with the square value of the necessary seeing distance of the target. On a dual carriageway (country road) two findings are evident:

1) in order to improve the chance of seeing a pedestrian fairly (>50%) if not safely (>90%), the object illuminance should exceed 3,6 respectively 8 lx. Since both headlamps contribute to the object illumination, this means that the illuminance on the measuring screen of each headlamp should exceed 8 lx@25m (5000 cd) in point E50R/L and 16 lx @25m (10 000 cd) in point E75R in order to give a fair chance of seeing a pedestrian or a similar obstacle from 50 m distance.
2) as already stated above in chapter 2.2, the glare intensity should not exceed 1lx@25 m (or 625 cd) in zone III for keeping discomfort glare in acceptable limits.




On a motorway, similar conclusions can be drawn:

1) Since the speed on motorways is higher, obstacles must be seen at greater distance in order to react in time. For motorways the headlamp intensity in E75R should exceed 36 lx@25m (20 000 cd) and have halve the values in E50L.
2) The influence of glare on visibility is much less than on dual carriageways and, as was concluded already above for discomfort glare, the glare intensity in zone III may rise to 2 lx@25m or 1250 cd (CoP)

Every increase in target illumination improves the chance to see further away, but it also increases the risk that with levelling changes due to load, these high intensities are directed towards the opposers where they evoke an unbearable glare sensation (see the diagram on discomfort glare on page 9 above).

## 2.4 Influence of the light emitting area on discomfort glare

An other issue of research on glare was dedicated to the influence of luminance or apparent surface because it was anticipated that smaller apparent surfaces would be more disturbing. According to research by Alferdinck at TNO-HFRI, Soesterberg, Netherlands, such an influence was found, be it much less than was expected. In the experiments for the evaluation of discomfort glare (page 5) the area of the glare source was about 150 cm$^2$. In his research for AFS, Alferdinck found that smaller headlamps increased the discomfort, larger headlamp areas decreased it. The influence of the apparent surface on the Glare Appraisal Mark when applied to the Schmidt-Clausen-Bindels Formula (page 5) is as follows:

$$W = 1{,}59 + W(L_{ad}, E_{eye}, \Theta) \; + \; 0{,}54 \log [(F/\,cm^2) / (F_n / cm^2)]$$

J.W.Alferdinck, Discomfort glare - effects of intensity and size, TNO-HFRI Soesterberg, 1998

This means that the difference in glare mark between a small apparent surface (28,3 cm$^2$ or 6 cm diameter) and a normal headlamp area ($F_n$ = 150 cm$^2$ or 12 cm diameter) is - 0,4 or nearly halve a step worse on the 9 point glare scale. In order not to worsen the comfort and

to reach an equal glare appraisal with smaller headlamp surfaces, the luminous intensity should be decreased by 33%. This has also been found by other researchers (Adrian, Sivak).

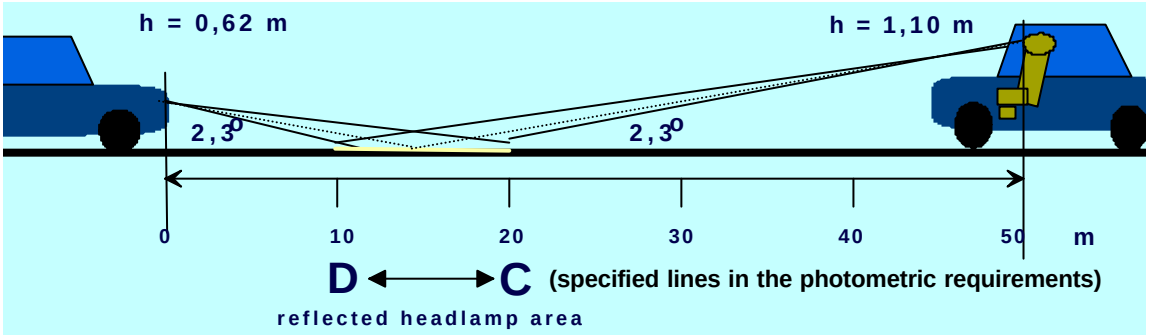
*M.Sivak, Effect of headlamp area on discomfort glare, J. Light.Res.Techn. 22(1), 1990*

*K.Manz, Einfluss der Scheinwerfergrösse auf psychologische Blendung, SAE 1999*

However, when the minimum surface of the simultaneously illuminated lighting units of the headlamp (see under appearance, chapter 4) are specified to be larger or equal 100 $cm^2$ in any case, no additional precaution needs to be taken for the glare intensities of lighting units with smaller areas in order to compensate for their higher luminance. The influence of the glare source area, however, remains very important for reflex glare on wet road surfaces as will be shown below.

## 2.5 Glare from headlamp reflexes on wet roads

On wet dual carriageways and in towns the opposers are dazzled by all kind of reflexes from which the headlamp reflexes from opposers are generally very disturbing. As research from the TU Darmstadt had already shown in context with the VEDILIS project and was verified during AFS tests with special passing beams for wet roads, the main reflexes towards opposers were found to originate from the foreground illumination by the vehicle headlamps at between 10 and 20 meter in front of the vehicle. These reflexes "mirror" the average luminance of the headlamps (in that direction) by about 50% when the water film is closed. Smooth fine asphalt is very critical in forming closed water layers. The more course road surfaces and in particular the ZOAB road surfaces as being used in the Netherlands form no such closed layers and produce less reflex glare.

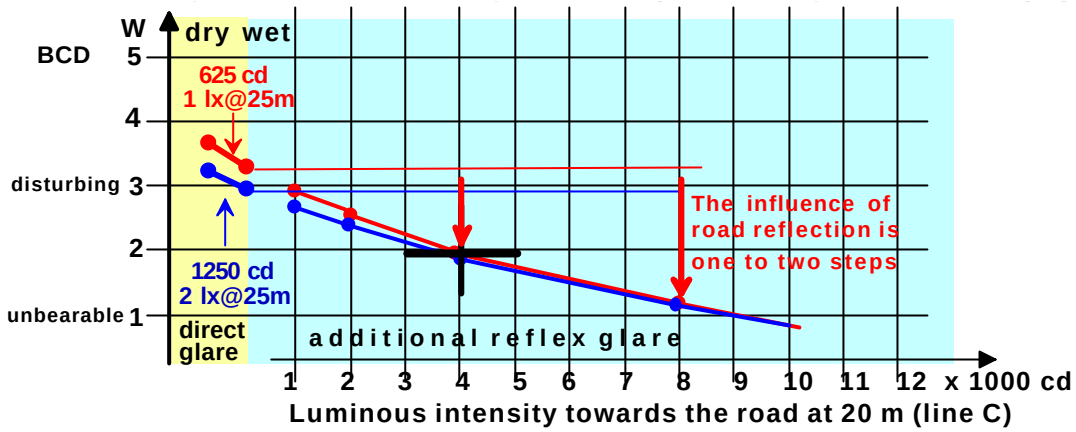



The reflexes of headlamps on a wet road are spread over a large area comprising about 20 $m^2$. The luminance of the road amounts to about 50% of the luminance of the headlamp in the direction to the vehicle foreground between 10 and 20m and produces a very high luminous intensity towards an opposer - most critically at 50 meter interdistance between the vehicles respectively between a vehicle and an observer. The luminous intensity towards the eyes of the opposing driver is found by the product of apparent road surface times the reflected luminance of the headlamp (~50%) in the mirroring direction. The headlamp luminance is given by the quotient of luminous intensity in the mirroring direction and the light emitting area of the headlamp.

$$I_{eye,\ reflex}/cd = I_{headlamp\ line\ C} \times (F_{road\ reflex\ area} \times \sin 1{,}6^\circ) / (F_{headlamp} \times \cos 3{,}2^\circ) = \sim \mathbf{38 \times I_{hl,\ line\ C}}$$

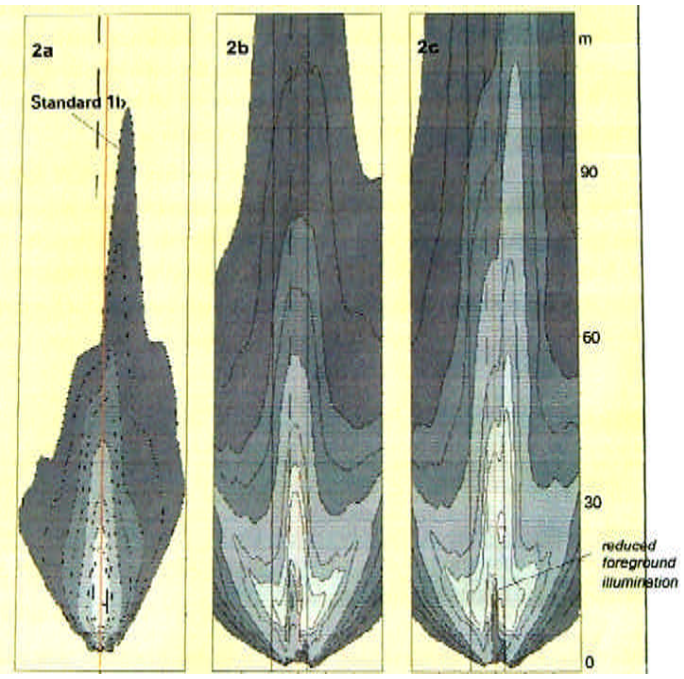
The indirect glare intensity from mirrored road reflexes is with about 38 times the downward intensity by far more than the direct glare intensity from the headlamp and would increase the discomfort tremendously, was it not that the great source area on the road is compensating this effect in part (see the above chapter on influence of glare source area). To show the influence by example, the discomfort glare including the influence of glare source area was calculated for smooth and highly reflecting wet road surfaces for a variety of headlamp intensities towards the foreground of the vehicle.

Calculation of discomfort glare for two headlamps and an opposer at 50m distance
glare angle $\Theta = 3^o$; $L_{dry} = 0{,}3\ cd/m^2$; $L_{wet} = 0{,}05\ cd/m^2$; $F_{road\text{-}reflex} = 20\ m^2$; $F_{hl} = 150\ cm^2$




For these conditions it becomes obvious, that the influence from reflexes exceeds by far the influence from direct glare.

When the foreground intensities of a headlamp range in the normal order of 8000 cd or 12,8 lx @25m for dry roads, the glare on wet roads becomes "unbearable" due to reflexes. As a consequence, the foreground illuminances should be shielded on wet roads or in any case be reduced. If the foreground illumination is reduced towards to or even below 2500 cd or 4 lx @25m, more than one step of glare mark is gained independent whether the direct glare is caused by 1lx@25m or 2 lx@25m. This was confirmed by tests. In order to make the overall glare less disturbing and improve the visibility, it is recommendable to reduce the foreground illuminance to below 4 lx@25m and increase the object illuminance in E50R/L and E75R in order to make the road delineation marking better visible. To make this technically feasible, the direct glare should be allowed to reach 2 lx@25m in zone 3 or 1250 cd (CoP). These findings are incorporated in the photometric requirements for wet road lighting. Examples of such wet road lighting beams are given below by 2b and 2c as compared to the basic beam pattern (2a).




*B. Wörner, Experimental AFS system and functional evaluation, PAL 2001*

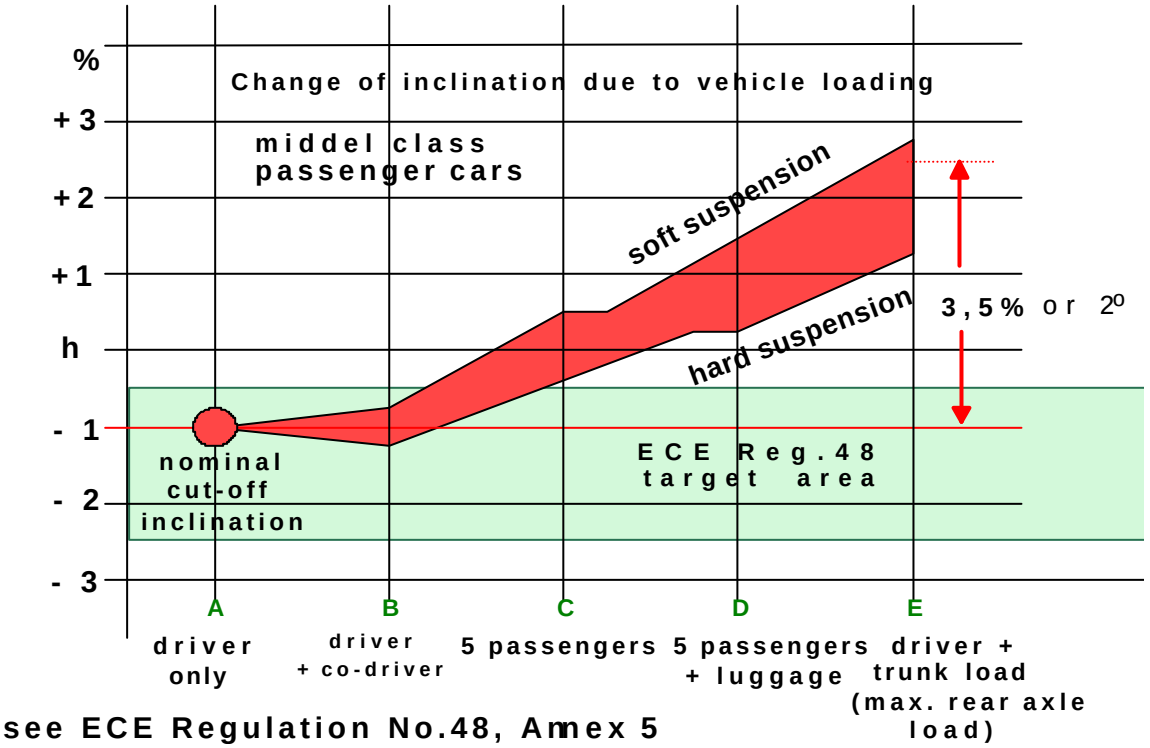
On wet roads it is in any case vital that high intensities towards E75R remain at the intended inclination - not so much to see pedestrians but to see the road delineations for guidance at sufficient distance. Although, the wet road reflexes of high luminance towards the opposers are shielded on motorways by the crash barriers, the increase of forward intensities towards E75R and E50R and the reduction of the reflex glare towards drivers in front from lines C an D remain very important issues.

### 2.6 Influence of vehicle inclination changes on glare

Since modern headlamps exhibit low glare values above the horizon and, for visibility, high intensities that are directed below the horizon to illuminate the road and possible obstacles ahead (E75R, E50R or E50L), the steep gradient between the glare and the illuminating zone (separated by the cut-off line) strongly demands that the beam pattern remains in its intended position relative to the road plane. This is the more the case when high performing headlamps as for wet roads and motorways are applied. Any upward inclination of the beam shifts higher intensities upwards towards opposers with the result of very disturbing or even unbearable glare sensation - but also with less visibility distance of road delineations and possible obstacles. Such inclination changes happen due to vehicle loading or by dynamic variations of the vehicles plane during acceleration and deceleration or due to unevenness of the road.

#### 2.6.1 Change of Inclination due to Vehicle Loading

The inclination changes due to vehicle loading can become as much as 2 degrees. They have to be compensated by a headlamp levelling device - either automatically or manually according to Regulation No.48. For lighting units that yield such steep gradients with very high intensities towards E50L or E75R an automatic levelling should avoid the misuse or neclectance of manual adjustment. Pending a mandate given to GTB for the proper performance criteria of when such high performance and the need for automatic levelling is given, AFS specified automatically levelling for special wet road and motorway lighting and when the emitted light flux from headlamps exceeds some limits.




see ECE Regulation No.48, Annex 5

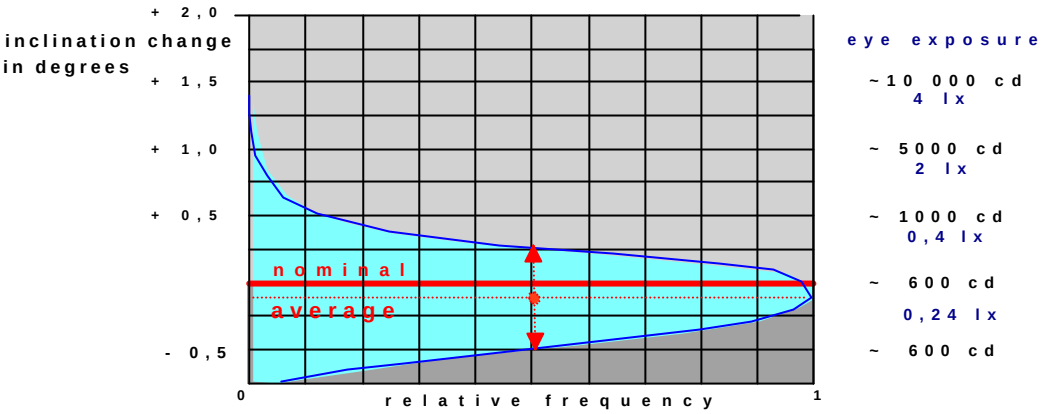
*H.Westermann, on levelling changes by load, J. Automobilindustrie, 1988*

### 2.6.2 Dynamic changes of headlamp inclination due to vehicle dynamics

With respect to short glare impulses that are caused by the vehicle dynamics when accelerated or decelerated or when moving on an uneven road, the AFS group had sponsored research at the Technical University of Darmstadt. This research and earlier investigations by BMW revealed that the dynamic inclination changes have less amplitude (maximum ± 1° ,average inclination - 0,2° ± 0,4° ) than the static changes due to load.

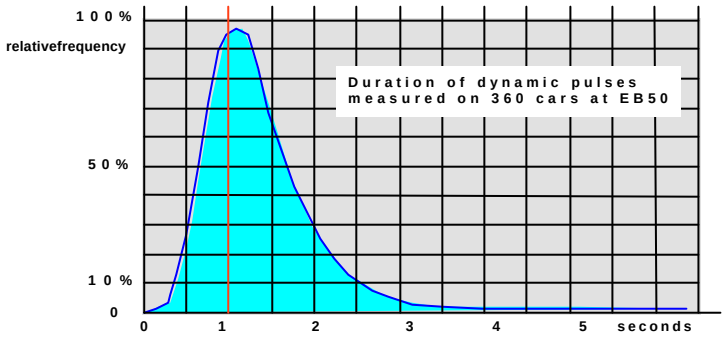
*C. Diem, Dynamic glare, AFS-research report FO-xx/98, TU-Darmstadt, 1998*
*W. Adrian, Transient adaptation process, CIE 22nd Session, Volume 2, 1991*

**FREQUENCY OF DYNAMIC LEVELLING CHANGES**



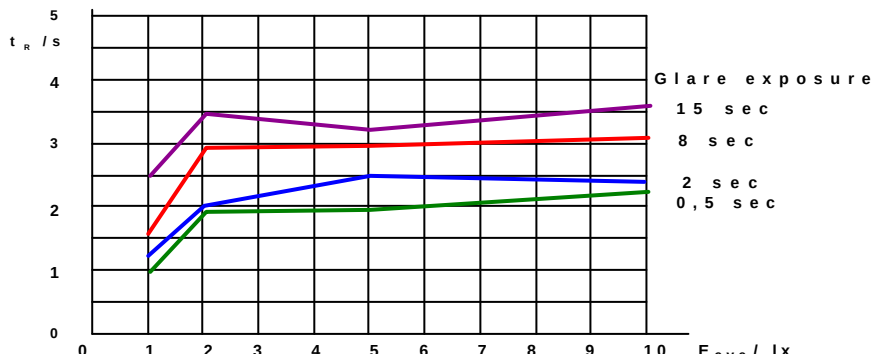

Also the duration of the glare impulses was found to be rather short, in average one second and hardly exceeding 3 seconds (during accelerations).

**DURATION OF DYNAMIC GLARE PULSES**




The investigation on re-adaptation time after a driver had been exposed to such glare impulses showed, that the re-adaptation time for glare intensities exceeding the normal 2 lux on the 25 m - screen in eye direction (or 1250 cd per vehicle with two headlamps) was practically independent of pulse duration and glare intensity.

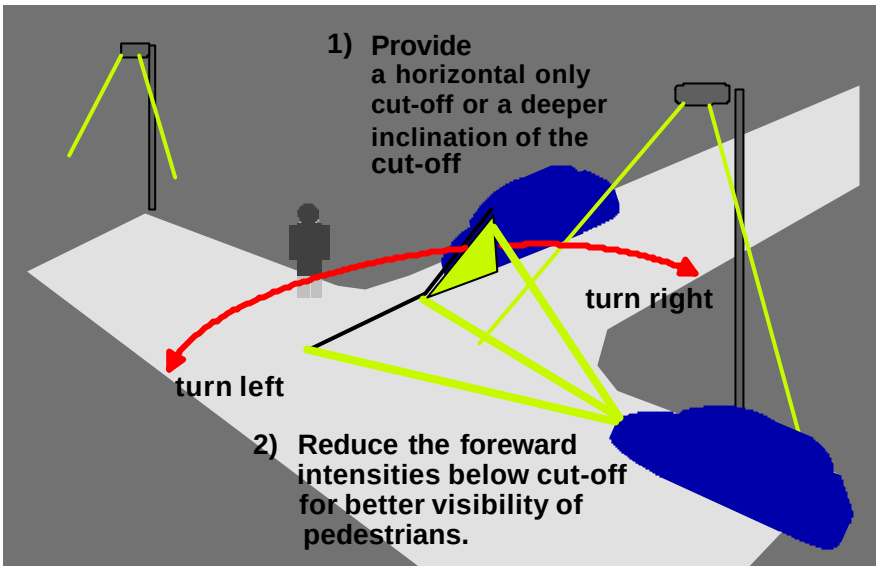
**RE-ADAPTATION TIME FOR GLARE IMPULSES OF DIFFERENT DURATION AND INTENSITY**




Dynamic glare impulses, if exceeding the static glare of 625 cd per headlamp, have thus no additional effect on visibility and can be disregarded.

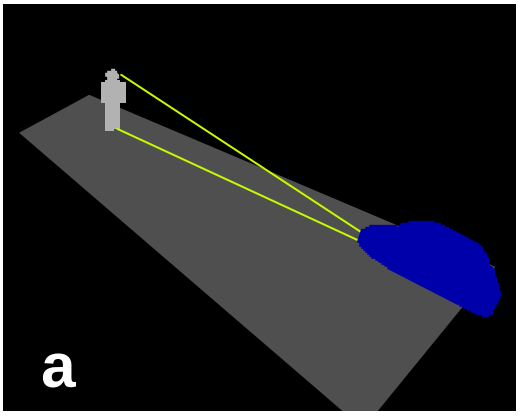
### 2.7 Glare reduction and visibility improvement under public lighting conditions

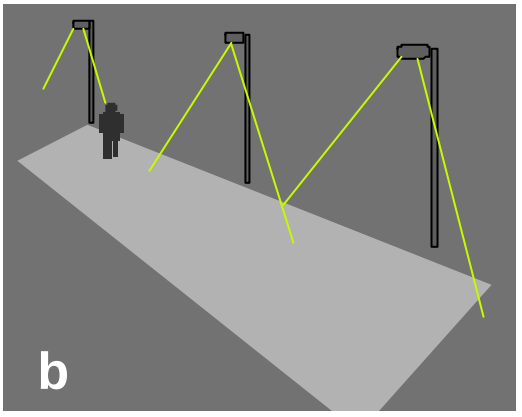
An other glare aspect occurs in towns and generally on illuminated roads, particularly on crossings with traffic lights. When cornering to the right (with right hand side traffic) the asymmetric light distribution of the passing beams strikes the eyes of drivers in waiting or approaching vehicles coming from the right. When turning to the left, the asymmetric part of the beams passes through the eyes of opposing drivers.



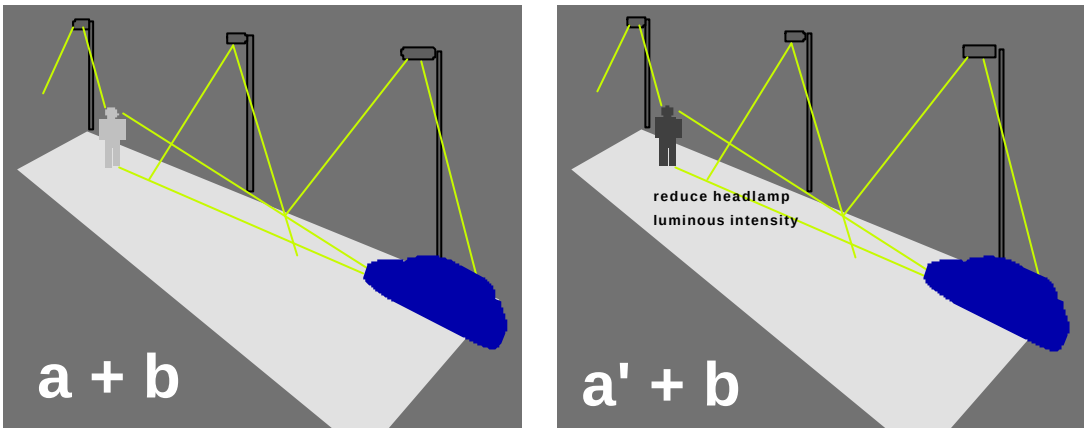

This is a known inconvenience that could easily be overcome in towns with special town lights that act as signals without contributing to the illuminance of upright obstacles (see below) or with passing beams that have no asymmetric but a horizontal cut-off.

Besides the glare effects in towns, the visibility of pedestrians earns special attention when driving on roads that have public lighting. Under rural conditions at night and when no public lighting is present, the road illuminance is relatively low but high illuminances prevail on upright obstacles such as pedestrians. Such obstacles become thus visible in positive contrast, bright against a dark road and environment (see picture "a" below). Under public lighting condition the situation is quite different. The light distribution of luminaires for public lighting is such, that the illuminance on the road surface is high, whereas the illuminance on upright obstacles is low. This is reason why obstacles are seen in negative contrast, dark against the relatively bright road and road environment (see picture "b" below).



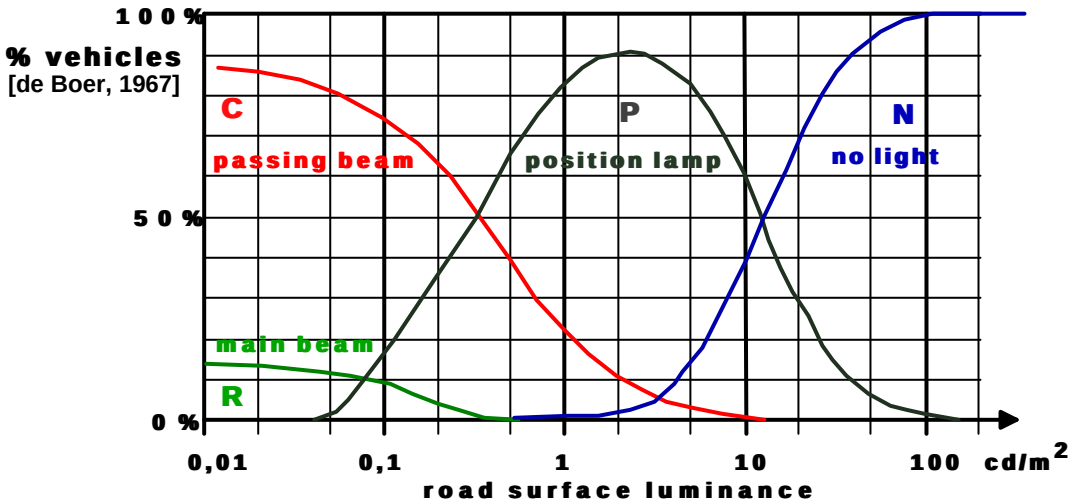




However, when vehicles with passing beams drive on illuminated streets, the positive contrast due to vehicle lighting and the negative contrast due to public lighting compensate each other, resulting in contrasts that are near to the threshold such that these obstacles cannot be discerned against their background (picture a + b). For this reason the intensity of vehicle front lights should be reduced as is schematically shown below (picture a'+ b).




Already in the 50th, as a remedy against reduced contrasts and visibility of obstacles, many European countries (under else France, Belgium, Netherlands) had a national legislation that required the use of position lamps when driving in towns. However, since the position lamps showed great differences in intensity (from 4 cd to over 50 cd), the judgement of vehicle distance was somewhat arbitrary. In addition, not all roads had public lighting installations that provided sufficient quality. This situation caused the EC to require the use of dipped beams in towns and make this one of the first European laws that was also incorporated in the Vienna Convention. Later in the 90th, the United Kingdom introduced a "town beam" with reduced intensity by national law. This, again, was overruled by EC-Directives for European vehicle approval, particularly by the mutual recognition of such approvals that did neither specify nor allow such devices.

Within the framework of AFS with adaptive front lighting performances, it became possible to address this "town lighting" issue again as an option. The question, however, remains, what is good enough public lighting that does not need support from headlamps? In the early 70th, when driving with position lamps was still allowed, an inventory was made how drivers applied their own vehicle lighting.




J.B. de Boer, Public Lighting, Philips Technical Library, 1967

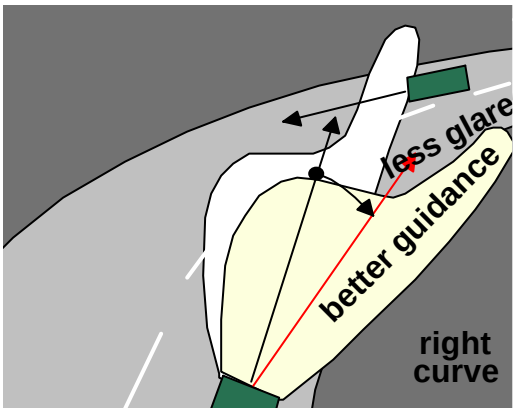
This made evident that with road surface luminances greater than 2 cd/m$^2$ , drivers judged to see well enough and used either no light or only their position lamps for being seen. Between 2 and 0,5 cd/m$^2$ the situation changed. An increasing number of drivers felt it necessary to improve their visual conditions by switching on their headlamps. Today, public lighting installations are all switched on when the surround lighting levels are as low as 20 lx or when the road surface luminance is 2 cd/m$^2$. Moreover, the requirements for public lighting demand 2 cd/m$^2$ for main traffic roads.

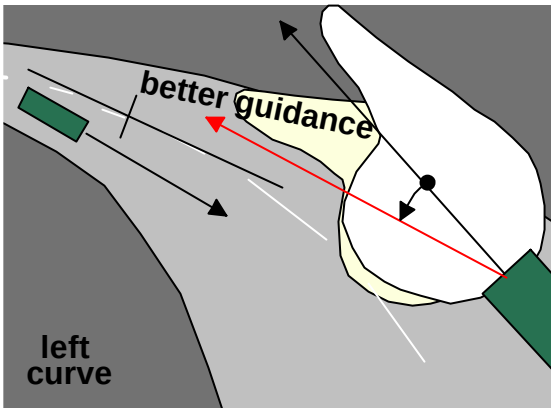
The AFS class passing beam for use on illuminated roads gives no strict requirement but yields the allowances that when sensors can detect that the vehicle is driving in a town area or under public lighting conditions, the front lighting may have either a horizontal cut-off, a lowered inclination of the cut-off and reduced intensity. For public lighting conditions these posibilities give an improvement with respect to both, visibility and glare, even under inferior road lighting qualities that prevail in residential areas. Moreover, when road lighting levels can be measured from the vehicle, these measures can be optimized within the range of specified allowances.

### 2.8 Glare reduction and visibility improvement in curves

The bending lighting by swivelling the headlamps in the direction of the change of movement has already been addressed and forms part of the proposed amendments to Regulations No.48, No.98 and No.112 that wait for approval by WP29./AC1.

The following sketch only illustrates the advantages under condition that the swivelling does not cross the road centre line at about 60 m distance (respectively. 100 times the mounting height of the headlamp). If this is respected, the drivers' visibility is improved by better visibility of the road and delineations on the right or respectively the left curb side. Also glare towards opposers is considerably reduced when driving in right curves, and not increased when driving in left curves.



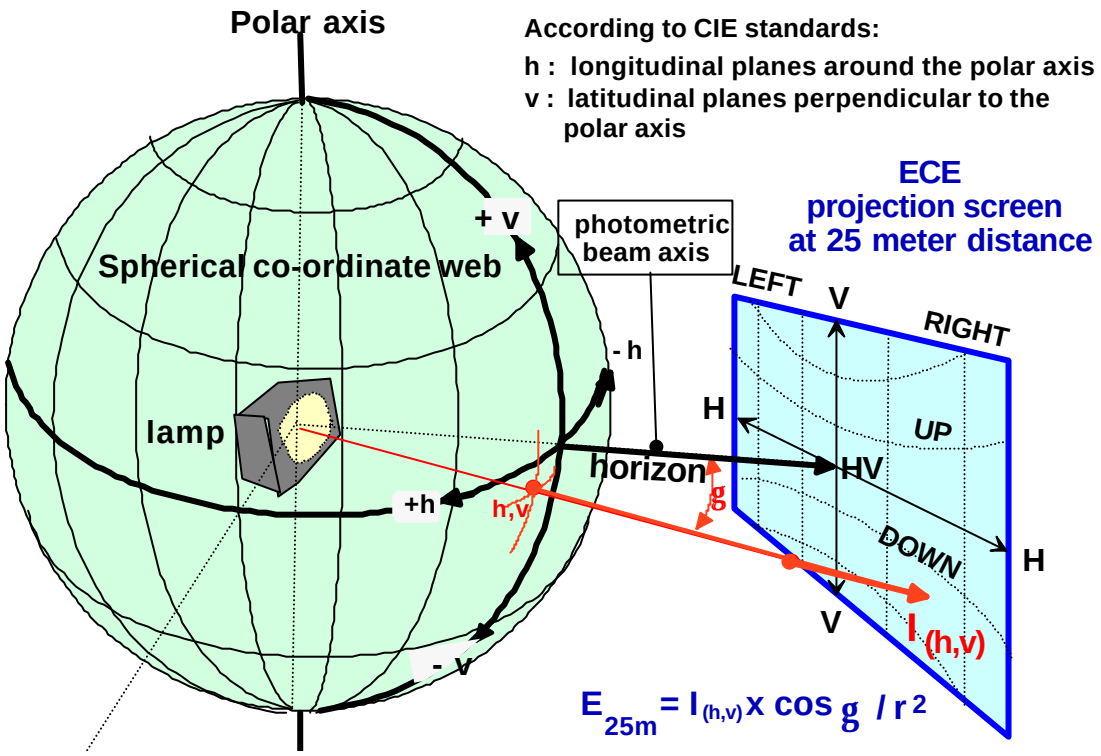

With the fundamentals and findings being addressed in chapter 2, the visibility and glare can obviously be improved for typical situations and environmental conditions of road traffic. For AFS corresponding classes of passing beams are defined and requirements given in the photometric tables.

# 3. Photometric requirements

## 3.1 Co-ordinates for headlamp photometry

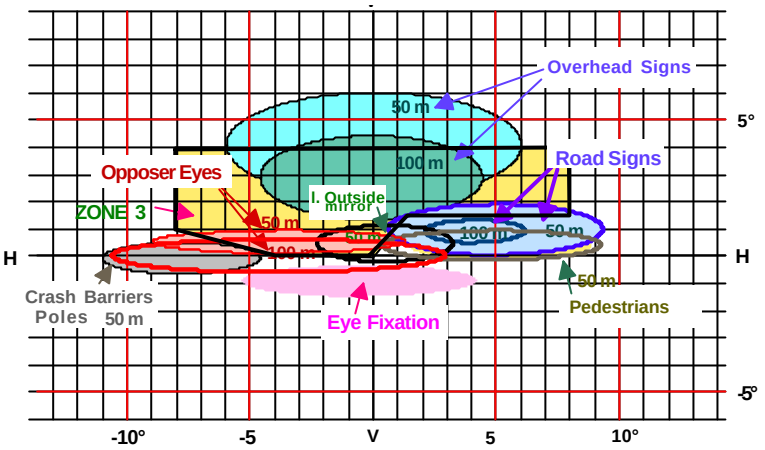
The positions of the measuring points and lines in the photometric tables are indicated in spherical co-ordinates corresponding to the angular webs for signalling lamps. The luminous intensities are not expressed in candela but in illuminance values at 25 m (abbreviated in this document as lx@25m). This corresponds to common measuring practice with gonio photometers normal to the direction of light radiation. This comprises a minor difference to measurements normal to the projection screen as earlier used at greater angles because of the cosine correction that has to be applied when measured normal to the screen.

The values in the photometric tables directly correspond to luminous intensities as being specified in US and Japanese requirements. To find the luminous intensity in cd the factor 625 (the square of measuring distance) is to be applied to the listed illuminances in lx at 25m.



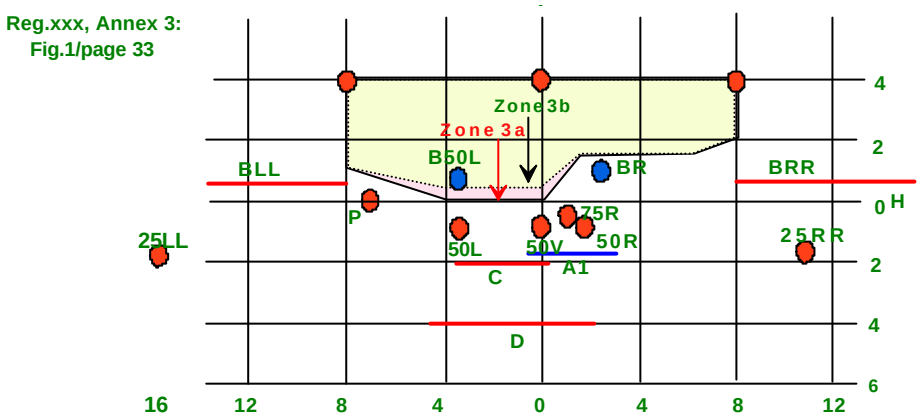

## 3.2 Specified values in the photometric tables

The requirements differ from earlier photometric requirements for passing beam headlamps. The basic passing beam mirrors the findings above in chapter 3 and 4 in combination with the improvements as specified by GTB for the harmonised passing beam. An exception form the glare values that are still based on earlier ECE regulations, because of the needs for comfort when driving on dual carriage roads. This is explained in detail above under the chapters 2 and 3. The position of the measuring points is such, that they represent an average or crucial position in relation to the targets of illumination. The statistical occurrence has been investigated by Damaski (1995). The appearance of these targets relative to the position of headlamps is given in the diagram below for positions at 50 meter and (for some targets) at 100 meter, too.

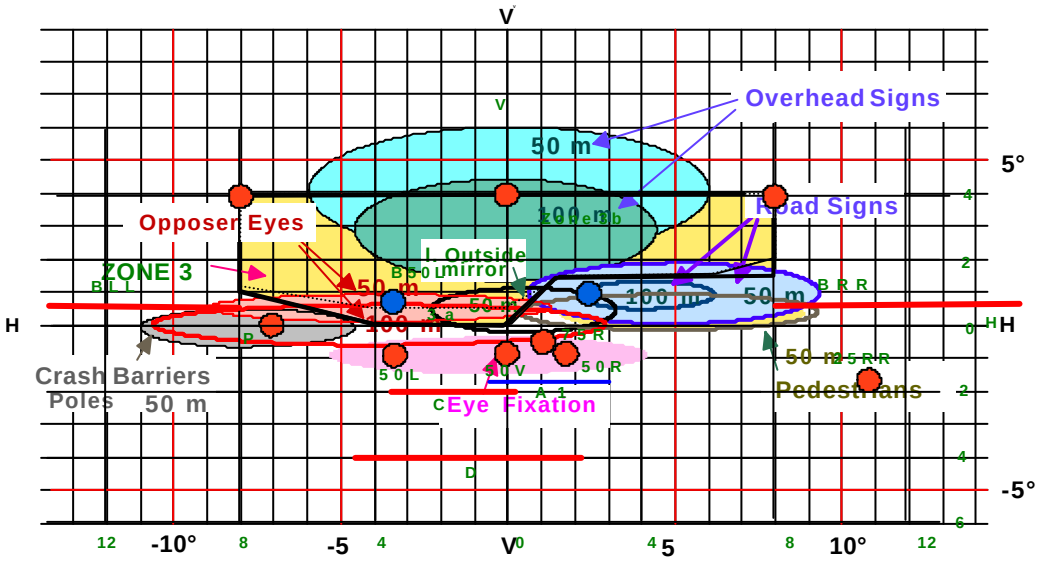



*J.Damasky, Anforderungen an Kraftfahrzeugscheinwerfer, Thesis D17, TU Darmstadt, 1995*

The photometric requirements are given in detail in the tables and summarised in figure 1 of Annex 3 of the AFS draft Regulation as shown below.

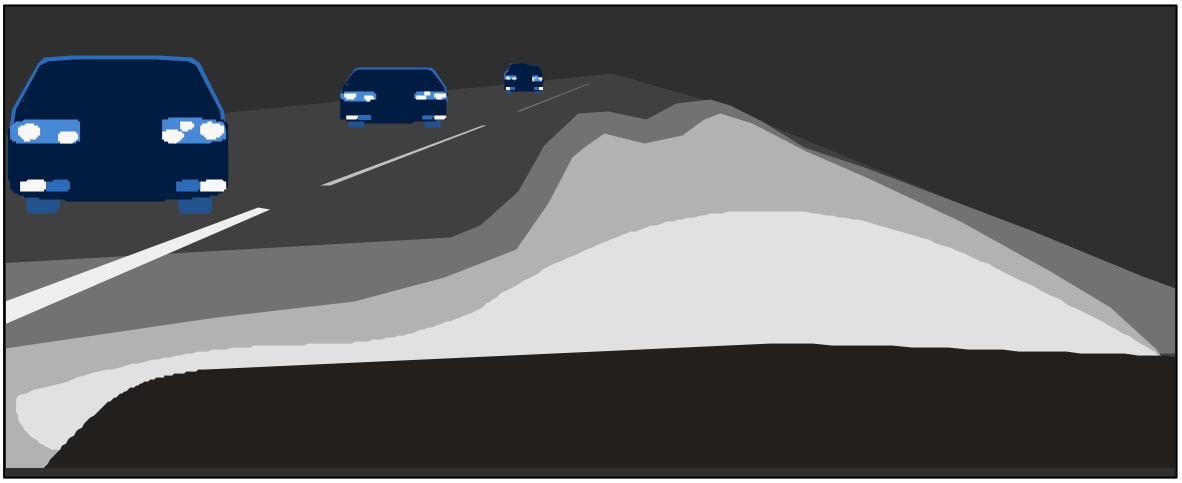



An overlay of this figure on the diagram of statistical occurrence shows the coincidence of the chosen and important measuring points with the targets that are to be illuminated or where lower limits are to be respected. The luminous intensity values correspond with those derived from research and tests as described in chapter 2 of this report.

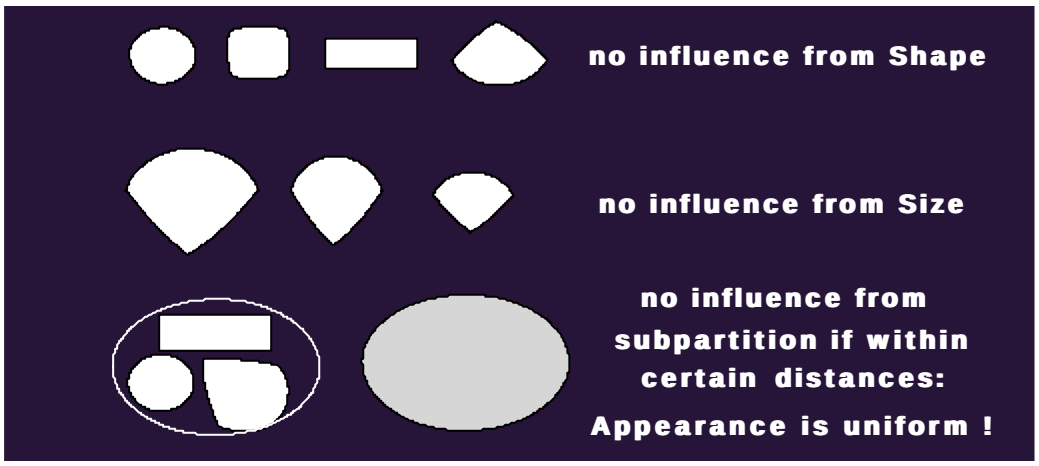


## 4. Vehicle appearance at night

When headlamp performance has to be adapted to various road and weather conditions, it is obvious that such an adaptable "passing beam headlamp" will consist of more than one lighting unit per vehicle side as compared to conventional headlamps. In particular cases such as in curves, the number of activated lighting units may be uneven and not fully symmetric relative to the vehicle median. For pedestrians, however, as for other road users this may not lead to misunderstandings. A four wheeled vehicle must appear and be recognised as a four wheeled vehicle.



For this purpose a thorough investigation on the vehicle appearance for pedestrians and other road users was done by IENGF in Milano. In parallel the AFS tests included such arbitrary configurations that confirmed the findings of IENGF.




*P.Soardo,Rossi, Iaccomussi, Recognition distance and appearance, IENGF, Milano, 1999*

1) differences of shape were found of no influence on appearance.
2) Differences of size had also no influence when the intensity ratio between the left and right hand side of the vehicle towards the observer did not exceed a factor of 10.
3) The clusters of lighting units appeared as one single unit when certain distances between the activated lighting units in horizontal and vertical direction were respected.
4) It was found, however, that the distance of the nearest symmetric lighting to an asymmetric lighting unit (when present on only one side of the vehicle) needed to be smaller than was the case for symmetrically placed lighting units. In order to maintain the accustomed appearance of a vehicle, the separation between the lighting units on the right and left side of the vehicle should be at least 400 mm.

These findings were implemented under the special AFS requirements in Regulation No.48 (see figure on page 7 of TRANS/WP.29/GRE/2002/20).