and more frequent in relation to the load as well as the acceleration and deceleration of the vehicles.

Real progress in the dipped beam seems now strictly conditioned by the possibilities of maintaining constant the accurate adjustment of the headlamps.

In the course of the coming years, one will inevitably witness a development and, let us hope, a compulsion to use automatic devices, enabling maintainance of this adjustment, both "statically," which means according to the load of the vehicle, and "dynamically," according to the conditions of acceleration or deceleration to which the vehicle is submitted.

In his paper, "Motorcar Vehicle Lighting and Self Levelling Devices for Headlamps," Pierre Cibié, specialist on this question, describes the problem and fixes the conditions for the automatic leveling devices (80).

HOW TO REDUCE OR SUPRESS DAZZLING

The dipped beam, a modern development of Bossu's original idea (beam B), aims to reduce the dazzling caused to the oncoming drivers by endeavoring to limit, as strictly as possible, regions which, on one hand, must be illuminated to allow a clear vision of the obstacles and which, on the other hand, must be maintained as dark as possible in order to avoid dazzling.

This is an optical problem which must ensure a "space selection" and which was mentioned previously. The nondazzle research was not limited to this "space selection." Many other aspects were thought of: the chromatic selection, the temporal selection, and the physical selection.

The first case is related the use of the selective yellow light, the second case to the interrupted light, and the third case to the polarized light.

SELECTIVE YELLOW LIGHT - Only the first solution was the subject of a total practical application, as it has been since 1936 absolutely generalized and compulsory in France with the exclusion of all others.

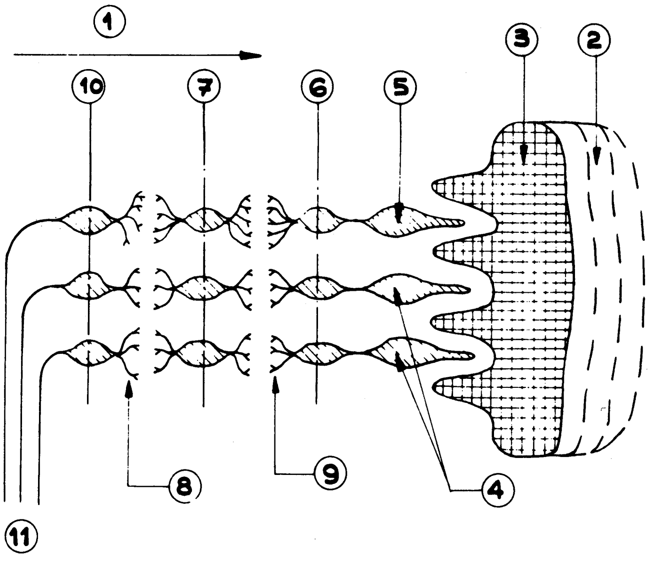

Fig. 10 - Cones and retina rods. 1.- Light direction, 2 - Choroid, 3 - Pigmentary epithelium, 4 - Retina rods, 5 - Cone, 6 - Cellular bodies first neurons, 7 - Bipolar cells (neurons) first condensation zone, 8 - About 6-10 bipolars, 9 - To about 4-20 visual cells, 10 - Multipolar neuronic cells - second condensation zone, 11 - Axones (optic nerve)

Its study and application have raised many discussions. There exists on this subject an important literature (29-41), and we shall only recollect the principal points.

The visual impressions result from the excitement of two types of receivers: the cones and the retina rods. The cones constitute the central part of the eye or fovea and, each being connected to a distinct and thin fiber, particularly ensure the shape's discrimination (Fig. 10).

The retina rods compose the peripheral part of the eye or perimacula and particularly ensure the color perception and evaluation of intensity.

In the macula, between the fovea and the perimacula, a mixture of cones and retina rods meet, where the number of the latter grows as one moves away from the fovea (Fig. 11).

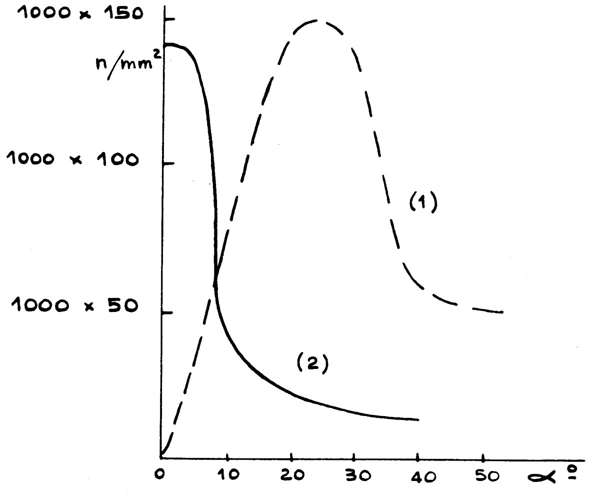

Fig. 11A - A number of retinal elements n by mm^2 in terms of the angle α of the retinal region with relation to the foveal center. (1) for the rods, (2) for the cones

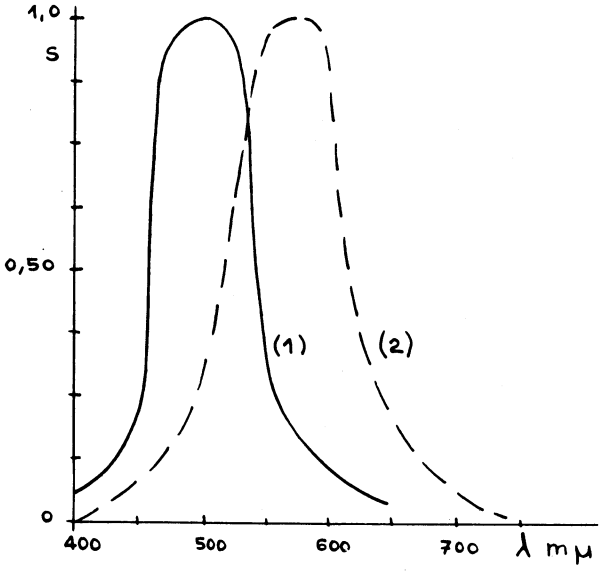

Fig. 11B - Relative sensitivity s in terms of the wavelength of the light radiations, (1) for the rods, (2) for the cones

The cones are sensitive to long wavelength radiations or red band; the retina rods are sensitive to the short wavelengths or blue band and are practically insensitive to the red band.

Under the influence of a dazzling light, the retina rods sensitivity can be reduced to 1/10,000th of the normal sensitivity, whereas that of the cones is at most reduced to 1/10th. After disappearance of the source of dazzlement and rest in darkness, the cones regain their normal sensitivity after a relatively short time, whereas the retina rods recover only gradually. The readaptation to normal vision is only complete when the retina rods have recovered the integrity of their function.

In order to decrease dazzling, it is therefore of interest to withdraw the retina rods, which are the most fragile receiving elements, from the short wavelength radiations to which they are particularly sensitive.

The study of the photochemical reactions led to the same conclusion. In the darkness, the external segments of the retina rods are loaded by a red matter, called the retinal purple, which turns yellow when the eye is submitted to the influence of a bright light. This retinal purple can only be restored after the disappearance of the source of dazzling, probably due to the blood rush.

According certain authors, the curve of the absorption power of the retinal purple presents a maximum for radiations of a wavelength nearing 0.56 micron; that of the retinal yellow, which is very little different than the previous one for radiations of long wavelengths, indicates, on the contrary, a power of absorption practically nil for the blue and violet radiations.

This shows that after a prolonged dazzling, the retinal purple having turned to retinal yellow, the eye does not register any short wavelength radiation; in other words, it takes its guard against the radiations which caused the dazzling.

It is therefore necessary to study the effects of all the radiations of the spectrum on the human eye to establish the causes of dazzling and to find the best lighting.

If one examines by spectroscope the light supplied by an incandescent body, for instance, a filament heated to 3000 K, one is struck by the fact that the spectrum zone which seems to be the most luminous is the one corresponding to the green/yellow.

One may conclude that this greater luminosity is the result of the fact that a greater energy is bent to the production of radiation of the said color. This is not the case, as shown by the spectral energy curve of the black body at 3000 K (Fig. 12), which is at its maximum in the neighborhood of 1.0 micron. This impression thus results from the fact that our eye is very sensitive to radiations neighboring 0.56 micron.

According to the well-known curve of relative visibility*, one will notice that at equal energy the eye is seven times less sensitive for the radiation of a wavelength of 0.6 micron (orange), 62 times for the radiation 0.4 (violet), and 84 times for the rediation 0.7 (red).

Different results of physiological studies show the particular action of the green-yellow radiation on the eye; one will note that the maximum of sensitivity and the minimum of fatigue occur for the green-yellow of wavelength of 0.56 micron as for the maximum energy of the solar spectrum.

On the other hand, the rays which are harmful to the retina are chemical rays and visible rays of short wavelength (violet, indigo blue). It is thus that the influence of the yellow lens on sick eyes appears in the form of two simultaneous beneficial effects: a sensation of better illumination and a sensation of calm.

To these advantages of yellow glasses must be added a sharper sensation of relief contrasts and distant illumination.

From all this, there results a keen interest in selective light, from the point of view of both visibility and dazzle.

Visibility - For the driver, the fovea or central part of the retina, which is that serving the vision in the line of sight, perceives more easily if distant objects are illuminated with lights of long wavelength.

The perimacula, which affords vision for everything not in the line of sight, that is, the road verges, perceives more readily the short wavelength variations. The result is that, from the point of view of road illumination, there is an interest in using a beam rich in radiations of long wavelength (red, orange, yellow, green) in such a manner as to conserve for the perimacula all its sensitivity for perception of the verges illuminated by the crepuscular light which above all comprises the radiations of short wavelength (blue and violet).

Dazzle - In the case of dazzle produced by automobile headlights, we are concerned with the transient action of an intense light source, losing the benefit of the crepuscular adaptation.

The duration, intensity, and brillance of the source of dazzle play a very important role on the value of this insensitivity, and consequently on the delay to the recovery of vision.

Arising from the preceding explanations, this dazzle is provoked by the radiations of short wavelength against which the eye protects itself just as that resulting from the curve of absorption of retineal yellow.

Dazzle is thus of less importance with a light deprived of radiations of short wavelength, which does not desensitize the

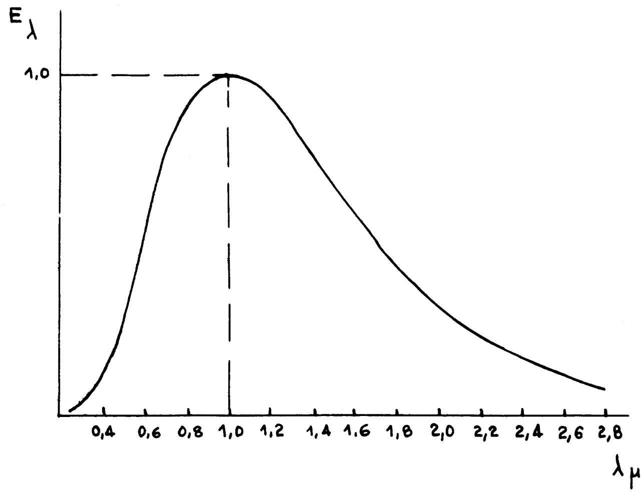

Fig. 12 - Relative spectral energy of the radiations of the black body at 3000 K in terms of the wave length

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*Standard visibility curve by CIE.

the retina rods, which alone are capable of assuring crepuscular vision on a wide surrounding area.

Excited by such a light, the eye quickly recovers its nocturnal vision because the reduction in sensibility of the cones of the center part is small, and, as a result of the use of long wave radiations, the perimacular sensitivity has altered very little, owing to the relative blindness of that part of the eye for these radiations;

Fatigue - Ultraviolet rays harmful to the retina are those which induce the phenomenon of eye fatigue. These rays exist in large quantities in the light produced by the incandescent lights presently in use, and the usual glass of potassium or magnesium base is incapable of filtering them sufficiently. There is thus a case for stopping all fatigue-provoking ultraviolet rays in addition to the violet and blue rays which cause dazzle.

Transmission into Atmosphere - In addition to its felicitous physiological properties, selective yellow light allows, owing to its small diffusion, a better penetration and a better visibility in atmospheres which are not clear. A foggy area consists of transparent particles in suspension in equally transparent surroundings, but with a different index of refraction.

We shall restrict ourselves in the following to a succinct review of the results of the most important research work which can serve as a basis for all research on the influence of mist and fog on the propagation of light.

Lord Rayleigh has shown that when diffusion is produced only by diffraction of the light on particles whose dimensions are small as opposed to the wavelength of the radiations, the light flux diffused is proportional to the square of the volume of the particles and inversely proportional to the fourth power of the wavelength.

According to this expert, the regular transmission factor r of a nonabsorbing foggy area formed of spherical particles of small diameter, in comparison with the wavelength of the light used, is given for a thickness x of the area by the formula:

$r = e(-kx/\lambda^{\mu})$. When the dimensions of the particles are no longer negligible in relation to the wavelength, Lord Rayleigh's law is no longer strictly applicable, short wavelength radiations being always less diffused than indicated by this law.

Boutarie has expressed this in the form $r = e(-kx/\lambda^{n})$, in which n is inferior to 4.

More recently, Cheneveau and Audubert, studying the diffusion by dark areas consisting of transparent spheres of diameters ranging 1-12 microns, have established by experience that, in the formula of Lord Rayleigh generalized for foggy areas of large particles, the exponant n can vary from a positive to a negative value when the diameter or number of the particles increases. The exponent n is liable to take on values ranging between +4 (for particles whose diameter is less than the wavelength of the radiations) and -1 (for particles whose diameter is in excess of the wavelength). If n is positive, the foggy area diffuses blue more than red; if n is negative, the foggy area diffuses red more than blue.

This phenomenon explains the coloring of the dark areas. The blue color of the sky is due, as indicated by Lord Rayleigh, to the diffusion of the solar light by the gaseous molecules of the thin atmosphere at high altitudes.

The dimension of particles in fogs generally observed in our region gives for n a positive value, which explains the generally bluish coloring of automobile headlamp beams.

On the other hand, the tests of Rocard have shown that the atmosphere can never be considered absolutely pure.

Molecular diffusion leads to a coefficient of transparency of the order 0.99/km when the coefficients of transparency of the atmosphere are never greater than 0.95 in regions of low altitude and normal atmospheric pressure. The presence of particles of various origin (dust and smoke) must be accepted, having a mean diameter of approximately 0.2 microns, which affect the light in the same way as the molecules of a foggy area with small particles. Thus, the generalized formula of Lord Rayleigh in which n is equal to 2.5 is always applicable to the diffusion of headlamps, even in clear conditions as normally encountered by various automobile users.

The preceding study of the transmission of radiations in a foggy area thus shows that it is advantageous to eliminate all the radiations of short wavelength which are most diffused and to make use of a light rich in long wavelength radiations.

Arising from the above general considerations, the advantages of a yellow light, from which violet, ultraviolet, and blue radiations have been filtered out, can be considered from two points of view, physiological and physical.

From the physiological point of view:

1. Reduction of the rise and fall in eye fatigue to a minimal value.
2. Harmlessness of yellow rays bringing about a feeling of improved illumination and of calm.
3. Diminution of ocular fatigue.
4. Improvement of sense of contrast and improved long-range illumination.
5. Better use of eyesight faculties owing to the sensitivity of the macular region of the eye to the sighting of distant objects straight ahead, when the perimacular region, insensitive to long wavelength radiations, is more directly interested in crepuscular vision; that is, alongside the road.

From the physical point of view, such a yellow light gives the following advantages:

1. It is less diffused by fog, mist, and dust held in suspension in the atmosphere.
2. It increases contrasts as a result of lower diffusion of light.

Faced with such indisputable facts, establishing the reasons for using a yellow light completely free of short wavelength radiations, it was thought to be advantageous to use, in both clear and foggy conditions, lamps whose bulb will be produced with a glass having the property of internal absorption, in spite of thin wall thickness rendered necessary by the manufacturing technique of the bulbs, of short wave radiations (ultraviolet, violet, indigo, and blue), and of transmitting with the minimum of absorption radiations of long wavelength (yellow, orange, and red).

About 1933, during major research on yellow light, Monnier and Mouton, in collaboration with qualified glass manufacturers, succeeded in obtaining a glass of cadmium sulfide base, lightly fluorescent, which, following a special treatment, gives, even with a thickness of 0.3 mm, a good golden coloring by transparency and a greenish-yellow by reflection.

This selective glass, which has been used in France for the production of all electric bulbs for automobile headlights, has the following characteristics:

1. Low absorption of long wavelength radiations from 0.530 microns upward.
2. Total absorption of radiations of a wavelength less than 0.490 microns.
3. Rapid diminuation of transmission factor, very sharp-cut. Fig. 13 shows the transmission curves obtained on two samples, one clear, the other of a deep hue. Total transmission factor for the radiation of a bulb with tungsten filament whose color temperature is 2800 K varies from 0.75 (deep hue sample) to 0.83 (clear sample). The radiated light is, in Maxwell's trichromatic triangle, characterized by its dominant wavelength (0.578 microns) and its saturation (0.95) for the deep hue glass, 0.91 for the clear glass.

Following numerous experiments carried out as much in the laboratory as on the road, the following advantages in favor of the selective yellow light were recognized:

1. Improvement of contrasts as a result of the diminution of the atmospheric diffusion which tends to make brilliances uniform.
2. Improvement of visual acuity. In consequence of spherical aberrations and achromatism of the eye, visual acuity is at its maximum for monochromatic radiation with a wavelength of 0.56 microns. The suppression of blue and violet radiations brings about a diminution of the aberrations and consequently an improvement in visual acuity.
3. Improvement of perceptibility (the faculty of perceiving the existence of an object) and of visibility (the faculty of distinguishing of this object). This results from the improvement of contrasts, from the influence of color, green and yellow shades predominating in nature, and from the particular sensitivity of the eye to yellow radiations.
4. Lessening of ocular fatigue, as a consequence of the total elimination of the radiations passing from ultraviolet to blue, of the less harsh lighting of the countryside which takes on the appearance of being illuminated and yet uncluttered, and of the attenuation of diffusion which reveals details with less fatigue and which attenuates the proper visibility of the beams whose oscillation while driving is the cause of nervous fatigue during a prolonged journey. The lessening of pupillary reaction as a consequence of reduction in dazzle produced by strongly lit areas of high diffusion equally engenders a modicum of fatigue.
5. Lessening of the time of psychomotor reaction, as a result of better visibility and greater comfort of vision.
6. Completeness of the instantaneous crepuscular perception in the case of a sudden extinction of the headlights. The retina rods of the perimacular region, relatively insensitive to yellow light, remain practically at rest and are thus constantly ready to receive an impression from the crepuscular light should the headlights be totally extinguished, which, in this always-dangerous situation, will allow the driver to continue to control his vehicle and avoid a serious accident.
7. Lessening of dazzle.
8. Improvement in the perceptibility of obstacles situated near dazzling headlights, as a consequence of the diminution of dazzle and of the diffusion halo.
9. Important diminution in the time of readaptation after a prolonged period of dazzle. This is a major factor, since it diminishes the time when an observer who has been dazzled has lost his visual faculties.
10. Distance of visibility increases notably in the presence of dazzling headlights.

All these advantages have been duly confirmed over and over again, by various experimenters and at various times, the last

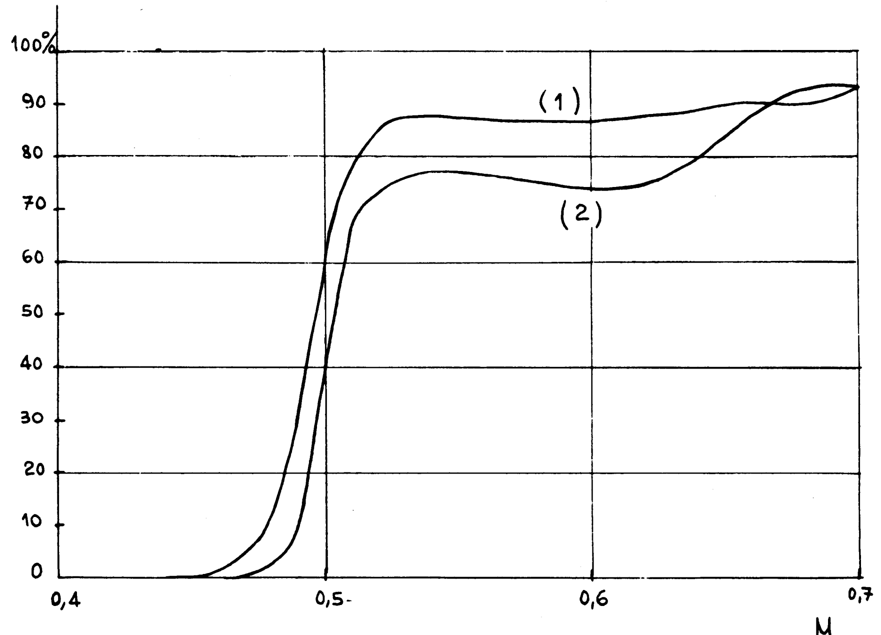

Fig. 13 - Transmission curves of two samples of selective yellow glass: (1) clear glass; (2) deep hue glass