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**Summary** This study evaluated the effects of voltage on rise time and light output from incandescent brake lamps for a range of voltages representing realistic values for large trucks. The findings indicate that, relative to nominal voltage of 12.8 V, realistic voltages for large trucks lead to significant increases in rise time and to decreases in light output. At 9 V, for example, 90% of the asymptotic light output is reached about 113 ms later than at 12.8 V, and the asymptotic light output is about 28% of the output at 12.8 V. Analogous comparisons of 6 V with 12.8 V indicate an increase in the rise time to 90% of asymptotic light output of about 316 ms and a decrease in asymptotic light output to about 5%. The changes obtained in rise time and light output of incandescent lamps as a function of voltage are of practical importance because they can be expected to increase following drivers' reaction times to brake signals and to increase the frequency of missed signals.

# Effects of voltage drop on the rise time and light output of incandescent brake lamps on trucks

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## 1 Introduction

This study dealt with the effects of voltage drop on rise time and light output of incandescent brake lamps. Even under nominal conditions when 12.8 V is applied, incandescent brake lamps have a relatively slow rise time. No measurable light is emitted for about 50 ms, and about a quarter of a second is required for the filament to reach 90% of the asymptotic output[1]. This slow rise time of conventional brake lamps can cause important delays in warning information to following drivers[1,2].

The problem is aggravated as the voltage is reduced from the nominal 12.8 V. Voltage drop is particularly a problem in large trucks (lorries). A recent survey performed for the US Department of Transportation[3] examined the issue of voltage drop in a sample of 546 large trucks. The results at 700 rpm (normal idle) are shown in Table 1. (The voltages at 1 100 rpm were only slightly higher. For example, the mean for doubles at 11 000 rpm was 9.9 V, compared to 9.8 V at 700 rpm.)

**Table 1** Voltage at brake lamps (V) for a sample of 546 large trucks (adapted from Copenhaver *et al.*[3])

| Vehicle type | Minimum | Maximum | Mean | Standard deviation |
|---|---|---|---|---|
| Dumptrucks | 10.3 | 13.1 | 12.2 | 0.8 |
| Vans | 8.8 | 13.8 | 11.6 | 1.0 |
| Tanks | 7.5 | 13.4 | 11.5 | 1.2 |
| Flatbeds | 6.5 | 13.2 | 11.4 | 1.2 |
| Doubles | 6.0 | 12.4 | 9.8 | 1.5 |
| Triples | 5.5 | 11.1 | 8.4 | 1.6 |

The major factors affecting voltage drop across any electrical circuit are the effective length of the cable, wire gauge (size), and connector/wiring integrity[4]. A recent investigation found that low voltages in large trucks were primarily due to undersized wiring[4].

The present study evaluated the effects of voltage drop on rise time and light output for a range of voltages representing realistic in-traffic values for large trucks. On the basis of the survey discussed above[3], the range of voltages used was from 12.8 V to 6 V.

## 2 Method

### 2.1 *Brake lamp*

We used one brake lamp for all measurements. The lamp had a standard incandescent light source, No. 1157. This light source has two filaments; the voltage was applied to the brake filament.

### 2.2 *Voltages*

A regulated power supply was used to generate one of eight different voltages: 12.8, 12, 11, 10, 9, 8, 7, and 6 V.

### 2.3 *Procedure*

Light output (after it had passed through the red lens of the lamp) was measured by a Minolta illuminance meter, Model T-1, positioned 1 m from the brake lamp. The voltage and illuminance information were fed into an oscilloscope. The images of the changes of voltage and light output were photographed for later analyses. The lamp was left in the off state for one minute to cool down between measurements.

## 3 Results

The light output curves by voltage (normalised to the output at 12.8 V) are presented in Figure 1. Table 2 lists the delay in reaching the 90% level of asymptotic output as a function of voltage. Table 3 lists the asymptotic light output as a function of voltage.

## 4 Conclusions

The present findings indicate that, relative to a nominal voltage of 12.8 V, in-service voltages of large trucks lead to significant increases in rise time and decreases in light output from incandescent brake lamps. At 9 V, for example, 90% of the asymptotic light output is reached 113 ms later than at 12.8 V, and the asymptotic light output is 28% of the maximum at

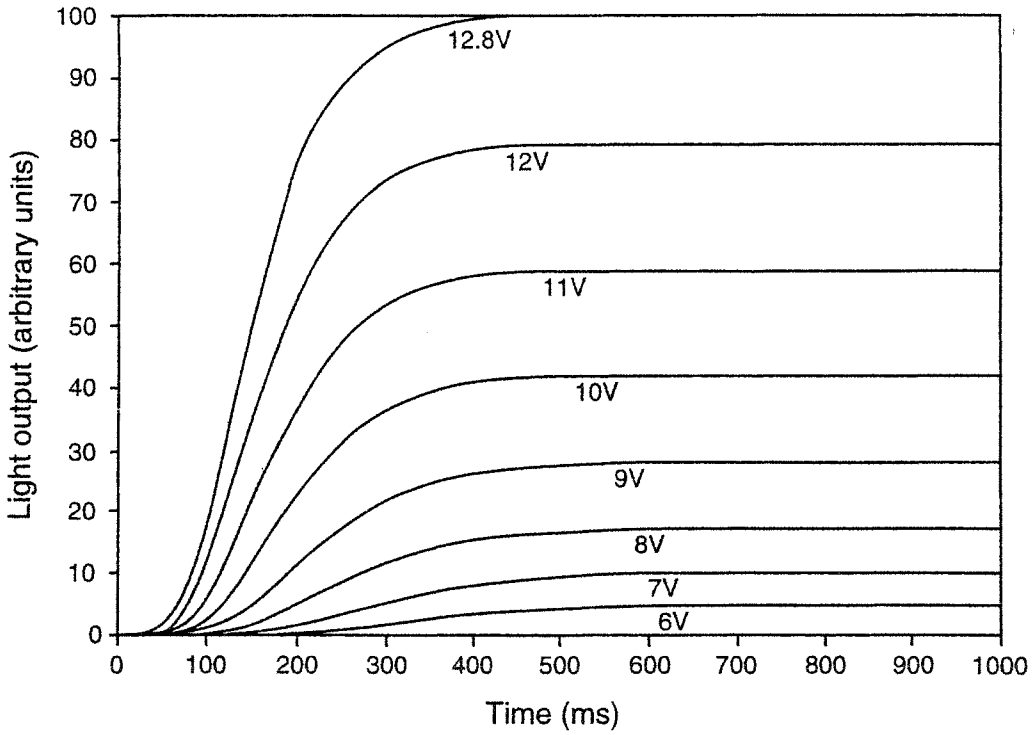


**Figure 1** Light output as a function of voltage

**Table 2** Delay in reaching 90% of asymptotic light output by voltage

| Voltage (V) | Delay (ms) |
|---|---|
| 12.8 | 259 |
| 12 | 282 |
| 11 | 294 |
| 10 | 320 |
| 9 | 372 |
| 8 | 410 |
| 7 | 487 |
| 6 | 575 |

**Table 3** Asymptotic light output by voltage (as a percentage of asymptotic light output at 12.8 V)

| Voltage (V) | Light output (%) |
|---|---|
| 12.8 | 100 |
| 12 | 79 |
| 11 | 59 |
| 10 | 42 |
| 9 | 28 |
| 8 | 18 |
| 7 | 10 |
| 6 | 5 |

12.8 V. Analogous comparisons of 6 V with 12.8 V indicate an increase in rise time of 316 ms and a decrease in light output to 5%.

Reaction time to the onset of light stimuli increases with either an increase in the rise time of the stimulus[1], or a decrease in the intensity of the stimulus[5]. Consequently, the changes obtained in rise time and light output of incandescent lamps as functions of voltage are of practical importance. Reduced voltage can be expected to cause an increase in following drivers' reaction times to brake signals. Furthermore, the reduced light output will likely result in an increase in the frequency of missed brake signals.

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