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## Department of Lighting Technology

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# Lighting Performance Requirements in Vehicle Lighting Exemplified by System Requirements for AFS -

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**HELLA KG Hueck & Co., Lippstadt**

## Lighting Performance Requirements in Interior and Public Lighting.

When early this century first lighting requirements were normalised, preference was given to specify and classify the photometric characteristics of the luminaires and to give simple recipes about their arrangement. For public and interior lighting, this practice was left already in the 40th (in UK in the 60th) and replaced by illuminating requirements for the space to be illuminated. The way and with what means this had be done was left open, except that in directions where glare could be expected, the maximum luminous intensities of the luminaires were specified. In the 60th additional qualifying specifications were introduced to improve comfort and visual performance. They were based on luminance in the field of view - the only what is pictured in the human eye and as such seen as visual environment. In Interior lighting this lead to specifications on modelling or agreeable "room and object appearance" by the spatial ratios of incident light and it also lead to luminance requirements and classes of luminaires for normal directions of view but also infield vision of the luminaires themselves. In public lighting the road surface luminance and its uniformity (in dry condition) was introduced. Because of the mainly extra- foveal appearance of luminaires in the field of view of drivers, glare was specified in terms of eye illuminance and this again is transformed into limited intensities of luminaires for specified directions towards the traffic flow. These changes have not only improved the visual comfort in interior and exterior lighting, they have also considerably widened the freedom of design of lighting installations allowing great variations in arrangements and technologies in interior as well as in public lighting, e.g. catinary lighting for public roads where fog prevails or floodlighting of complicated intersections or 6 and 8 lane roads. Subsequent

new technologies and designs could be applied without the necessity to change requirements. One can say, that these fields of lighting application have settled in terms of performance requirements independently of and including further technological progress.

**Practice in Vehicle Lighting Requirements**

None of this changes entered into vehicle lighting requirements and still today the functional lighting devices are individually specified with respect to their spatial luminous intensity distribution and restrictive specifications on apparent shape and mounting on the vehicle. This seems partly to be justified by the fact, that all mandatory vehicle lighting devices form together an information system, providing information on presence and changes of movements of vehicles in the traffic flow. It seems however not justified where it concerns the front lighting performance. For front lighting not only different practice has developed in USA and Europe, but - in the absence of clear performance requirements - many if not most of technologic developments in light sources and lighting technology have caused and are still causing adaptive changes of regulations before such more economic or better performing technologies become applicable. This is equally the case for signalling devices. It is a rather sad experience of the regulators of being steadily kept on-work for amending old items while new issues have often to wait for treatment. This resulted in the expressed wish of WP29, that vehicle safety requirements be preferably formulated in terms of functional performance rather than specifying constructional or material characteristics of devices.

In the 80th NHTSA tried to introduce front lighting performance in terms of spatial illuminances - but struggled on the proposed measuring concept. The AFS project is again aiming at adaptable front lighting system performance in order to create more possibilities of complex and integrated designs than the more conventional concept were NHTSA had strived for. AFS will obviously encounter more problems in finding an adequate and - from traffic point of view - a "safe" method for performance and approval testing of such systems before and after such AFS systems are installed on vehicles. Before tackling this challenging issue of the future, allow me some more remarks on the past.

## From Branching National to Harmonised International Requirements.

It is for sure, that national regulations have been for long a political issue of protecting national interests. But, the still existing differences in Regulations have also a sound basis in differing technology and traffic practice. Today, with globalising markets, such differences are disturbing and international "harmonisation" has become a key issue - but on which premises ? Averaging regional standards which are both good practice in order to become one single requirement may sound simple - but it is definitely not a wise way as I will show you.

## Existing Headlighting Practice in Europe and USA

Although different technology with in Europe shielded bulbs and in the United States sealed beam headlamps have caused a difference in photometric properties - in Europe with a defined cut-off but low utilisation of luminous flux, in the USA with higher values above the horizon for longer reach on the own traffic lane and with higher utilisation of luminous flux. It was primarily the different traffic environment which had caused this different choice which in both cases is sound and most adequate.

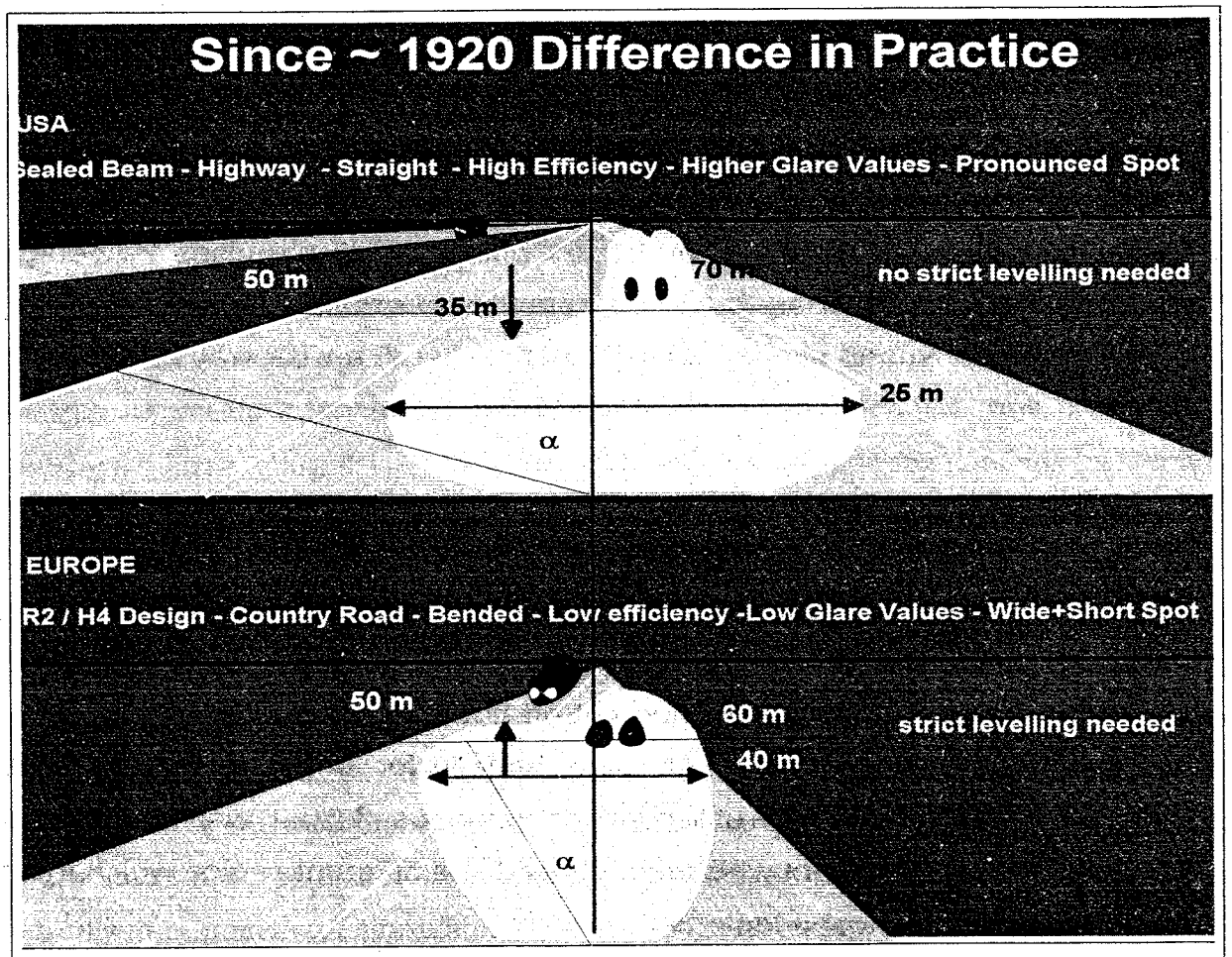
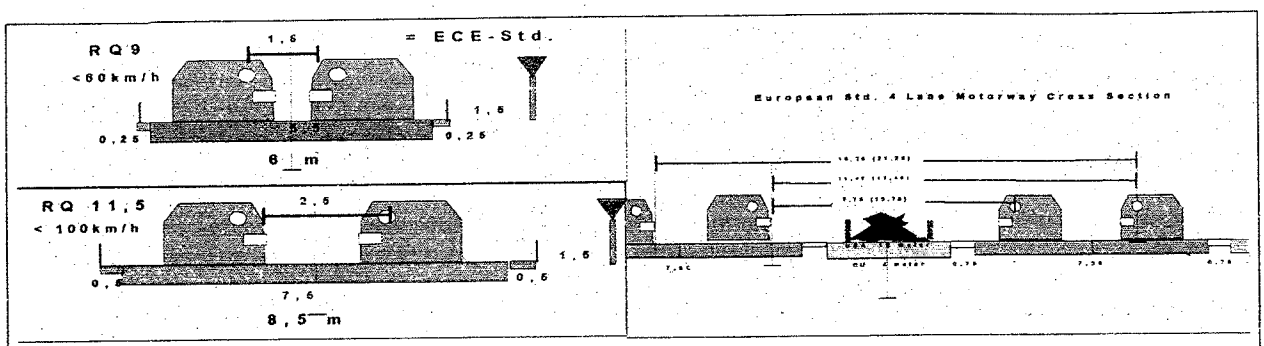



***Fig. 1.1 European Practice Based on 6 m Rural Road Compared to US Practice Based on Highways with Separated Lanes***

Between Europe and USA a principal difference exists (Fig.1.1). In Europe most of the traffic flow and of accidents is concentrated on country and urban roads, where mot fatalities occur - highways with separated lanes were most safe in terms of accidents and still are today. In USA most of the traffic flow was concentrated on Interstate and similar highways with separated traffic lanes, and this was also the case in urban areas. If we look on the main difference and struggles of harmonisation - glare values - it becomes evident that from local practice point of view, no difference exists. Why? - Both, discomfort and disability glare, depend strongly on the peripheral angle under which glare sources appear in the field of view. The central reserve of highways as compared to rural dual carriageways enlarges this "glare angle" and in consequence allows for the same discomfort a glare intensity at a given

distance twice the value (for disability glare more than ten times the intensity would be equivalent). On the other side, the higher speed on highways demands for a longer visibility reach than on small and curvy rural and urban roads, which have also speed limitation (see Fig.1.2). Both practices were evidently well defined and most adequate - but, an average of two practices would harm the visual performance in both cases, leaving less reach on highways and introducing great dazzle for opposers on small rural and urban roads. The solution in this conflict is either to combine the better parts of both - low glare values and far reach - or to define highway lighting different from that of dual carriage roads. The one way of approach is covered by the progress in harmonisation, the other is incorporated in the AFS philosophy. It would be wrong, however, to see AFS as an alternative to harmonisation - AFS includes the possibilities which harmonisation offers but it goes a step further in offering alternative possibilities on top.




| | | | | | |
|---|---|---|---|---|---|
| Side Distances | 1,5 | 2,5 | 7,70 | 11,50 | 15,25 |
| Eye to Headlamp | | | | 13,70 | 17,50 |
| | Rural and Urban | | | Motorway/Interstate Highway | |

**DISABILITY GLARE**

Schmidt-Clausen/Bindels 1971

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

$$I_1 / I_2 = (\Theta_1/\Theta_2)^{2,0}$$

**DISCOMFORT GLARE**

Schmidt-Clausen/Bindels 1971

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

$$I_1 / I_2 = (\Theta_1/\Theta_2)^{0,46}$$

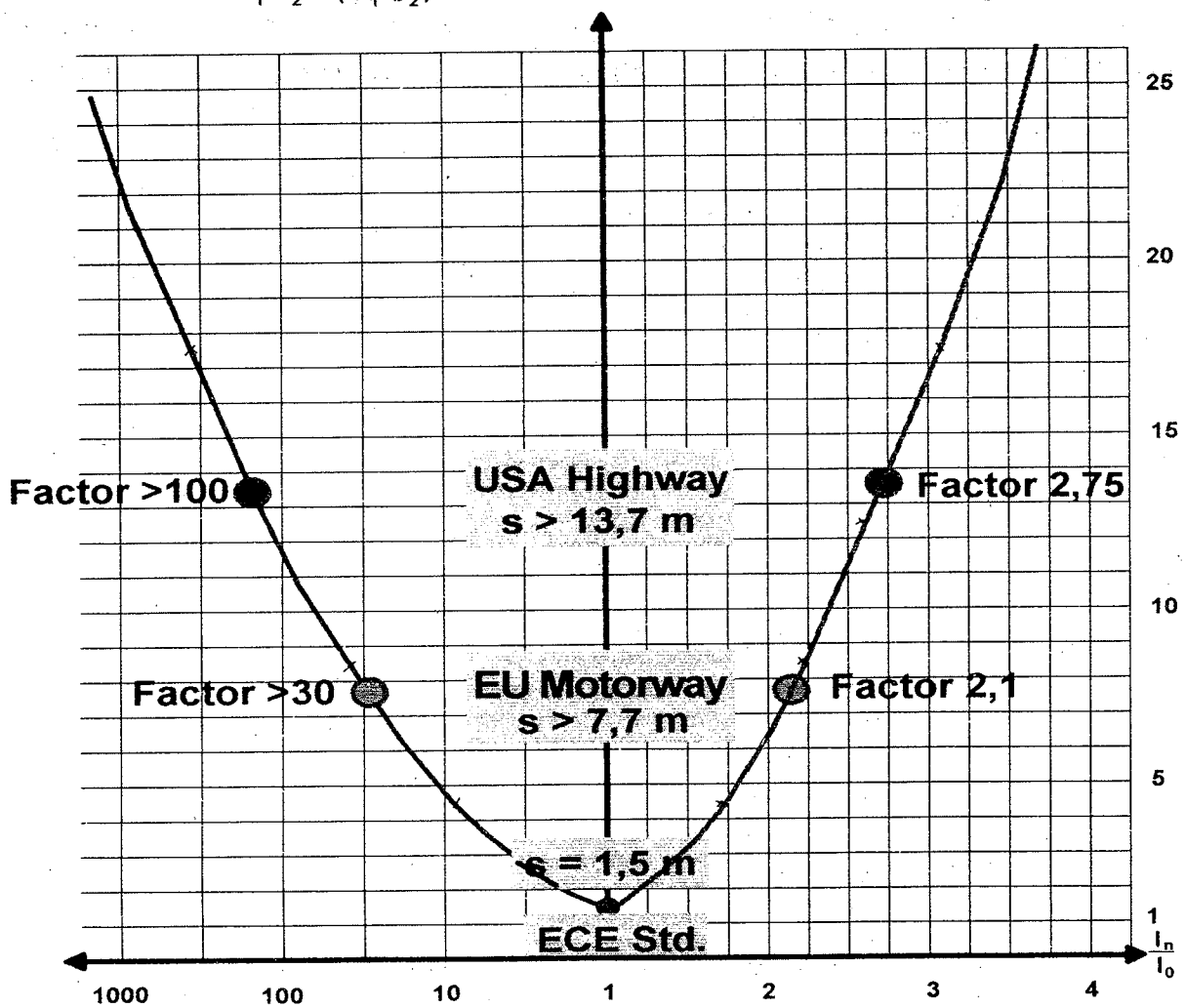



*Fig. 1.2 Luminous Intensity Ratio for Equivalent Glare on Motorways relative to the ECE Rural Standard Road*

## Overhead Sign Lighting

This is also a field of divergence where something needs to be done to solve the problem without introducing unfeasible requirements in Regulations or detrimenting visibility for 99% of cases in order to satisfy the 1% of occurrence of overhead signs which again are dominantly on highways only and scarcely on rural roads. What is the problem here?

Overhead signs appear in the zone where low luminous intensities are specified in order to protect from excessive glare. Such low glare intensities are not directly calculable but result mainly - beyond strict screening and optical control of direct and reflected light being emitted - from biasing secondary and non-controllable spread light such as reflexes from lead wires, coil and bulb reflexes and from inter-reflections of higher order on curved glass, prismatic edges or interreflecting parts of reflector and housing. If in order to illuminate overhead signs the spread light is not only to be avoided but has purposly to be designed to be repeatably and quantitatively present (CoP), this is contraproductive to the glare values and makes them rise (Fig.2).

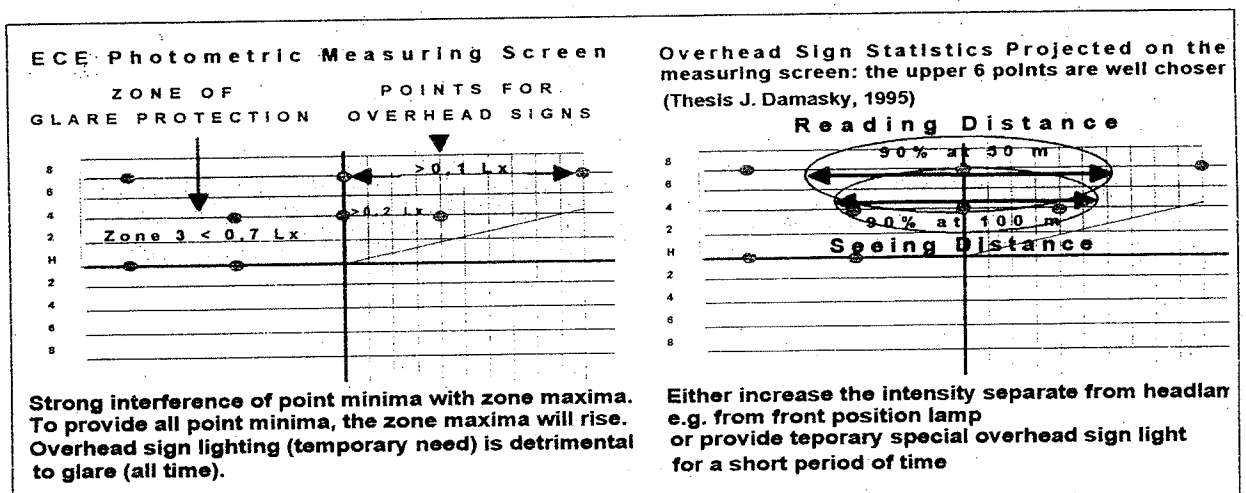



***Fig. 2*** ***The temporary usefulness of overhead sign lighting interferes with the need of continuous of glare protection by rising the glare values - this conflict needs a more adequate solution.***

Grouping the point values for overhead sign lighting as being proposed is one possibility to cope with statistics of biasing spread light. A special illuminating source for overhead sign lighting would be an other, more adequate solution. In the latter case account of, or even rising the luminous intensities of front

position lamps may be the solution, or introducing a special fixture which is designed for temporary use as an overhead sign light. Any other way is no solution but a conflict relative to glare protection or overhead sign lighting introducing risks of non compliance or even lies which can not be the purpose of any regulation. In this case again, AFS offers such possibilities which perform properly - but also the most recent proposal for harmonised dipped beam lighting enhances such a possibility.

**The AFS Concept**

Both examples show clearly, that a move into system performance requirements would be a wishful way not only to escape continuous amendments and corrections of regulations with any new technological progress, but also to support a more general trend for improved active safety by creating and leaving a choice for higher front lighting qualities, which do not interfere with but just extend existing lighting practice to a higher level of performance for common adverse situations. The problem lies not in missing knowledge, what should and can be improved, but how a variable and as such adaptable lighting performances can be checked on proper functional performance and be approved in a similar way as is today's' practice.

Already in the sixties first approaches towards a performance approach with multiple use of overlaid beams was made (Fig.3) - but abandoned because of the non- reproducibility of the necessary filament and positioning precision - at that time.

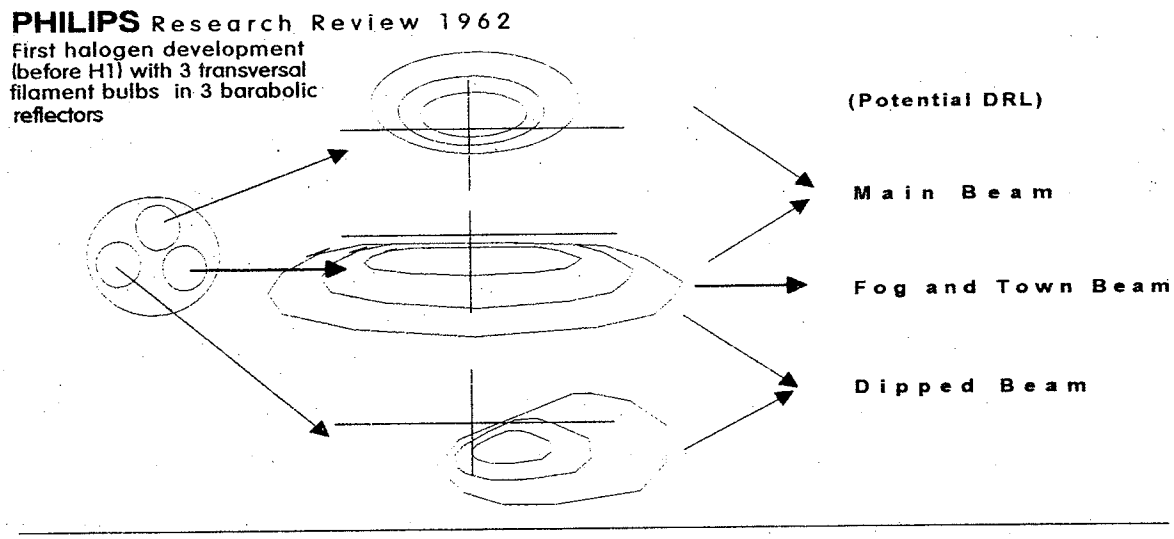



***Fig. 3 Concept of integrated headlamp design dating from 1962: 4 to 5 lighting functions are enabled by three lamp devices. The concept was abandoned because of inaccuracies.***

But today, and looking in other lighting fields as we did, we find examples how performance could be traced on measurables. Primarily, the vehicles' lighting - such as it results from all lighting devices working together and contributing to an intended lighting task or function - must enable proper visual task performance for the driver, and, secondly, the appearance of the lighting units (in luminance and luminous intensity) and their configuration on the vehicle must be recognised as an approaching vehicle but not produce dazzle or inconvenience for other road users. Since both aspects can be traced back on the active components of the system. By neglecting the lesser importance of parallaxis, the measurement of photometric performance would be most easy, be it not that the system performance is variable with the surrounds and triggered by sensor signals which are representative for these ambient conditions: whether the road is wet or dry, whether the vehicle is driving straight forward or in a curve, on a rural road or on a highway. This implies two problems. One is the quality of the sensor signal, which can be simple (wiper of front windows "on", steering angle of front wheels or speed of the vehicle) or rather sophisticated (digital GPS information on actual road curvature, information on distance of preceding or following vehicles etc.). These sensor signals and their "automatic" impact on control of vehicle forward lighting has to

adapt the lighting performance to the traffic conditions and to prevent from deteriorating glare effects for other road users. As long as lighting performance contains and maintains a minimum lighting quality which is comparable to actual requirements, the first issue of road illuminating performance should form no problem. It could, however, become a problem if during (or as a result of) performance changes the glare values rise above the valid standards. Both these performance effects have to be checked during approval testing. Moreover, and in view of the dynamic of lighting performance, a fail safe requirement is indispensable which allows a safe continuation within the traffic flow or leaving it, and which avoids excess glare towards opposers - all under provision that the driver is attended to the occurrence of a system error.

Thus the active lighting performance can be traced on measurables and corresponding checks be performed in laboratory conditions if the varying lighting performances are varied the same way as vehicle sensors and switches will do this later on the vehicle. Equally all interrelations between active system parts which are visible to other road users can be checked on their merits of marking the vehicle as such by tracing it to the mutual dimensional and - where necessary - luminance aspects as being intended to be used on the vehicle.

After the system has been approved on its performing aspects by simulating the vehicle controls, the final operation on the vehicle has to be verified, whether the signals behave as was simulated (as used in the simulating device) and whether the mounting positions as foreseen in the system description are adequate.

In principle, the variable performance of systems can be traced on photometry and system controls - but, as always, the devil may the hidden in the details and here the AFS development is progressing and analysing such possible details which could cause unsafe conditions and how to overcome them. This is the actual state of how performance requirements can be established for such a complex matter as an AFS system. The possibility to cope with complex performance requirements brings us back to the starting question: which are the functions and varying performances where AFS is aiming at.

## The Function Tree of AFS

Basically there will be passing and driving lights between which the driver is switching and there will be front position lamps and day time running lights. The difference starts with the directive that the photometric result in performance and appearance counts and not the <+">means <-">how such a performance is physically created - thus leaving more freedom of design and technologic development. The next difference exists in automatically controlled (or timely switched) photometric characteristics which adapt the lighting performance to the visual needs in typical ambient and driving conditions

- driving at night, at day or approaching a tunnel,
- driving on a rural, urban or an express road,
- driving straight forward, in a bend or turning-off the road,
- driving in clear weather, on wet roads, in fog, heavy rain or snowfall,
- approaching an overhead sign, which also today with few spread light of some 60 cd only can easily be seen on great distance - but not be read.

All these special conditions ask for different lighting performance of the passing and even the driving lighting. In the context of AFS they are abbreviated AL for adverse weather lighting, BL for bending light, CL for country road lighting, TL town lighting and ML motorway lighting and accomplished by OVL overhead sign lighting.

As the new proposal for a harmonised dipped beam or for a harmonised front fog lamp already shows, the appropriate lighting of road kerbs and road bends can be effected by a wide light spread - but this needs more luminous flux and e.g. does not reduce glare in right curves, which a lateral movement of the asymmetric part of the beams could do with less power consumption, and this also applies to additional bending light . Such alternative possibilities which all improve the drivers or opposers visual performance in comparison to conventional frontlighting are included in AFS. However, it is left to the vehicle manufacturer, which one to choose.

A gallup report on driver demands in France, Germany, Italy and Sweden had shown that the major interest and need for visual improvements is seen in

adverse weather conditions, directly followed by visual improvements when driving in bends. Overhead signlighting, e.g. was not judged worth to spend any extra money and also motorway lighting gained no high priority.

Thus, let us concentrate on the situation when roads are wet and when it is raining. A major difference compared to dry roads is the strong forward reflection on wet roads of the light from headlamps. This makes the appearance (luminance) of the road surface rather dark but also causes, that vertical obstacles are more outstanding in positive contrast. The one would compensate the other, be it not that the road reflexes of headlights from opposing vehicles are so disturbing and veiling the recognition of the course of the road and of obstacles on or near the road. The responsible indirect luminous intensity to the eye via the road reflexes turn out to be much higher than the direct light from the headlamps. To improve the own vision and reduce the overall glare effects the beam pattern needs to be different - with laterally and longitudinally a further reach for better orientation, and with slightly increased direct glare but much less intensity to the most reflecting foreground, in order to minimise overall glare.

I will not go into too much details - this will be done by the speakers that follow and you will also have the opportunity - be it not to drive - but at least to see six test vehicles which have been used during tests and which all provide one or more AFS subfunctions in different ways. The systems being different in design were all were judged as a wishful step towards an improved traffic safety in conditions which are known to be prawn to stress and accidents. Not all test equipment and vehicles used can be shown, but what can be shown gives an idea for what AFS stands for.

**Early and Late Night Show of AFS cars at the Darmstadt Airfield**

Before dark the six test vehicles which were used during AFS driving tests and their AFS concept and properties will be shown and be explained by the sponsors by a poster and hardware demonstration. This will inform on the functioning and type description of the AFS subfunctions which are installed, including their photometric performance and their control. The organisation in groups and time is so arranged as to give everybody a chance to be adequately

informed and to get hopefully all the answers on open questions which may exist concerning the system.

When it is dark, all the vehicles will pass revue in front of the tribune to show their lighting performance and improvement for seeing the road course and obstacles in comparison to conventional headlights.

Pity enough, the two days' symposium leaves no space for gaining driving experience individually. The promised presence of the cars during the GRE meeting made it possible to bring them here too a week earlier. However, if you will arrange a test drive and do not participate in the GRE meeting during the week after the PAL Symposium, please contact the vehicle sponsors for an arrangement.

**Further Proceedings of the AFS Project**

The AFS Project started on third of June 1993 with - at that time - 12 manufacturers, which were interested in such an improvement program of active traffic safety. The challenge of such a system approach and the necessary and not so easy change towards performance and system requirements was clearly seen - but also the prospects of possible safety improvement. Meanwhile two phases - the feasibility and development phase - are finished (see Fig. 4). A lot of experience and information has been gathered by tests and research and all this knowledge has now to be transformed in a draft document which can serve as an entry in the process of rule making.

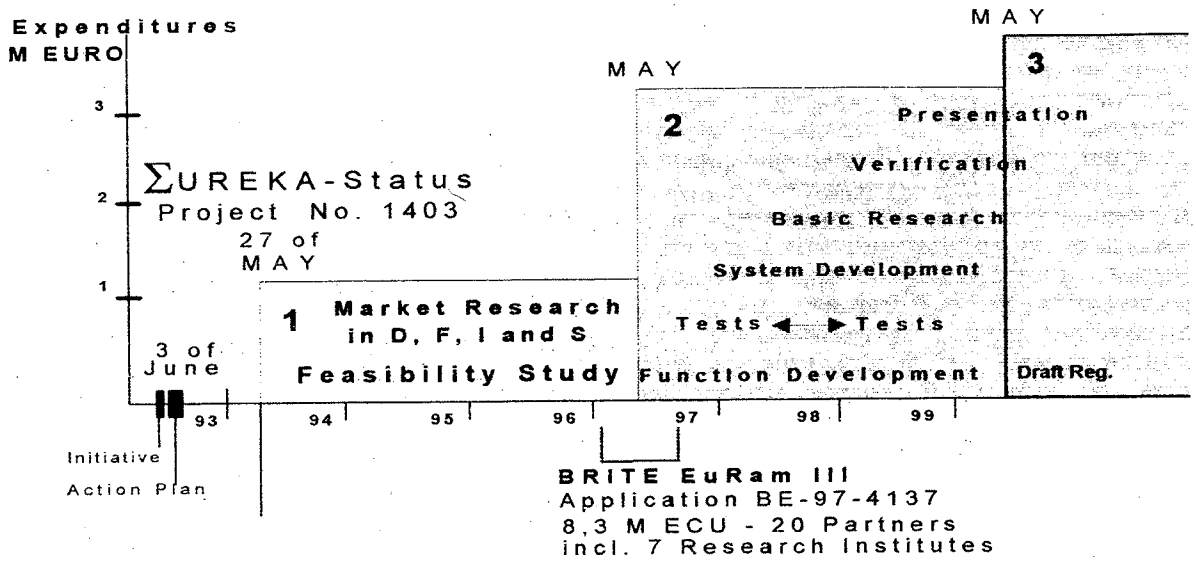



*Fig. 4 AFS PROJECT DEVELOPMENT - ACTIVITIES and COST*

In this last phase eighteen members stay behind the project in a rather global composition such that it is evident, that AFS is aiming at world-wide recognition of the requirements.

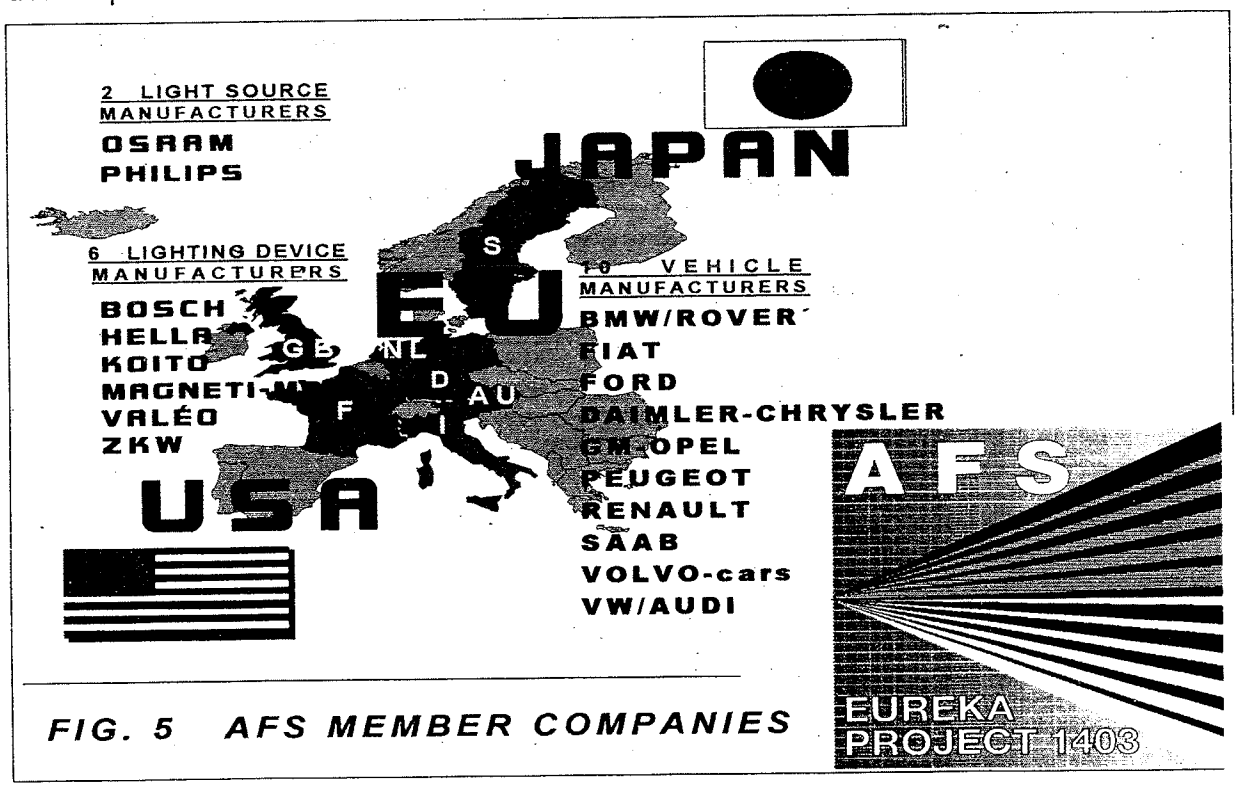



*FIG. 5 AFS MEMBER COMPANIES*