RECOMMENDED TEST VOLTAGE FOR WORLDWIDE HARMONIZED HEADLAMP PHOTOMETRIC SPECIFICATIONS

Michael Sivak
Michael J. Flannagan
Toshio Miyokawa

The University of Michigan
Transportation Research Institute
Ann Arbor, Michigan 48109-2150
U.S.A.

Report No. UMTRI-99-3
February 1999

Technical Report Documentation Page

1. Report No. UMTRI-99-3	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Recommended Test Voltage for Worldwide Harmonized Headlamp Photometric Specifications		5. Report Date February 1999 6. Performing Organization Code 304655
7. Author(s) Sivak, M., Flannagan, M.J., and Miyokawa, T.		8. Performing Organization Report No. UMTRI-99-3
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, MI 48109-2150 U.S.A.		10. Work Unit no. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address American Automobile Manufacturers Association 7420 Second Avenue Detroit, MI 48202 U.S.A.		13. Type of Report and Period Covered 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The purpose of this research was to develop a recommendation for a test voltage to be used for harmonized headlamp photometric specifications. Two separate activities were performed: a survey of expert opinion, and an analysis of published field data on lamp voltages.

The survey dealt with recommendations for test voltage under current electrical systems that have a nominal voltage of 12 V, as well as under potential future, higher-voltage systems. Responses were received from 120 experts. The opinions of experts varied widely, both between continents and within continents. The most frequent recommendation for the test voltage under the current electrical system was 12.8 V in North America and 12.0 V in Europe and Asia, but values between 12.0 and 13.5 V found a substantial amount of support on all continents.

The published field data on lamp voltages are limited, and most of the data were collected under controlled conditions, as opposed to sampling a variety of normal driving conditions. The two studies that measured voltages under normal driving conditions suggest a mean voltage of between 13.0 and 13.2 V, but with a wide variation between vehicles.

Our first-choice recommendation is to use 12.8 V as the harmonized test voltage for the current 12 V electrical systems. There are four reasons for this recommendation. First, this value is acceptable to substantial proportions of experts in different parts of the world. Second, many on-the-road lamp voltages are near this value. Third, this value is currently the basis of some photometric standards (e.g., in North America). Fourth, there is a benefit in maintaining continuity with at least one of the existing voltage standards (12.0 or 12.8), and the higher of those standards (12.8) is close enough to the best estimate of the mean on-the-road voltage (13.0 to 13.2) that it does not seem worthwhile to adopt an entirely new value. Our second-choice recommendation is to use 13.2 V as the test voltage. Considerations relevant to these alternative recommendations are discussed further in the main text.

17. Key Words headlamps, lamps, photometry, compliance, voltage, harmonization, low beam, survey		18. Distribution Statement Unlimited	
19. Security Classification (of this report) None	20. Security Classification (of this page) None	21. No. of Pages 18	22. Price

ACKNOWLEDGMENT

This research was supported by the American Automobile Manufacturers Association.

CONTENTS

INTRODUCTION

During the past several years, substantial progress has been made in worldwide harmonization of headlamp beam patterns. Most of the relevant activities have been initiated by AAMA (American Automobile Manufacturers Association), GTB (Groupe de Travail "Bruxelless 1952"), JASIC (Japan Automobile Standards Internationalization Center), or SAE (Society of Automobile Engineers). AAMA, GTB, and JASIC commissioned several research projects (e.g., Sivak, Helmers, Owens, and Flannagan, 1992; Sivak and Flannagan, 1993; and Sivak and Flannagan, 1995). The results of these and other research projects have been used in extensive deliberations in GTB and SAE. One consequence of all of these deliberations is the apparent agreement on a harmonized low-beam pattern that was reached at a meeting of the GTB Coordinating Committee in November 1998 in South Africa.

In anticipation of eventual success in harmonizing the low-beam pattern, we were asked to address the issue of harmonized test voltage for photometric compliance. The motivations for this research include both the efficiency of having a common test voltage throughout the world, as well as the improved validity of having a test voltage that more closely reflects on-the-road voltages, in order to realistically assess quantities of seeing light and glare light.

The present research was not designed to address the issue of whether voltage (as used in North America) or luminous flux (as used in Europe) is the more appropriate parameter. Instead, the charge was to develop a recommendation for a test voltage based on (1) the opinions of experts and (2) available field data on voltages at lamp terminals. Consequently, this study had two parts. The first part involved a worldwide survey of experts concerning appropriate test voltage. The second part consisted of an analysis of the limited published data concerning test voltages in actual traffic.

SURVEY OF EXPERT OPINION

Questionnaire

The questionnaire consisted of three personal-background questions (affiliation, years of lighting experience, and country of residence), and five technical questions (see Figure 1). The first two of the technical questions dealt with current electrical systems that have a nominal voltage of 12 V. In the remaining three technical questions, the respondents were asked to assume a potential future electrical system with a substantially higher primary voltage (e.g., 42 V). Furthermore, they were asked to assume that in such a system, a lower, highly regulated voltage level would be available for headlamps and other lighting devices, and that this level would be somewhere in the range that would allow continued use of current bulbs.

Respondents

A written questionnaire was mailed to 364 experts in headlighting. All members of the following groups were contacted:

- AAMA (Vehicle Lighting Task Group)
- GTB (Coordinating Committee, Harmonization Working Group, and Safety and Visual Performance Working Group)
- SAE Lighting Committee (Distributive Lighting, Headlamp Harmonization, International Standards, Lighting Coordinating Committee, Replaceable Bulb, and Road Illumination Devices)

Additionally, the questionnaire was sent to our contacts in the lighting area. Table 1 presents a tabulation by country of persons who were contacted and those who responded. Table 2 presents an analogous tabulation by continents. Table 3 and 4 list the primary affiliations of the respondents and years of lighting experience, respectively.

For Questions (1) and (2) assume the current electrical systems with a nominal voltage of 12 V.

(1) I recommend that, given the current electrical systems, the harmonized test voltage for headlamp photometry should be ______ volts.

(2) This recommendation is based on (please circle one):

field data of lamp voltages (please send copies)

my educated guess

my opinion

other ____________________________

For Questions (3) through (5) assume an electrical system with a substantially higher primary voltage (e.g., 42 V). Furthermore, assume that in such a system, a lower, highly regulated voltage level would be available for headlamps and other lighting devices. This lower level would be somewhere in the range that would allow continued use of current bulbs.

(3) I recommend that the operating voltage for headlamps under such a dual-voltage electrical system should be ______ volts.

(4) This recommendation is based on the following consideration(s):

(5) I recommend that the test voltage for headlamp photometry under such a dual-voltage electrical system should be ______ volts.

Figure 1. The five technical questions in the survey of experts.

Table 1
Numbers of experts who were contacted and who responded, by country.

Country	Contacted (n)	Responded (n)	Responded (%)
U.S.A.	190	66	35
Japan	71	20	28
Germany	29	11	38
France	13	2	15
Italy	10	4	40
U.K.	9	3	33
The Netherlands	8	3	38
Sweden	7	3	43
Canada	5	2	40
Spain	4	0	0
Switzerland	4	0	0
Belgium	3	0	0
Czech Republic	3	1	33
Austria	2	1	50
Brazil	1	0	0
Denmark	1	0	0
Hungary	1	1	100
P.R. of China	1	1	100
Slovenia	1	1	100
South Africa	1	1	100
Overall	364	120	33

Table 2
Numbers of experts who were contacted and who responded, by continent.

Continent	Contacted (n)	Responded (n)	Responded (%)
Americas	196	68	35
Europe	95	30	32
Asia	72	21	29
Africa	1	1	100
Overall	364	120	33

Table 3
Primary affiliation of the respondents.

Primary affiliation	Percentage
Industry	81.7
Government	4.2
Academia	3.3
Other	7.5
No answer provided	3.3

Table 4
Years of experience of the respondents in lighting (mean = 19.7).

Years of experience	Percentage
Less than 6	10.0
6 –10	12.5
11 – 20	35.0
More than 20	38.3
No answer provided	4.2

Results

The results will be presented by continents as follows: North America (the U.S. and Canada), Europe (including South Africa), and Asia (one respondent from China, with the rest from Japan).

As expected, several respondents from Europe and Asia indicated that luminous flux, and not voltage, is the appropriate parameter, and that the current ECE test procedure that constrains the luminous flux should be continued. Nevertheless, all but two of these respondents provided a corresponding approximate voltage. Because the ECE procedure is approximately equivalent to using 12.0 V, the "luminous flux" responses of the remaining two respondents were classified as "12.0 V" responses. (One additional respondent recommended using watts. The responses of this person are not included in the analysis.)

Current 12 V electrical systems

The recommended test voltages for headlamps under the current 12 V electrical systems (Question 1) are shown in Figure 2. These results indicate that the most frequent response in North America (29%) was 12.8 V. However, 20% recommended 12 V, and 46% recommended values between 13 and 13.5 V. In contrast, the most frequent response in Europe (28%) and Asia (38%) was 12 V. However, 12.8 V was the voltage of choice for 24% of Europeans and 29% of Asians. Furthermore, voltages between 13 and 13.5 V were also recommended by substantial proportions of respondents from these two continents (42% from Europe and 33% from Asia).

Question 2 asked the reason for making the particular recommendation concerning the test voltage under the current electrical system. The most frequent responses were one's opinion (36%), one's educated guess (24%), and field data on lamp voltages (10%).

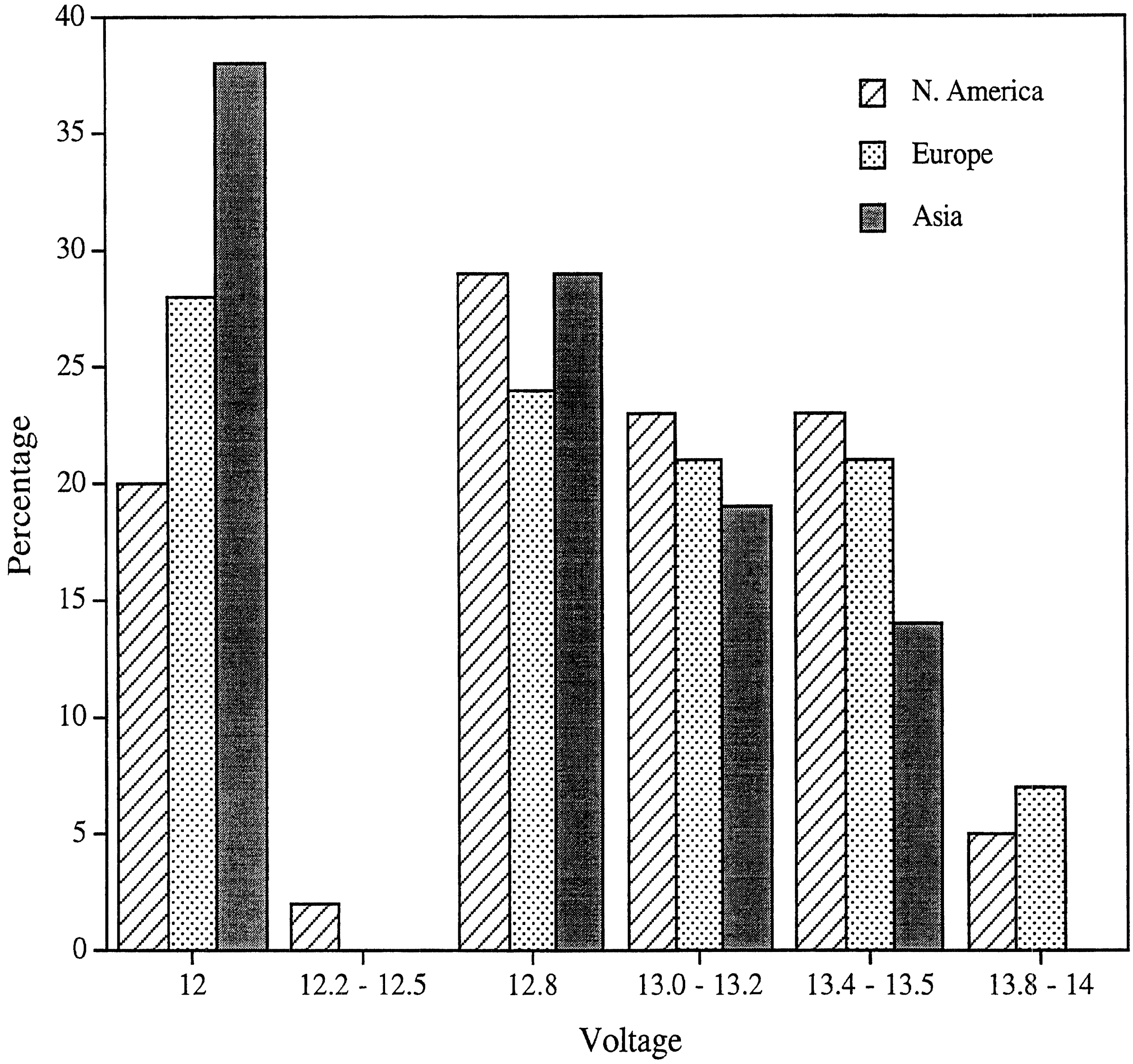

Figure 2. The recommended test voltages for headlamps under the current 12 V electrical systems.

Dual, higher voltage electrical systems

The recommended operating voltages for headlamps under a dual-voltage system (Question 3) are shown in Figure 3. These results indicate that in North America, the preferred operating voltage for these future systems is between 12.8 and 13.2 V (53%). On the other hand, the European responses peaked higher (between 13.4 and 13.5 V, 29%), while the Asian responses peaked lower (at 12 V, 43%).

Question 4 asked the reason for making the particular recommendation concerning the operating voltage under a dual-voltage system. The most frequent responses were the ability to use current bulbs (29%), and current system voltage and life of bulbs (each 14%).

The recommended test voltages for headlamps under dual, higher voltage electrical systems (Question 5) are shown in Figure 4. These results indicate that in North America 60% of the respondents recommended a test voltage between 12.8 and 13.2 V. On the other hand, in Europe and Asia the recommended voltages tended to be lower, peaking at 12.0 V (43% of the European respondents and 45% of the Asian respondents).

A comparison of the answers to Questions 3 and 5 indicates that the European respondents tended to recommend higher values for the operating voltage (peaking between 13.4 and 13.5 V) than for the test voltage (peaking at 12 V). On the other hand, the North American and Asian respondents tended to recommend the same values for the operating voltage *and* the test voltage. Specifically, the recommended values for both voltages peaked between 12.8 and 13.2 V in North America, and at 12.0 V in Asia.

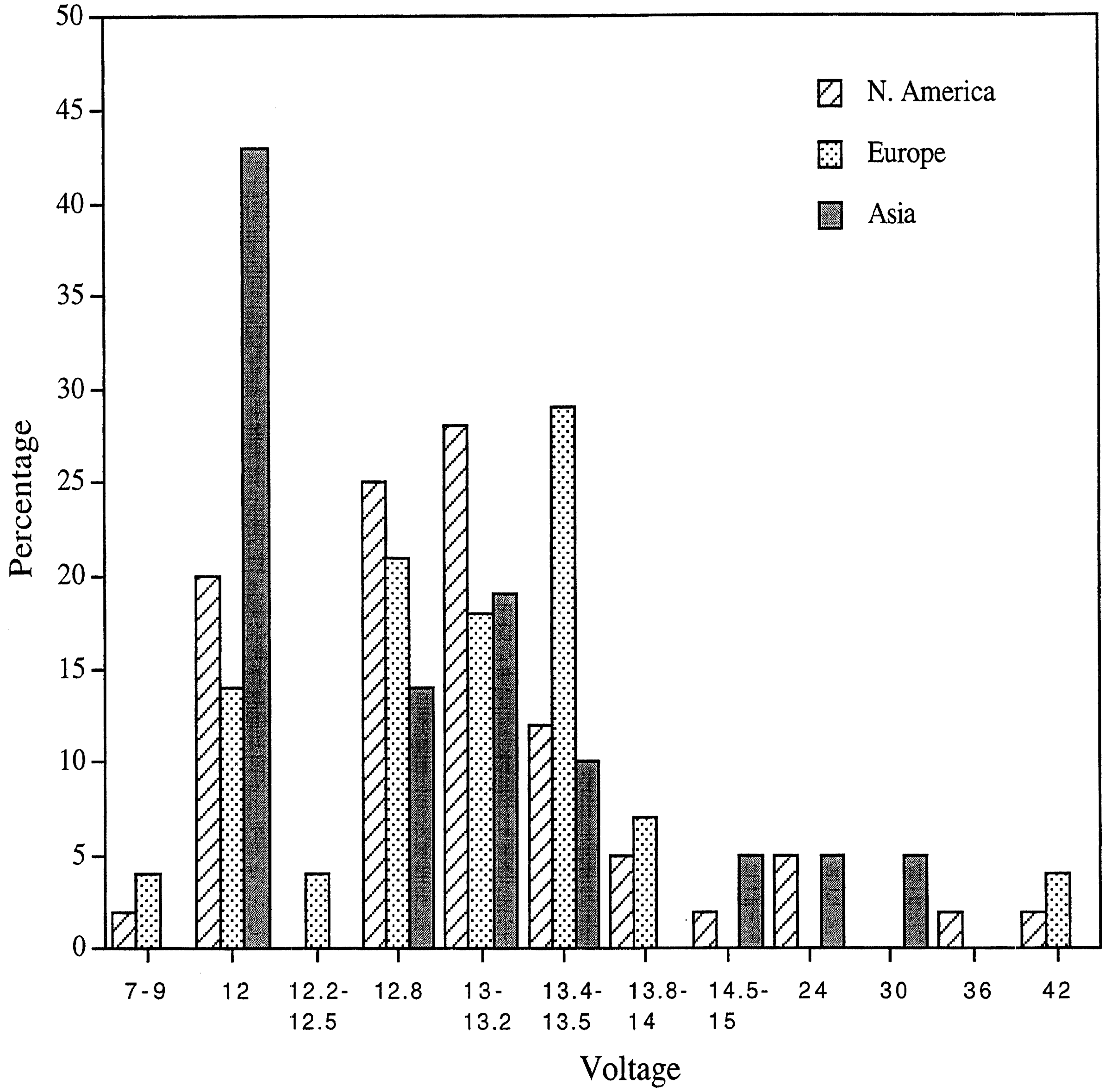

Figure 3. The recommended operating voltages for headlamps under the future, dual and higher voltage electrical systems.

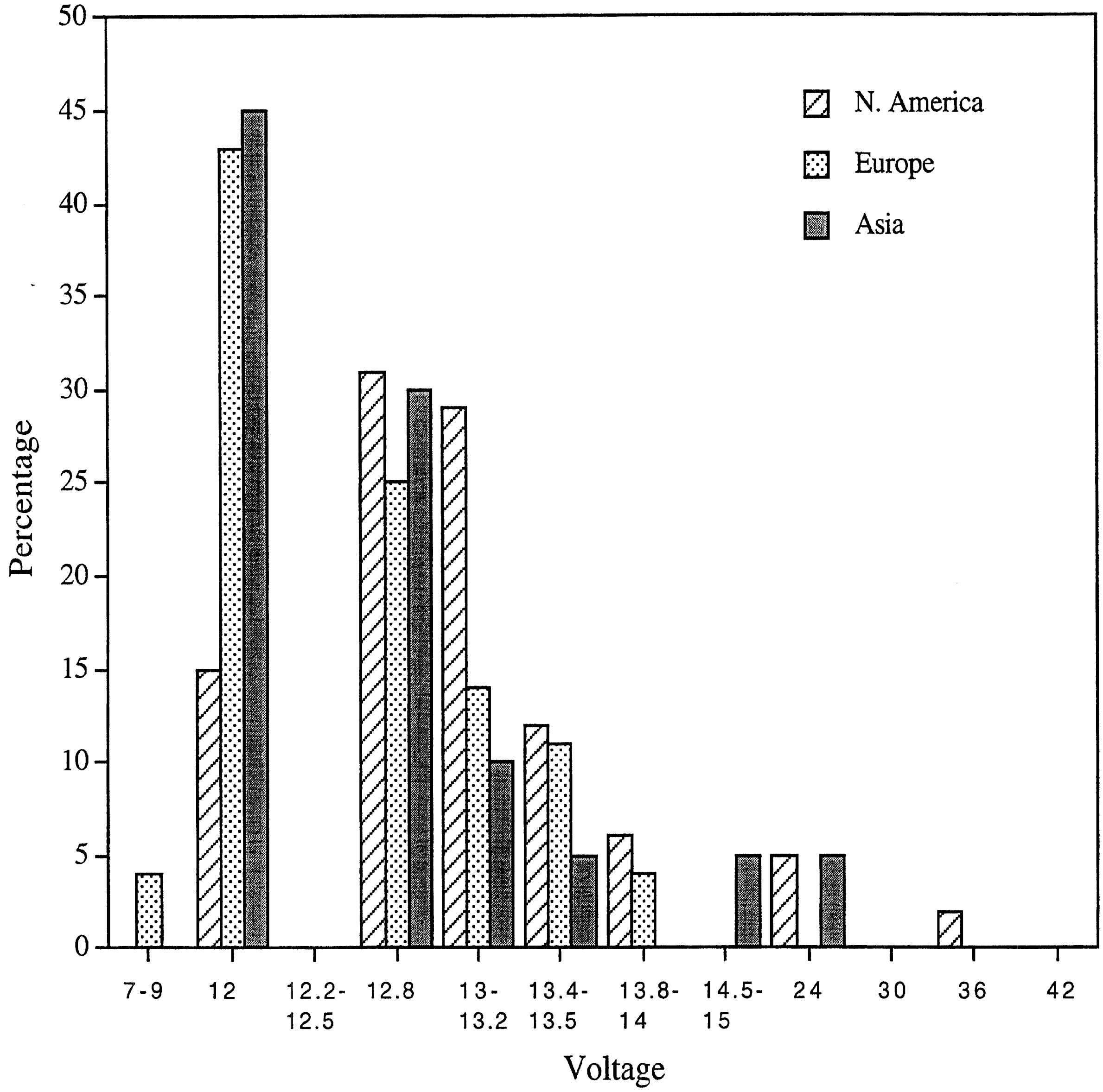

Figure 4. The recommended test voltages for headlamps under the future, dual and higher voltage electrical systems.

FIELD DATA ON OPERATING LAMP VOLTAGES

Only limited field data exist on voltages at lamp terminals. The published data are of two types: voltages obtained under controlled conditions (e.g., with the engine running at specified revolutions per minutes), or voltages obtained under normal driving (and thus under a variety of realistic conditions, including different ambient temperatures and varying levels of other demands on the electrical system). The later type of information is more relevant to the issue at hand.

Voltages obtained under controlled conditions

Padmos and Alferdinck (1988). In this study, lamps from 50 cars were evaluated as to the voltages at the lamp terminals. The article indicates that the data were collected "with the car's motor running" but no additional information about the method is provided. The *median* value was 13.2 V, with a standard deviation of 0.9 V. (In a separate publication, Amerlaan and Vellokoop [1996] indicate that the *mean* value in the Padmos and Alferdinck study was 13.0 V.)

Amerlaan and Vellokoop (1996). This study evaluated lamp voltages on 17 cars using the ISO 3559-1976 method entitled "Road vehicles: Working voltages for lights fitted to motor vehicles and their trailers." In essence, the method calls for using a system voltage that corresponds to the battery voltage of a prewarmed engine running at half the speed at which the maximum power is developed, while several electrical components (including the low beams) are switched on. The mean lamp voltages were found to be 13.4 V for the left lamps and 13.3 V for the right lamps, with a standard deviation of 0.3 V in each case. (The overall mean was 13.4 V.)

Italian Transport Administration (1998). Voltages at low-beam terminals were measured for 14 vehicles. The engine was running at 2,500 rpm. The mean values were 13.6 V for the left lamps and 13.5 V for the right lamps, with a standard deviation of 0.2 V in each case. (The overall mean was 13.5 V.)

Voltages obtained under normal driving

Meli (1992). This study measured lamp voltages of low beams during normal driving, sampling at a rate of 40 Hz. A total of 11 cars were monitored. The testing was done during cold weather (in January). The results indicate that the mean values were 13.4 V for the left lamps and 13.3 V for the right lamps, with a standard deviation of 0.5 V in each case. (The overall mean was 13.4 V.)

Silva (1998). This interim report describes a not-yet-completed study in which low-beam voltages were measured on three vehicles while they were driven in normal traffic. Lamp voltages were sampled at a rate of 10 Hz, for a period of one year for each vehicle. (Our summaries of these data are estimates based on the graphical information provided in the interim report. The final report is expected to be published in 1999.) The mean voltages appear to be as follows: 12.5 V (a midsize sedan), 13.1 V (a small sedan), and 13.2 V (a pickup truck). The interim report also includes separate graphs of the distributions of voltages for each of four three-month periods, allowing estimates of the effects of gross seasonal changes in ambient temperature on voltage. Our estimates are that, for the three vehicles tested, the seasonal means varied by about 0.4 V (with the highest voltages during winter months).

SUMMARY

Opinion of experts concerning test voltage under current 12 V electrical systems

Expert opinion varied substantially, both between continents and within continents. The most frequent response in North America was 12.8 V. In contrast, the most frequent response in Europe and Asia was 12.0 V. However, in all three continents, voltages of 12.0, 12.8, and between 13.0 and 13.5 V were recommended by substantial proportions of respondents. Thus, based only on the opinion of experts, a reasonable range of test voltages would be rather wide—between 12.0 and 13.5 V.

Field voltage data

The available field data on voltages at lamp terminals are limited. Furthermore, the data show substantial variations between vehicles. The standard deviations in four of the studies reviewed here averaged 0.5 V. (The standard deviations in the individual studies were 0.2, 0.3, 0.5, and 0.9 V.) A standard deviation of 0.5 V indicates that 95% of the voltages are within about ±1.0 V of the mean (or a total range of about 2.0 V).

Another concern with the available field data is that most of them were obtained under controlled conditions, as opposed to sampling from naturally occurring conditions. We are aware of only two published studies that measured voltages during actual driving (Meli, 1992; Silva, 1998). Meli's data indicate a mean of 13.4 V. However, these data were obtained during winter, and thus would tend to be higher than those obtained during summer. (Silva's data indicate that gross seasonal variations can cause lamp voltage to vary by about 0.4 V.) Silva's interim report presents graphical information for three vehicles that were monitored for a whole year. The means for these three vehicles appear to be 12.5, 13.1, and 13.2 V. (In comparison, the three studies that measured voltages under controlled conditions [e.g., the engine was running at a certain rpm], reported means of 13.0, 13.4, and 13.5 V.)

CONCLUSIONS AND RECOMMENDATIONS

(1) There is a wide range of expert opinion concerning the appropriate test voltage for current electrical systems, with values between 12.0 to 13.5 V having substantial support.

(2) Most of the limited field data on lamp voltages were obtained under controlled conditions (e.g., with engines running at controlled revolutions per minute), and thus do not provide information about voltages under a variety of natural conditions.

(3) There is a wide range of lamp voltage in the available field data, with the standard deviation averaging about 0.5 V.

(4) The limited field data that were obtained in natural driving conditions suggest a mean voltage between 13.0 and 13.2 V.

(5) Our first-choice recommendation is to use 12.8 V as the harmonized test voltage for the current, nominally 12 V, electrical systems. There are four reasons for this recommendation. First, this value is acceptable to substantial proportions of experts in different parts of the world. Second, many on-the-road lamp voltages are near this value. Third, this value is currently the basis of some photometric standards (e.g., in North America). Fourth, there is a benefit in maintaining continuity with at least one of the existing voltage standards (12.0 or 12.8), and the higher of those standards (12.8) is close enough to the best estimate of the mean on-the-road voltage (13.0 to 13.2) that it does not seem worthwhile to adopt an entirely new value.

(6) Our second-choice recommendation is to use 13.2 V as the test voltage. If 13.2 V (or any other non-standard voltage within the range from 12.0 to 13.5 V) were to be adopted, a straightforward multiplication by a constant of all photometric values applicable for another voltage (e.g., 12.8 V) could be used to adjust existing photometric standards. (This would be justified because changes in voltage within the range from 12.0 to 13.5 V were shown to result in proportional light-output changes throughout the beam pattern [Sivak, Flannagan, Traube, and Miyokawa, 1998].)

REFERENCES

Ammerlaan, H. and Vellekoop, L. (1996). *A survey of on-board voltages of present M1 vehicles* (Informal Document No. 8, presented at the 37th GRE Session). Geneva: GRE.

Italian Transport Administration. (1998). *Voltage measurement on vehicles* (Informal Document No. 12, presented at the 40th GRE Session). Geneva: GRE.

Meli, L. (1992). *Voltage testing of headlamps and park/turn/stop lamps* (Document No. 474). Warren, MI: General Motors Corporation.

Padmos, P. and Alferdinck, J.W.A.M. (1988). Car headlamps: Influence of dirt, age, and poor aim on glare and illumination intensities. *Lighting Research and Technology, 20,* 195-198.

Silva, D. (1998). *Long-term on-vehicle lighting usage and voltage measurements* (Interim Report, presented at the GTB meeting in South Africa). Dearborn, MI: Ford Motor Co.

Sivak, M. and Flannagan, M.J. (1993). *Partial harmonization of international standards for low-beam headlighting patterns* (Report No. UMTRI-93-11). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Sivak, M. and Flannagan, M.J. (1995). *Evaluation of the SAE J1735 draft proposal for a harmonized low-beam headlighting pattern* (SAE Technical Paper Series No. 950597). Warrendale, PA: Society of Automotive Engineers.

Sivak, M., Flannagan, M.J., Traube, E.C., and Miyokawa, T. (1998). *Do changes in voltage result in proportional changes throughout headlamp beam pattern?* (Report No. UMTRI-98-27). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

Sivak, M., Helmers, G., Owens, D.A., and Flannagan, M.J. (1992). *Evaluation of proposed low-beam headlighting patterns* (Report No. UMTRI-92-14). Ann Arbor, MI: The University of Michigan Transportation Research Institute.