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The Applicability of a Motorcycle Headlamp Modulator as a Device for Enhancing Daytime Conspicuity

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ABSTRACT

Considerable research is needed before any positive steps are taken to further the general use of modulated high-beam headlamps as motorcycle conspicuity aids. Such research cannot proceed satisfactorily without rigorous measurements of the visual characteristics of a modulating device, which have so far been lacking. The purpose of this paper is to provide an example of such measurements and, in particular, to report on the measurements of the relevant photometric characteristics of the Q-Switch modulating device. The results of these measurements demonstrate that the device falls within the specifications recommended by the authors for an extended flashing-signal code to be used by motorcyclists and moped riders, and clearly show that measurements in field conditions will form an essential part of any future conspicuity program based on lights.

Flashing light signals are used extensively in the road environment. On vehicles they are used as turning indicators, hazard warning lights, and emergency vehicle identifiers. On the highway they are used to indicate roadside hazards, temporary construction work, railway crossings, and so forth. These diverse applications have the common purpose of alerting a road user immediately and certainly to an uncommon situation that is potentially hazardous or requires distinctive identification.

The use of flashing signals in the road environment has been reviewed by the authors (1). They proposed a coherent code of flashing signals for the traffic environment that encompasses and extends their applications to allow for the use of a modulated light device to enhance the conspicuity of motorcyclists, bicyclists, and moped riders. The problem of motorcycle conspicuity is widespread and important in many different countries (2-4), resulting in several investigations of the efficacy of headlamps, daytime running lights, and motorcyclist's clothing as aids to frontal conspicuity. The potential contribution of modulated lights is substantial. There have been some reports of promising conspicuity response effects from the use of modulated headlamps on motorcycles from Olson et al. (5).

Olson et al. compared many different types of conspicuity aids for day and night conditions, including low-beam, modulated high-beam, and reduced-intensity (10 percent) low-beam headlamps and various garments for conspicuity enhancement. They found that the modulated high-beam headlamp was the most effective daytime conspicuity aid evaluated. However, no details of the characteristics of the device were given.

Considerable research is needed before any positive steps are taken to further the general use of these devices as conspicuity aids. Such research cannot proceed satisfactorily without rigorous measurements of the visual characteristics of the modulating devices, which have so far been lacking. The purpose of this paper is to provide an example of such measurements and, in particular, to report on the measurements of the relevant photometric

characteristics of the Q-Switch manufactured by Do-Tech, Inc., North Carolina, and used by Olson et al. (5). The results demonstrate that the device falls within the specifications recommended by the authors (1) for an extended flashing-signal code to be used by motorcyclists and moped riders, and clearly show that measurements in field conditions will form an essential part of any future conspicuity program based on lights.

PERCEPTION OF FLASHING LIGHTS

The authors (1) reviewed the current Australian specifications for flashing lights for vehicle and highway use and concluded that the specification of frequencies within the range of 0.8 to 2.0 Hz is somewhat arbitrary. This specification reflects the lack of knowledge of the effect such frequencies have on the visual system. The terminology used in the literature to describe the types of flashing signals is inconsistent and can lead to considerable confusion. The following definitions (also shown in Figure 1) are suggested as a classification of the various forms of flashing signals on the basis of

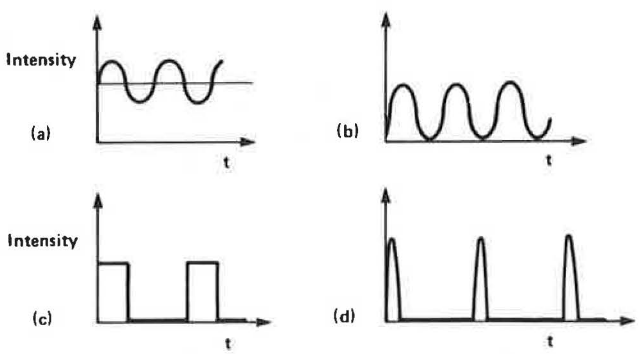

FIGURE 1 Examples of wave shapes for (a) modulating, (b) pulsating, (c) interrupted, and (d) stroboscopic signals, as defined in text.

their visual appearance and physical characteristics (these definitions are only suggested and may need to be modified in the light of empirical evidence):

Modulating signal--a signal that fluctuates continually and regularly between two levels of intensity (or luminance), neither one of which is zero (Figure 1a).

Pulsating signal--a signal that fluctuates from one level of intensity-to-zero. The fluctuations may or may not appear to decrease to zero depending on a number of factors (e.g., frequency and adaptation level) (Figure 1b).

Interrupted signal--a steady signal that is periodically turned off (electrically switched or physically occluded) at intervals. There are two types of interrupted signals: (a) those in which the light pulses are separated by sufficiently long, off periods for the individual pulses to be regarded as independent of one another, and (b) those in which the light pulses cannot be regarded as independent of one another. The off-period criterion is at least 300 to 400 msec. This term is normally, but not necessarily, applied to regular pulse frequencies (Fig. 1c).

Stroboscopic signal--a signal with a large ratio of intensity-to-pulse time and a pulse duration of less than 10 msec. The pulse interval is measured between intensity levels that are 1 percent of the peak intensity (see Figure 1d).

The following physical properties must be specified to uniquely describe a flashing light.

- Frequency of modulation,
- Pulse shape and intensity,
- Pulse-to-cycle fraction,
- Angular size, and
- Color.

Each of these physical properties has an effect on the visual appearance of the light and all of the properties interact with one another. The appearance of the flashing light is also affected by the level of background luminance, the presence of other lights, and the location of the flashing light in the visual field.

If flashing lights are to be used in the road environment, it must be ascertained whether they are to be seen under threshold conditions or suprathreshold conditions, because quite different effects are apparent in the two regimes. Flashing lights used to warn of roadside hazards should be visible from as great a distance as possible and therefore should be first seen in the threshold regime. Flashing lights on vehicles are generally seen at much closer distances and are often a means of enhancing the vehicle's conspicuity; they should therefore be viewed under suprathreshold conditions. It must also be decided whether the sequence of flashes is independent or interacting. The authors (1) suggest that if the period between flashes is greater than 350 msec, the flashes can be regarded as independent.

The appearance of suprathreshold flashing lights is shown in Figure 2 as a function of frequency.

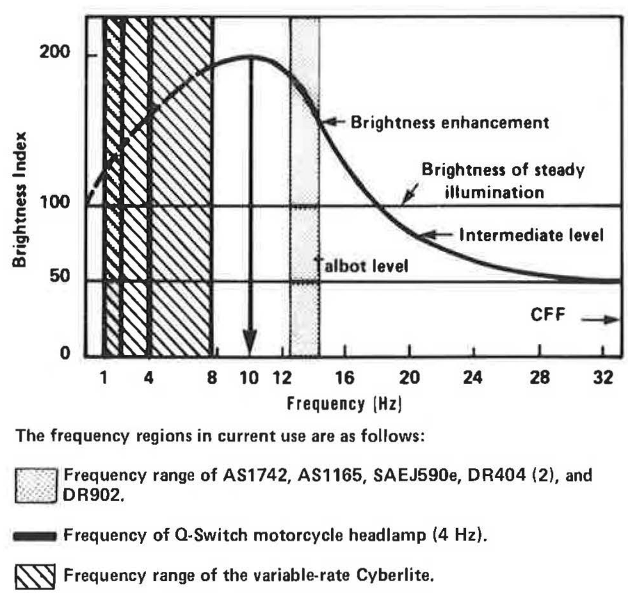

FIGURE 2 Relationship between brightness of a pulsating or interrupted signal and its frequency.

The brightness enhancement effect strictly applies to the 6- to 18-Hz frequency range in which the observer is aware of a steady intensity component and a fluctuating component. (The maximum enhancement occurs at about 10 Hz.) Below approximately 4 Hz, the observer is aware of the dark phases between the light pulses (a different visual phenomenon) and the

observer is no longer able to make a simple comparison with a steady light. Some proprietary conspicuity devices operate in the 3- to 4-Hz range.

Nevertheless, it is possible for the observer to make brightness comparisons between light pulses and a steady light. Such comparisons show that brightness increases as indicated by the dashed line, but this is not only the region of brightness enhancement, but also the region of conspicuity enhancement.

The different frequency ranges currently used by some devices in the Australian road environment are also shown in Figure 2. Temporally modulated lights have the following advantages over steady lights with respect to the conspicuity of a light signal:

- They enhance brightness in the 6- to 18-Hz range[Brucke-Bartley effect (6)];
- They enhance conspicuity in the 1- to 8-Hz range;
- They elicit faster response times (7,8);
- They avoid the possibility that the headlight might produce a camouflaging effect [e.g., the Yehudi camouflage lights (9)];
- They are easy to discriminate from steady lights (10);
- They materially reduce the energy requirements while maintaining conspicuity; and
- They display more urgency than passive or steady-state devices.

However, temporally modulated lights have the following limitations:

- They are not easy to discriminate from other flashing lights (10,11);
- They may cause problems for photosensitive epileptics (12); and
- They may devalue the effect of flashing signals currently in use in the road environment.

The authors, in an earlier paper (1), concluded that any proposed code for flashing signals must not contradict their established uses, but can extend them with due regard to their ergonomic principles and visual characteristics.

The characteristics of flashing signals that have proved to be the most promising are frequency and color. It was considered that an extra frequency range of 3 to 8 Hz could be included in the traffic environment that would be discriminable from other signals currently in use. The current code could also be expanded to include white.

Nevertheless, before the general use of such devices can be advocated unequivocally, much more research is required. In particular, experimental field work is needed to quantify the effects on conspicuity of the interaction between several modulated headlamps and between other flashing signals. More work is also needed to understand the perception of modulated lights in the central and peripheral fields of vision and to assess the use of other physical characteristics of modulated lights besides color and frequency as coding dimensions.

APPLICATION TO MOTORCYCLISTS

Evidence from accident statistics shows that motorcyclists are over-represented in certain types of accidents (13). In an analysis of accidents involving motorcycles in Victoria, Australia, from 1961 to 1962, Foldvary found significant differences between the ratio of motorists to motorcyclists in different types of accidents (14). In accidents involving an error of right-of-way, turning, or signaling, the motorist was more often in error. Foldvary concluded that the lack of conspicuity of the motorcycle and rider was the major contributing factor to these types of accidents. Other more recent studies have also reinforced the problems that motorcycles have with poor frontal visibility during the daytime (15-18). A flashing light would be expected to enhance the daytime conspicuity of motorcyclists for the reasons outlined earlier. The expansion of the flashing-signal code suggested by the authors might then accommodate the use of modulation devices to enhance motorcycle conspicuity without any detrimental effect on the current use of flashing signals by highway authorities. Another advantage of using a unique code for motorcycles is that it will readily identify them as a specific class of vehicle.

PHOTOMETRY OF THE Q-SWITCH HEADLAMP MODULATOR: RESULTS AND DISCUSSION

The Do-Tech Q-Switch is one of several commercially available headlamp modulators. It creates a modulation that lies within the frequency range of 3 to 8 Hz. A Q-Switch was used to provide a concrete example of the photometric properties of a headlamp fitted with such a modulator. Olson et al. (5) used the device to obtain positive conspicuity results for certain motorcycle configurations in highway conditions; however, no details of the photometric characteristics of the device were provided.

The headlamp employed for the Australian Road Research Board tests was a sealed-beam Stanley 6.1097 (12 V, 40 W/3.4 W) fitted to a 1979 Honda 1048-ml CBX. This is a large machine which, because of its ample power generation capabilities, does not require the reductions in current effected by the use of a modulated headlamp to sustain daylight use of the headlamp. The photometric measurements were made in a dark tunnel and the results are given in the following sections.

Lamp Voltage Versus Engine Speed

The photometric properties of the modulated headlamp were best measured while it was off the motorcycle because the positioning and mounting accuracy of the headlamp is greatly reduced when it is actually on a motorcycle. Nevertheless, it is obviously important to gauge the performance of the headlamp on a motorcycle. Therefore, the lamp voltage at the lamp terminals was then measured with the headlamp mounted on the motorcycle as the engine speed was held at a number of values ranging from idling to 5,500 rpm or 92 Hz (5,500 rpm corresponds to approximately 120 km/hr in top gear on this machine). Subsequent photometric measurements carried out at a known lamp voltage from a stabilized power supply could then be related back to engine speed. The results of lamp voltage as a function of engine speed are given in Figure 3.

Headlamp Intensity at Different Lamp Voltages

The headlamp was mounted in a goniometer and positioned so that the photometer recorded the maximum intensity on high beam. The power supply was stabilized and the lamp voltage was monitored at the lamp terminals. The intensity of the headlamp was found for a range of voltages from 10 to 14 V for both high- and low-beam conditions. The results are shown in Figure 4.

Measurement of Modulated Headlamp Intensity

On Motorcycle

The modulated headlamp intensity was measured while the headlamp was attached to the motorcycle because the very approximate positioning of the headlamp in

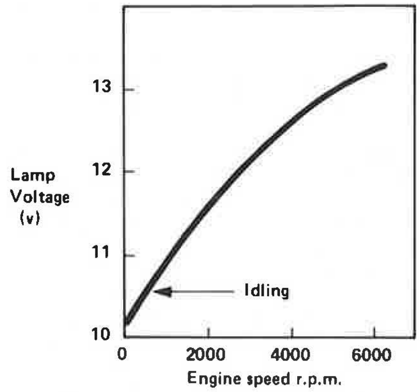

FIGURE 3 Lamp voltage (measured at lamp terminals) as a function of engine speed (measured by tachometer).

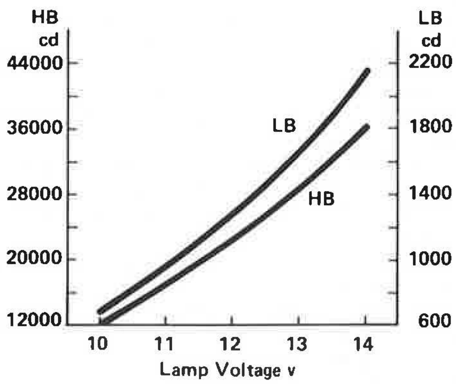

FIGURE 4 Headlamp beam intensity at the straight-on position as a function of lamp voltage for high-beam (HB) and low-beam (LB) conditions.

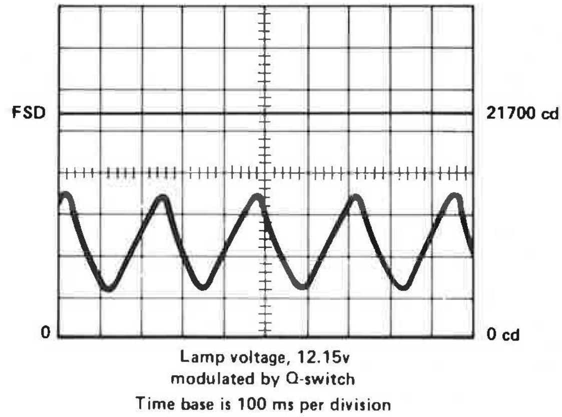

FIGURE 5 Oscilloscope trace recording of modulated headlamp intensity with headlamp mounted on a goniometer for a time base of 100 msec per division.

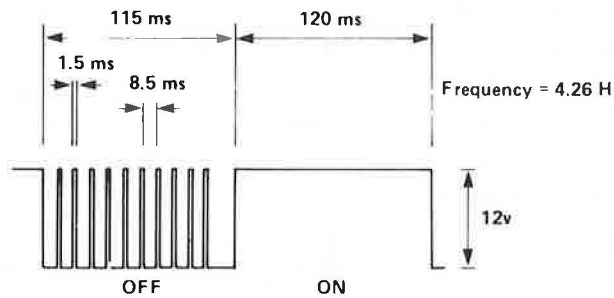

FIGURE 6 Output waveform of the headlamp modulator device.

the yoke and the uncontrollable variations in lamp voltage are common characteristics of such vehicles on the road. The output of the photometer was displayed on an oscilloscope. Measurements were taken while the motorcycle was idling and with the engine switched off and the headlamp driven by the battery only. The maximum and minimum intensities of the headlamp are given in the following table.

	Engine Idling (cd)	Battery Only (cd)
Maximum intensity	13 400	10 460
Minimum intensity	3620	3160

Off Motorcycle

When the headlamp was mounted in the goniometer and positioned to give maximum illumination at the photometer on high-beam, the lamp voltage was set at 12.15 V. The output of the photometer was displayed on a storage oscilloscope with a wide frequency response and a calibrated time scale. The waveform of the headlamp intensity, as shown in Figure 5, is practically triangular with a frequency of 4.20 Hz. The steady-state intensity level is 21 700 cd; the maximum value of the intensity waveform is 13 920 cd (64 percent of the steady-state value); and the minimum value is 4505 cd (21 percent of the steady-state value).

The input waveform at the lamp terminals was also monitored, as shown in Figure 6. It can be seen that during the off period of the duty cycle, the lamp filament received short duration pulses that would promote a slower drop of filament temperature than would otherwise occur. This would also have the effect of extending the life of the bulb. The measured frequency of the input waveform was 4.26 Hz.

The current drain of the modulation device was about 200 mA, which is negligible in comparison with the 4 to 6 A drawn by the headlamp bulb. The long-term reliability of the device has been tested independently by the Electrical Testing Laboratories, New York, who certified no degradation in performance after 2 million pulses (i.e., 6 to 7 years of average use in the United States).

It is instructive to look at another, quite different motorcycle and headlight combination. This motorcycle [a Yamaha RZ350(K), which is a type of RZ250, a popular model in the key novice rider category] had a much smaller engine capacity and the headlamp had a much higher rating (12 V, 60 W/5.5 W).

Under laboratory conditions and with a stabilized power supply, the steady-state intensity at 12.15 V was 31 600 cd on high beam compared with 21 700 cd for the first headlamp test. Of course, the frequency of the modulated headlamp intensity and the ratios of the maximum and minimum modulated intensities to the steady-state intensity are determined almost completely by the Q-Switch and thus remain the same as in the first test (64 percent and 21 percent, respectively). It was not possible to measure the steady-state high-beam intensity for the battery-only condition because the current drain was so great that the light output rapidly decreased. Consequently, the low-beam intensity would probably have better results in this combination.

Another feature of the small motorcycle and high-

rated headlamp combination was that the lamp voltage varied rapidly over a narrow range of engine speed from idling to 2500 rpm (42 Hz), which resulted in considerable variation of light intensity at these low engine speeds. It was also apparent that at low rpm levels, which are typical of a stationary machine awaiting a turn, the dipped beam was delivering a higher intensity than the main beam.

It should be noted that both machines were in as-new condition. The two examples of motorcycle and headlamp combinations serve to forcefully illustrate the need to combine rigorous photometric data with the results from experiments of behavioral responses. Field results differ substantially from laboratory measurements. The point of application of all such conspicuity enhancement measures is field performance on real machines.

SUMMARY

Positive on-road conspicuity effects have been reported by Olson et al. (5) using a proprietary device: the Q-Switch headlamp modulator. Considerable research is needed before any positive steps are taken to further the general use of such modulation devices as conspicuity aids. In particular, experimental field work is needed to quantify the effect on conspicuity of the interaction between several modulated headlamps and between a modulated headlamp and other flashing signals in the road environment. A greater understanding of the peripheral and foveal perception of modulated lights at suprathreshold intensities is also needed. Such research cannot proceed satisfactorily without rigorous measurements of the visual characteristics of such modulating devices, which have so far been lacking. An example of such measurements was provided in this paper by examining the Q-Switch device photometrically.

The maximum and minimum values of the intensity waveform were 64 percent and 21 percent of the steady-state value, respectively. The frequency of the modulation was 4.20 Hz and the waveform was close to triangular. This device lies within the range of specifications suggested by the authors (1) for the enhancement of the daytime conspicuity of motorcyclists. These results complement the on-road conspicuity results of Olson et al. (5) and provide a reference for permissive or regulatory considerations.

The results clearly show that measurements in field conditions, with a typical distribution of motorcycles of different ages, will form an essential part of any future lighting-based conspicuity program.

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