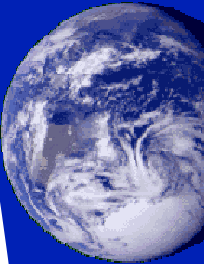


LEDs, Curfews and Solar Power Reduce Lighting Costs: Balancing Conservation With Driver Safety

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Special Series on Sustainability



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KEY SEARCH TERMS:

Roadway Lighting

Street Lighting

Light Emitting Diodes

Energy Conservation

Solar Power Generation

Solar Energy

Research Synthesis Bibliography No. 18

Research Synthesis Bibliographies (RSBs) are distillations of relevant transportation research on current topics of interest to researchers, engineers, and policy/decision makers. Sources cited are available for loan (or available through Interlibrary Loan) to VDOT employees through the VDOT Research Library.

VDOT, Other Highway Agencies Have Explored Lighting Changes in the Past

Many state departments of transportation are searching for ways to be more energy efficient while maintaining a transportation system that is safe, facilitates movement of people and goods, and improves the overall quality of life of citizens. Local budget shortfalls, overall economic downturns, upward trends in energy costs and increasing concern for the environmental impact of highway operations are driving state departments of transportation and similar agencies to reconsider current practices in roadway lighting. Such changes have been considered before, typically during difficult economic times or times when the cost of energy has risen unexpectedly, starting with the Oil Embargo of 1973-74. In fact, VDOT has explored the issue from conservation, safety, and risk assessment angles, documenting research results in the following reports (listed as "Initial Reading" in this RSB):

"Alternatives for Energy Conservation in Roadway Lighting," M. H. Hilton, 1979, 80-R8.

"Continuous Freeway Illumination and Accidents on a Section of Rte. I-95," M. H. Hilton, 79-R4.

"A Comparison of Full and Partial Lighting on Two Sections of Roadway," M. H. Hilton, 80-R52.

"Screening Methodology for Needs of Roadway Lighting," J. H. Lambert, 03-CR14.

The purpose of roadway lighting is to provide improved safety, security, and aesthetics for the various users of the roadways and associated facilities (including bridge and tunnel lighting, sign lighting, roadway delineation and even parking facilities). AASHTO's Roadway Lighting Design Guide, (October 2005, p. 7) cites National Highway Traffic Safety Administration (NHTSA) crash data as showing that "90 percent of fatal and injury crashes occur the roadway, where lighting guidelines specify that light be placed, are multiple vehicle crashes. The number of overall crashes tapers off substantially after midnight on weekdays and after 4:00 a.m. on weekend. At these late hours, most of the crashes are single vehicle, off-roadway crashes for which lighting may not be likely to help, except possibly at decision-making points such as ramp gorges, intersections, and merge areas."

AASHTO's guide notes that crash rates increase where lighting systems are turned off or where every other luminary is turned off. Dimming or "lighting curfews" may be less likely to result in increased crash rates. Still, in an effort to save money, many agencies periodically consider altering the way they light roadways. Some options for reducing energy consumption related to roadway lighting include:

- Solar-powered lighting for overhead highway signs or in other standalone applications.
- Lighting spaced farther spaced, or the "every-other-luminary" technique.
- Reducing the overall amount or level of continuous roadway lighting.
- Replacing traditional lighting elements with energy efficient elements (namely LED lights).
- Increased lighting curfews or "incremental dimming" of roadway or sign lights.
- Using more highly retroreflective of signs or safety markings or experimenting with electroluminescence or photoluminescence.
- Using sensors or other advanced technologies to automate lighting in a more precise way

“During the past decade, several highway agencies have switched off roadway lighting during periods of energy shortages to reduce maintenance and operating costs. However, quite often such lighting was restored when nighttime accidents increased. One fundamental problem with such light reduction techniques was that lighting was reduced or eliminated during the entire nighttime period, rather than only when traffic volume was low. By providing full lighting during periods when volumes are high and the roadway operated near capacity and providing reduced lighting as the traffic decreases, the potential exists for realizing considerable energy savings while still providing the benefits of full lighting at key locations (i.e. intersections) and at key times (i.e., high volume) where driver decision-making is the most critical and the greatest visibility is required.” (Roadway Lighting Design Guide, October 2005, p. 7)

--- Ken Winter, MLIS

DATABASES SEARCHED FOR THIS RSB

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TRIS Online
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Mechanical & Transportation Engineering Abstracts
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Wikipedia
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OVERVIEW

Research Synthesis Bibliographies (RSBs) are “selected listings” of resources on current topics of interest that are organized and distilled from the larger universe of research materials to save the time of VDOT employees or divisions. When available, links to online documents are provided. Selection criteria used by library staff include authority, relevance, and timeliness.

GETTING RESOURCES LISTED HERE

Full text copies of most resources listed in this document are available in the VDOT Research Library’s collections, or through Interlibrary loan, through the Library. In many cases, the Library owns both virtual and hard copies of documents, as well as formats such as CD-ROM.

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INITIAL READING

The following sources (journal articles, research reports, etc.) provide a good starting point for exploring ways to decrease the amount of energy and money used for roadway lighting. All the items listed here are available online, in hard copy from the VDOT Research Library or can be borrowed by the VDOT Research Library from other libraries nationwide on behalf of VDOT patrons.

Roadway Lighting Design Guide

CITATION: Washington, D.C. : American Association of State Highway and Transportation Officials, 2005, xvi, 67 p.

ABSTRACT: This guide replaces the 1984 publication entitled, An Informational Guide for Roadway Lighting ... Two appendices to this document are located online for reference purposes at <http://downloads.transportation.org/lighting.pdf>

ACCESS: Available at the VDOT Research Library, Call No. TK 4188 .A48 2005

Appendix A to Roadway Lighting Design Guide: Literature Review and References and also ***Appendix B: Lighting Basics***

CITATION: Not available.

ABSTRACT: Appendix A is entitled Literature Review and References, and contains information on research studies related to accidents and highway lighting, driver parameters, pavement parameters, and a summary of further references. Appendix B contains an overview of Lighting Basics, including background information on the various issues related to effective highway lighting."--P. 1./ "Publication code: GL-6"/ Includes bibliographical references and glossary

ACCESS: <http://downloads.transportation.org/lighting.pdf>

Energy Conservation in Transportation in Virginia. Alternatives for Energy Conservation in Roadway Lighting

CITATION: M. H. Hilton, 1979. Virginia Highway & Transportation Research; Federal Highway Administration. Pg. 24-p.

ABSTRACT: From a review of some of the possible methods of conserving energy in the operation of roadway lighting, it was concluded that the most favorable alternative would be to convert the existing mercury lighting to the more energy-efficient high pressure sodium lighting. The results of an inventory and analysis conducted by the Virginia Department of Highways and Transportation's Special Lighting Advisory Committee indicated that the conversion of 4,752 interstate system luminaires could yield a present worth savings of \$1.2 million over the average remaining service life of the various installations, assuming the use of available Federal participation. The conversion would require less than 10 years to break even on the total investment. With due consideration being given to traffic operations and safety under the current energy situation, other alternatives were reviewed and placed in order of preference. /FHWA/. Note: Final Reports on Tasks 1, 2, and 4 have been completed and approved.

ACCESS: Available at the VDOT Research Library, Call No. TJ 163.5 .T7 H56 1979

Continuous Freeway Illumination and Accidents on a Section of Rte. I-95

CITATION: M. H. Hilton, 1978. Virginia Highway & Transportation Research, 30-p.

ABSTRACT: Beginning with the oil embargo of 1973-74, highway lighting-and particularly continuous lighting on freeways-became one of the first items to be cut back to conserve energy and revenue. During this period of energy shortage, considerable lighting was turned off in Virginia and in particular the 13.8 km (8.57 mi) section of continuous lighting on I-95 between Springfield and Washington, D.C. By comparing the accident rate ratios for the lights turned off with those for the lights turned on it was found, in an earlier study, that the lighting decreased the

night accident rate on this section of I-95 during the three-month period studied. Subsequently, the lights were reactivated. The study reported here extended that data to cover a six-month period and used a more refined approach in the analysis. For the period including December, January, and February, when heavy traffic volumes are on the I-95 roadway during the early hours of darkness, the lighting was found to be particularly effective in reducing the nighttime accident rate. For the March, April, and May period, when the hours of daylight lengthen, the night accident rate was improved; but the improvement was not found to be significant at the 95% confidence level due, most likely, to the low number of accidents involved in the test. For the overall six-month period it was concluded that the lighting reduced the night accident rate. This finding was significant at the 95% confidence level. Evaluation of the night-to-day accident rate ratios on an unlit control section of I-95 substantiated this finding.

ACCESS: Available at the VDOT Research Library, Call No. TK 4188 .A48 2005

A Comparison of Full and Partial Lighting On Two Sections of Roadway

CITATION: M. H. Hilton, 1980. Virginia Highway & Transportation Research; Virginia Department of Highways. Pg. 21-p.

ABSTRACT: The average illumination levels and uniformity of the lighting were determined on two sections of roadway when all of the lighting was in operation and when the lighting was partially turned off. The illumination on both sections was found to be within the recommended quality and quantity standards when all of the luminaires were in operation. By turning out every third light during the early service life of one study section, a 22% reduction in the average levels of illumination occurred, but the uniformity and minimum average levels of illumination remained within the suggested standards. This finding was probably related to the customary over design of lighting system (with respect to the initial illumination output) to compensate for lamp lumen and dirt depreciation that results from normal continued use. After the lighting had been in service for slightly less than two years, the average levels of illumination had depreciated by 32% with all the lighting in operation. Had one-third of the lighting been turned off at that time, the uniformity of the illumination would not have been acceptable under the standards. Therefore, from the standpoint of quality standards, some reduction in the number of luminaires in operation on new or relamped systems might be acceptable until such time as the depreciation factors compensate for the initial over design.

ACCESS: http://www.virginiadot.org/vtrc/main/online_reports/pdf/80-r52.pdf

Screening Methodology for Needs of Roadway Lighting

CITATION: J. H. Lambert and T. C. Turley, 2003. University of Virginia, Charlottesville; Virginia Department of Transportation; Federal Highway Administration. Pg. 76-p.

ABSTRACT: Screening methods of the American Association of State Highway and Transportation Officials (AASHTO) and the National Cooperative Highway Research Program (NCHRP) that assess the local potential for fixed roadway lighting to decrease nighttime crashes have not been updated since the 1970s. The methods dilute the influence of important factors, are inadequate for locations where crash histories are unavailable, and lack a traceable theoretical foundation. This report evolves and complements existing screening methods in order to develop an updated method to aid engineers and planners in the screening of needs for fixed roadway lighting. Development of the method adopts principles of risk assessment and management that have been previously applied in diverse disciplines. The existing screening methods, which provide a basis for the developed screening method, are strengthened by the development of a theoretical foundation in benefit-cost analysis. The developed method has two phases. In the first phase, an exposure assessment is developed to describe individual and population exposures to crashes. Needs are compared by night-to-day crash rates, measured directly or estimated indirectly, and traffic

volumes. Outcomes of exposure assessment are identified based on potential crash reduction and costs of available lighting technologies. The second phase builds on selected concepts of the NCHRP method. In testing of the two-phase method, night crash histories for over eighty unlighted sections in three regions of Virginia are collected and studied. Example applications of the method to individual locations are demonstrated. The recommendations are as follows: (i) highway agencies should consider designating funds for lighting and visibility enhancement using the developed screening method in resource allocation; (ii) agencies should provide training and continuing education in the developed screening method, and emphasize the unity of principles of risk assessment and management across highway safety issues; (iii) through a testing phase, agencies should consider replacing the AASHTO and NCHRP methods with the developed method; (iv) agencies should perform regional data analysis and screening of unlighted locations on an annual basis; and (v) agencies should incorporate the method in holistic lighting master plans. ACCESS: http://www.virginia-dot.org/vtrc/main/online_reports/pdf/03-cr14.pdf

Highway Lighting Systems: Are They Really Necessary?

CITATION: Anonymous , Better Roads, December 1977.

ABSTRACT: Explores the belief of some highway officials that highway lighting may be unnecessary and that agencies should consider turning it off entirely.

ACCESS: Available at the VDOT Research Library, periodicals section.

Reduced Lighting During Periods of Low Traffic Density

CITATION: M. S. Janoff and L. K. Staplin. , Transportation Research Circular, No. 297, 1985, Pg. p.-9-10.

ABSTRACT: The object of this research is to determine if fixed roadway lighting on freeways can be reduced or eliminated during low volume nighttime periods without causing significant reductions in the ability of drivers to control their vehicles in a safe and effective manner. Specific project goals include developing alternative reduced lighting tactics, examining the costs and potential energy savings of these tactics, determining the potential legal implications of using these tactics, evaluating the effect of these tactics on driver performance, deriving cost-benefit relationships for these tactics, and preparing guidelines for their use.

ACCESS: Available at the VDOT Research Library, Call No. TA 1001.5 .T68 no.297

Reduced Lighting on Freeways During Periods of Low Traffic Density. Final Report

CITATION: L. K. Staplin, M. S. Janoff and L. E. Decina. , 1985. Ketron, Incorporated; Federal Highway Administration. Pg. 56-p.

ABSTRACT: The primary objective of this study was to determine if freeway lighting can be reduced or eliminated during nighttime periods when traffic volume is much lower than design capacity without causing significant reductions in the ability of drivers to control their vehicles in a safe and effective manner. This objective was met by the performance of ten tasks that included a review of the literature and state and foreign experiences; development of a conceptual model of visibility needs; identification of alternative light reduction tactics--including all (luminaires) off, every other off, one side off, and different types and levels of dimming; determination of the costs, potential energy savings, and potential legal implications of such light reduction tactics; and, finally, determination of the effect of such tactics on driver detection of simulated roadway hazards under actual traffic conditions. The major conclusions of this research are that present technology exists for implementing all of the identified tactics, with benefit-to-cost ratios greater than 1.0 for all but the most complex tactics; decrements in driver detection performance were measured under each reduced lighting tactic in comparison to performance under full lighting, minimally so for dimmed and every other configurations and significantly so for one sided and all

off configurations; and, a potential for legal problems may result with the use of reduced lighting tactics. The recommendations arising from this research include the preferred use of fixed dimming circuits, primarily for new systems, with an inexpensive alternative being the extinguishment of every other luminaire for either new or existing systems.

ACCESS: Available through Interlibrary Loan to VDOT employees.

SECONDARY READING AND GENERAL SOURCES

The following items (listed alphabetically, by title) show the range of research that has been conducted on issues surrounding roadway lighting and conservation, including: lighting curfews, LEDs and other energy efficient lighting, solar power, safety issues and warrants for roadway lighting. These sources may be helpful as background.

The 21st Century Lighting Project Based on LED and Phosphor Systems

CITATION: T. Taguchi. , Appearing in: Proceedings of 7th International Display Workshops - IDW'00, 2000. Inst. Image Inf. & Telev. Eng. & Soc. Inf. Display (SID). Kobe, Japan. Pg. 817-20.

ABSTRACT: "The 21st century white lighting" national project, which is based on light-emitting diode (LED) and phosphor systems, was started in 1998 in Japan. The outline and purpose of this project are introduced. Basic illumination properties of two types of lighting sources using phosphor-based white LED are described in detail. We have shown that the street lamp using 1400 units of white LEDs is confirmed to provide a brightness and an illuminance distribution that clearly exceed that displayed by the white incandescent bulb or the fluorescent lamp.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Activation Consistency of Internally Illuminated Pavement Markers

CITATION: Tanya Styles, Peter Cairney, Greg Studwick, et al. , Road and Transport Research, 2004. ARRB Transport Research Ltd. Vol. 13, No. 1, Pg. 85-87.

ABSTRACT: The features and advantages of self-illuminated pavement markers were analyzed. It was found that the solar powered LED illuminated pavement markers which activated in response to environmental conditions improved the road delineation. The tested pavement markers activated in response to the environmental conditions to which they are designed to activate. It was also found that these internally-illuminated markers provided consistent light output from a wide range of viewing angles resulting in a clear indication of road curvature throughout a curve.

Access: Available at the VDOT Research Library, periodicals section.

Adaptive Roadway Lighting

CITATION: Don McLean. , IMSA Journal, 2006. International Municipal Signal Association. Vol. 44, No. 5, Pg. pp-10, 12, 54-48.

ABSTRACT: This article discusses the use of adaptive roadway lighting against the backdrop of the necessity of reducing the energy consumed by passive sources. Adaptive lighting typically involves the use of a regulatory mechanism that allows for minimizing power consumption of such lights during non-peak hours. Lighting levels are typically determined by the amount of pedestrian conflict/activity in a given area. However, such levels are highly variable despite general predictability based on a few factors that include the hour or night, the day of the week, the season, or location of the area in question. Perhaps the most technically sophisticated systems allow operators to remotely control and monitor nearly all aspects of the lighting system in question. Some such features include the operating status of luminaries in a given system, the lumen output, and also potential expansions into wireless technologies. The article also provides brief examples of where such systems are being implemented.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Alert to Dangers

CITATION: Anon. , Highways, 2006. Alad Limited, Rochester, ME2 1BY, United Kingdom. Vol. 76, No. 2, Pg. 47-49.

ABSTRACT: Sequential guiding lamps are used for warning motorists of roadworks and for saving the lives of personnel. Nissen offers mainly two different types of sequential guiding lights that conform to Regulation 55 of the Traffic Signs Regulations 2002 and meet the light output requirement of BS EN 12352:2000. Star Flash, one of the two products, is a dual battery lamp that consists of Super LED. Star Flash automatically activates and synchronises other lamps in a row by activating the (front) first lamp and continue to flash in synchronous manner till the life of batteries. BakoLight which is an advanced sequential warning lamp, is equipped with long-wave receiver containing single Super LED. The receiver of the LED receives the signal from German time signal transmitter DCF 77 in Mainflingen. BakoLight works off a coded signal that automatically synchronises the lamp and maintains the sequential flash over long distances and it can be used at roadworks and incident on motorways.

ACCESS: Available through Interlibrary Loan to VDOT employees.

The Ambient Energy Streetlight

CITATION: M. Crampton. , Lighting Journal (Rugby, England), 2001. Institution of Lighting Engineers. Vol. 66, No. 6, Pg. 14-20.

ABSTRACT: A highly innovative street lighting system combining solar cells, wind generators and liquid crystal displays with a wide range of applications in the industry was developed. The MoonCell street luminaire consisted of solar panels and a small wind turbine, charging storage batteries through a charge management circuit. The batteries powered an array of LEDs that provided the illumination. The design target was the equivalent to the illumination of 150 W sodium lamp at eight meters. The LEDs were measured as consuming 186 mA at 5 V, the electrical energy required to exceed the output of 150 W street light was 0.93 W. Even if the LED lighting remained connected to the mains supply the energy savings was significant.

ACCESS: Available through Interlibrary Loan to VDOT employees.

The Applicability of High Intensity Sheeting on Overhead Highway Signs

CITATION: R. N. Robertson and J. D. Shelor. , 1975. Virginia Highway & Transportation Research. Pg. 28-p.

ABSTRACT: A survey was conducted in Virginia to determine the percentage of overhead signs meeting the criteria, under which the illumination could be eliminated if they were refurbished with high intensity sheeting. Data were collected relative to the installation, energy and maintenance costs for lighting overhead signs. The study concluded that the illumination could be eliminated on approximately 45% of the existing signs and 50% of the proposed signs through the use of high intensity reflective materials. The benefits anticipated from the implementation of the program include enormous money and energy savings, a significant reduction in the exposure of maintenance personnel to hazardous working conditions, and improved services to the motorists.

ACCESS: Available at the VDOT Research Library, Call No. HE 370 .R52 1975

The Application of LEDs in Lighting Technique and Traffic Lighting

CITATION: W. Pabjanczyk. , Przegląd Elektrotechniczny, 2003. SIGMA NOT. Vol. 79, No. 4, Pg. 229-33.

ABSTRACT: A general review of technological changes of LEDs is presented in this paper together with the most important features of them and a possibility of their usage in lighting techniques. Some domain of LED's applications in illumination are shown as well.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Application of White LED Lighting to Energy-Saving Type Street Lamps

CITATION: T. Taguchi, Y. Uchida, T. Setomoto, et al. , Appearing in: Light-Emitting Diodes: Research, Manufacturing, and Applications V, Proceedings of the SPIE - The International Society for Optical Engineering, 2001. SPIE-Int. Soc. Opt. Eng. San Jose, CA, USA. Vol. 4278, Pg. 7-12.

ABSTRACT: We describe the lighting characteristics and systems of the power energy-saving type street lamp which consists of white light-emitting diodes (LEDs), and a solar-cell and battery system. The prototype street lamp has been constructed by two LED light sources, each of which includes a total of 700 units of 10 cd-class white LEDs. The white LED lighting system is mainly divided into three components which are the control, the electric-power supply and LED lighting divisions. The illuminance is normally 80 lx. When a person approaches within 2m of the lamp, it is detected by the body sensor and the illuminance then increases to about 660 lx, which is about 50 times brighter than that of a white incandescent lamp. The color rendering index is estimated to be 85 which is similar to that of the three color fluorescent tube. The illuminance distribution can be analyzed by our recently developed "multi sources of LED light" theory.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Applications for Advanced Solid-State Lamps

CITATION: S. Peralta and H. Ruda. , IEEE Ind.Appl.Mag., 1998. IEEE. Vol. 4, No. 4, Pg. 31-42.

ABSTRACT: Since lighting accounts for a large fraction of electrical usage in the industrial sector, the energy efficiency of lamp systems is of major interest. One promising technology which has the potential for use in specialised energy-efficiency lighting applications is solid-state lamp technology. There are many reasons solid-state lamps may be especially useful for new applications. They exhibit long lifetimes, in the order of 100000 hours. Coupled with the ruggedness inherent in solid-state devices, this indicates usefulness for low maintenance applications. Fast response times also make them ideal for some applications. This review surveys the state-of-the-art in solid-state semiconductor lamp technology, with a focus on the potential for such applications, and on energy efficiency and brightness considerations. The different types of solid state light source are described: LED, diode lasers, superluminescent diodes and electroluminescent diodes. Their operating characteristics are discussed and the following applications described: illuminated signs, exit-signs, traffic control lights, airport runway lighting, vision sensors illumination, spotlighting, interactive and fast adaptive lighting and fibre-optic channeled lighting.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Back to Basics : Cutting Through the LED Alphabet Soup

CITATION: Vincent C. Forte and David Martin. , Traffic Technology International. Annual review, 1998. Surface Systems, Inc.; Nu-Metrics; TIR Systems; Valtron OInc.; Dialight Corporation; ComFuture Ltd.; Excellence Optoelectronics; Pulnix America; Golden River Traffic Limited; Redflex Traffic Systems; Truvelo; Jai Vision; MeterVision; Hewlett-Pac(TRUNCATED). Pg. p.-160-162.

ABSTRACT: This article gives an overview of the structure and technology behind light emitting diodes (LED). It describes the material and structure of LEDs, the wavelengths that are used, production method, and colors that are achieved.

ACCESS: Available at the VDOT Research Library, periodicals section.

Bright Future For Leds : The High-Brightness LED Is Gaining Momentum

CITATION: James Foster. , ITS international. Vol.7, Issue no.4, 2001. Pg. p.-58-59.

ABSTRACT: This article focuses on high-brightness light emitting diodes (LED) looking at how the technology has seen increased applications in Intelligent Transportation Systems (ITS). The lights are being used in center high-mounted stop lights in automobiles, traffic signals variable message

signs (VMS), and in the general illumination market. ACCESS: Available at the VDOT Research Library, periodicals section.

A Bright Future: Light-Emitting Diodes, Already in Use as Taxiway Edge Lights, Hold Promise as a More Efficient, Effective Choice for Runway Lighting

CITATION: Richard Klein and Sangam Napat. , Airport Magazine, 2007. AAAE Service Corporation, Incorporated. Vol. 19, No. 2, Pg. pp-22-25.

ABSTRACT: Traditional airport runway lighting-usually halogen or incandescent bulbs or flashtubes-is becoming more expensive and less efficient. The authors discuss efforts by airports to install light emitting diodes (LEDs) for taxiway lights and runway edge lights for runway operation cost reduction and safety increases. (LEDs currently do not meet federal full-scale runway lighting application standards.) LEDs have an 8-10 year lifespan, require almost no repair or maintenance, and are energy efficient and extremely durable. They also are able to demonstrate special features through an instantaneous and very responsive on-off property.

ACCESS: Available to VDOT employees through Interlibrary Loan.

The Bright Lights: Energy-Saving LEDs Highlight Major Louisville Airside Upgrades

CITATION: Carroll McCormick. , Airports International, 2006. Key Publishing, Limited. Vol. 39, No. 4, Pg. pp-31-33.

ABSTRACT: This article describes Louisville International Airport's experience upgrading its runway lighting with 447 Light Emitting Diode (LED) taxiway edge lights. The upgrade allows the airport to reduce energy demand, thereby reducing pollution from local power plants. Another 400 LEDs are expected to be installed. Each LED consumes eight watts of electricity versus 30-watts for the quartz lights they replace. In addition, the LED is designed to last 57,000 hours compared to 1,000 for the average quartz light. The article describes the type of fixtures chosen and why, and how the upgrade was handled. In addition, it describes several other airports that have installed LEDs.

ACCESS: Available to VDOT employees through Interlibrary Loan.

CALTRANS Flexes Its Power

CITATION: S. C. Prey. , California Department of Transportation Journal, 2001. California Department of Transportation; California Department of Transportation. Vol. 2, No. 3, Pg. 3-p.

ABSTRACT: The California Department of Transportation (Caltrans) reduced agency-wide energy consumption by 21% in response to threats of rolling blackouts in 2001. More energy-efficient facilities such as the new building in downtown Oakland are one source of savings. Another is the award-winning light-emitting diode (LED) traffic signal upgrade effort, which, when complete, will reduce signal grid demands by 92%. Lighting plans can make better use of lights, conserve energy and make roadways safer by reducing the number of poles and fixtures. The department also contracted with a private company to conduct energy audits and implement efficiencies under a savings-sharing system. After examining other areas, such as bridge and tunnel lighting, bulk energy procurement and roadway sign lighting, Caltrans has identified about \$181 million over 10 years in savings.

ACCESS:

http://www.dot.ca.gov/dist07/aboutdist7/pubs/journals/Nov_Dec_2001/Journal%20Nov_Dec%202001.pdf

Characteristics of High-Efficiency InGaN-Based White LED Lighting

CITATION: Y. Uchida, T. Setomoto, T. Taguchi, et al. , Appearing in: Display Technologies III, Proceedings of the SPIE - The International Society for Optical Engineering, 2000. SPIE-Int. Soc.

Opt. Eng. Taipei, Taiwan. Vol. 4079, Pg. 120-6.

ABSTRACT: The basic illumination characteristics of an efficient white LED lighting source, which is composed of cannon-ball type 10 cd-class InGaN-based white LEDs, are described. It is noted that the temperature and forward-bias current dependence under full wave rectification of AC 100 V gives a significant effect to both electroluminescence properties and luminous efficacy. We have obtained a maximum luminous intensity of 95000 cd/m² and a luminous efficacy of about 27 lm/W at a power of 20 W (constant current of 10 mA). The developed white LED lighting source indicates two injection electroluminescence peaks at 465 and 555 nm, which originated from a blue LED and a YAG:Ce³⁺ phosphor, respectively. The illuminance distribution of the LED lighting source was analyzed using our "multi sources of LED light" theory. We have performed the design of a street lighting as a practical application using the 700 LEDs array lighting source.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Continuous Freeway Illumination

CITATION: R. P. JOHNSON and T. N. Tamburri. , 1965. California Division of Highways.

ABSTRACT: the effectiveness of continuous highway illumination, particularly on freeways, in reducing nighttime accidents is evaluated. Three indirect procedures used were comparison of the ratio of the number of day to nighttime accidents of two illuminated freeways versus these ratios on non- illuminated freeways /partially illuminated at interchanges/ , comparison of illuminated and nonilluminated freeways considered to be similar in design and comparable average daily traffic, and comparison of the accidents occurring between 5 p.m. and 7 p.m. in June, which is daylight, versus accidents occurring between the same hours in December, which is dark, on both illuminated and nonilluminated freeways. Accident data on the freeways in Los Angeles County from Jan, 1960 through June 30, 1962 were utilized. The illuminated freeways studied had average maintained levels of illumination ranging from 0.20 footcandles to 0.35 footcandles which is approximately 1/2 of the recommended level of illumination by AASHO. The study did not show conclusively that illumination is not beneficial or that it is beneficial in reducing night accidents. There was some indication that continuous illumination was reducing accidents not involving fixed objects and was increasing the fixed object accidents primarily due to the disproportionate frequency of light pole collisions. The frequency of light pole collisions was attributed to the dark color of the light poles and their closeness to the pavement edge. Perhaps the most meaningful results of the study were obtained from the comparison of the number of accidents occurring in June to those occurring in December. From this investigation it was found that darkness is a causative factor and that artificial illumination did not completely counteract the effects of darkness. Day-night accident ratios were found to be approximately the same for illuminated freeways as for nonilluminated freeways /partially illuminated/. The ratio of day to night accidents increases with increasing total day traffic volume even though the ratio of day to night travel remained approximately constant. The illuminated freeways had nighttime and daytime accident rates which were considerably higher than the rates for the same categories on the nonilluminated freeways, both in the injury plus fatal accident and the property damage accident only categories.

ACCESS: Available at the VDOT Research Library, Call No. HE 5614.4 .L6A52 1965

Cost Savings Continue to Drive The 'Green' Agenda on the Streets

CITATION: Emma Clarke. , Traffic Engineering and Control, 2007. Hemming Group Ltd, London, SW1V 2SS, United Kingdom. Vol. 48, No. 7, Pg. 301-303.

ABSTRACT: Kent County Council will engage in a major traffic signal overhauls and will commit &#pound;1.8M to replace every traffic signal head with new 3G light emitting diode signals from TSUK. Every signal head and illuminated push button will be changed and the plan is to finished the 600 plus site by the end of this financial year. Addressing climate, environmental and energy

efficiency issues, LED signals guarantee a 70% power reduction equating to a saving of & pound; 360,000 pounds a year. Other related projects on alternative energy signs include installation of solar-powered signs, wind-powered signs, electroluminescent traffic signs, and improved road delineation and intelligent road studs using solar-powered LEDs.

ACCESS: Available at the VDOT Research Library, periodicals section.

Costs, Benefits, and Legal Implications of Reduced Freeway Lighting

CITATION: M. S. Janoff and L. K. Staplin. , APWA Reporter, 1984. American Public Works Association; American Public Works Association. Vol. 51, No. 10, Pg. p.-16-17.

ABSTRACT: A group of lighting experts were asked to rate various reduced lighting systems with respect to potential effects on energy use, safety, other traffic operations, practicality, cost, and legal problems. Both older, oil-embargo related systems, such as turning off the lights on all or part of specified roadways during various time periods, and modern systems controlled by special ballasts, electronic sensors and controls, and computers were studied. The simplest (all off) tactic and dimming 50 percent after midnight scored highest, followed by two luminaires per pole, one side of, variable level lighting as a function of traffic volume, and every other light out after midnight. Simple systems had high benefit/cost ratios, while more sophisticated systems scored higher in safety results and legal implications. A review of court cases and the legal literature indicates municipal agencies would be liable for damages incurred as a result of reduced lighting. It is therefore imperative that the decision to reduce lighting be based on sound scientific information encompassing foreseeable contingencies.

ACCESS: Available at the VDOT Research Library, periodicals section.

Design and Development of 24 V, 150 W Photovoltaic Modules

CITATION: S. Ravi, N. Anaiida Rao, S. R. Krishnamurthy, et al. , BHEL Journal, 2005. Bharat Heavy Electricals. Vol. 26, No. 2, Pg. 1-8.

ABSTRACT: Solar photovoltaic (PV) modules (single crystalline silicon-based) are manufactured by electronics division of BHEL, Bangalore, for various applications such as electric power generation, street lighting, domestic lighting, water pumping, railways & road traffic signalling and telecommunication, BHEL has successfully installed and commissioned a large number of grid-interactive PV power plants of the order of 100 kW (typical) capacity, in various islands such as Lakshadweep, Mousini (West Bengal), Andaman and Nicobar. A typical 100-kW PV power plant consists of 1340 PV modules of 75 W rating each connected in series-parallel configuration, and each module having a rating of 12 V with 36 solar cells wired in series. However, deployment of a large number of PV modules in the field renders the plant installation and servicing cumbersome and costly, especially in remote locations. A larger size and rating PV module is an answer to lowering the overall power plant installation and maintenance cost. This paper reports the evolution of a 24 V, 150 W PV module designed & developed by BHEL, and its evaluation for deployment in 100 kW PV power plants. This development enables reduction in the number of PV modules from 1340 to 670 per 100 kW PV power plant, with die modules configured in such a way that the installation and maintenance efforts are eased to a great extent. Various design features including the optimisation of the process parameters that led to the fabrication of high-efficiency solar cells required for such PV modules, are also discussed.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Design of Efficient Illumination Systems

CITATION: Anonymous , Appearing in: Design of Efficient Illumination Systems, Proceedings of the SPIE - The International Society for Optical Engineering, 2003. SPIE-Int. Soc. Opt. Eng. San Diego, CA, USA. Vol. 5186, No. 1.

ABSTRACT: The following topics are dealt with: LEDs and lightpipes (including: LED applications for illumination; colored LED sources; lightpipe illumination system); lightpipes and displays (including: TIR lens for conformal luminaires; illumination design for DMD systems; projection system; DLP panel); daylighting and artificial lighting; beam pattern homogenization; etendue illumination system.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Design of Photovoltaic Charger of LED Street Lamp for Intelligentized Community

CITATION: Zhang Jun-jun, Sun Pei-shi and Liang Hai-tao. , Chinese Journal of Power Sources, 2007. Tianjin Inst. Power Sources. Vol. 31, No. 2, Pg. 157-9.

ABSTRACT: A new design for high-power photovoltaic charger of LED street lamp for intelligentized community was given; working characters of LED and solar battery, and main circuit topological structure of the photovoltaic charger were shown. Control strategy and maximal power point tracking (MPPT) were analyzed based on PIC16F874 CMOS chip that was produced by Microchip Company. Lastly, circuit principle figure and control principle figure for the photovoltaic charger were given. The actual working shows that the photovoltaic charger of LED street lamp has excellent performance. Note: M1: Copyright 2007, The Institution of Engineering and Technology.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Development of a Tool for Analyzing the Performance of Solar-Powered LED Night Delineator

CITATION: R. C. Smith and M. SAITO. , Appearing in: Applications of Advanced Technologies in Transportation Engineering. Proceedings of the Eighth International Conference, 2004. American Society of Civil Engineers. Pg. p.-340-344.

ABSTRACT: Internally illuminated, photovoltaic have been used today in many parts of the world. Unfortunately, some of these devices have been misapplied to locations where there is not enough sunlight to adequately meet their output needs. In order to prevent such misapplications, a tool named the Solar Calculator, was developed. The spreadsheet-based Solar Calculator program determines whether or not a particular internally illuminated, photovoltaic device, programmed for night application is likely to possess the power management needs of a given location. The Solar Calculator synthesizes weather and sunlight patterns for any given location, determines how well a particular device will perform under the simulated weather conditions, and displays the results in interactive figures. When used in coordination with a GIS, device performance can be displayed over a region, allowing the user to determine exactly where the particular device should and should not be applied.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Development of LED Display Devices and Their Applications

CITATION: Kazuhisa Murata. , Shapu Giho/Sharp Technical Journal, 1991. No. 50, Pg. 63-67.

ABSTRACT: As higher luminous efficiency of LED has been achieved, much attention has been given to the LED for indoor/outdoor information boards and road signs. We have developed common-anode dichromatic LED and solid state lamps for large scale outdoor sign boards. Currently developed blue LED is not sufficiently luminous for outdoor use, but enough luminance has been obtained for red and green LEDs for the same application. In this paper, we introduce the technique of highly luminous LED outdoor display devices and their applications.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Development of the Integrated Circuits for Road Sign Illuminated By Using the White Light Emitting Diode With The Solar Cell

CITATION: T. Tanaka, A. Yujiri, H. Arakawa, et al. , Bulletin of Hiroshima Institute of Technology Research Volume, 2003. Hiroshima Inst. Technol. Vol. 37, Pg. 1-4.

ABSTRACT: The development of an integrated circuit for a road sign illuminated by using a white light emitting diode (LED) with a solar cell was demonstrated. This road sign consisted of the solar cell, road sign, controller, and battery, and was installed at Kenkyu Seika Katsuyou Plaza, Hiroshima, in October 2002. The electrical power consumption for lighting the road sign with a white LED using a block duty circuit was low - down to about 3 W, and this value is 1/3 compared with static operation. As a result of using the block duty circuit, the size of the solar cell becomes 1/3, and the capacity of the battery becomes 1/2.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Dynamic Road Marking Module Using Chip-On-Board Phosphor-Converted White LEDs With Application-Specific Primary Optics

CITATION: E. Lenderink and A. H. M. Raaijmakers. , Appearing in: Tenth International Symposium on the Science and Technology of Light Sources, 2004. Inst. of Phys. Toulouse, France. Pg. 229-30.

ABSTRACT: An improved design for a DRM light module that makes use of "chip-on-board" LEDs is shown, instead of standard LED packages. The primary optics of the LEDs is designed specifically to meet the beam shape requirements of the application. Different optics designs are used depending on the precise function of the road marking: on highways, the marking must be visible from long distances and at small angles; at intersections, they must be visible from short distances and at large angles.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Eco-Friendly?

CITATION: Tom Allett. , Airports International, 2008. Key Publishing, Limited. Vol. 41, No. 3, Pg. pp-34-35.

ABSTRACT: This article provides an overview of how airports worldwide are working towards reducing their emissions. In the U.K., East Midlands Airport is aiming to be carbon neutral by 2012. Part of its efforts include the installation of wind turbines to generate electricity, an achievement that has already been done at Liverpool John Lennon Airport. In Europe, Stockholm-Arlanda Airport's buildings are almost solely heated with biofuels. Zurich Airport is using eco-friendly de-icing effluents, while Munich Airport receives electricity generated from solar roof panels. In Boston, Logan's Terminal A was the first U.S. airport terminal to receive certification for its green technology. Vancouver International Airport receives hot water at its domestic terminal from solar roof panels. Changi Airport in Singapore uses energy-saving skylights and features a butterfly garden and foliage in its open areas. In closing, the article discusses the use of LED lights on airfields, touting them for their energy saving aspects and longer working lives.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Economical Production of Heat Sinks For LEDs

CITATION: L. Posca. , Kunststoffe International, 2007. Carl Hanser Verlag GmbH & Co. KG. Vol. 97, No. 5, Pg. 64-6.

ABSTRACT: Compact and rugged LEDs can be found everywhere today-whether in automotive head-lights, street lamps, traffic signals or office and household lighting. The latest products have an injection moulded and FEA-optimised heat sink design made of a thermally conductive plastic compound can streamline LED production. A ceramic powder-filler polyamide 12 contributes to

economical and cost-effective production of LED lighting.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Effect of Reduced Freeway Lighting On Driver Performance

CITATION: Michael S. Janoff and Loren K. Staplin. , Journal of the Illuminating Engineering Society, 1985. Vol. 15, No. 1, Pg. 159-166.

ABSTRACT: This paper presents the results of an experiment that was designed to determine the effect on driver performance of reducing or eliminating freeway lighting during periods of low traffic density. Five different light reduction techniques were employed: uniform dimming of all luminaires (two levels); extinguishing every other luminaire; extinguishing all luminaires on one side (of two) of the roadway; and all luminaires extinguished. A significant decrement in driver's ability to detect a simulated hazard on an urban freeway under normal traffic conditions was associated with incremental reductions in lighting; the uniform dimming techniques caused the smallest reductions in performance, followed by the every other luminaire tactic. The one-sided and total elimination tactics led to the greatest decrements in performance.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Effect of Street Lighting On Night Traffic Accident Rate

CITATION: E. Lozano and F. D. Wyatt. , Highway Research Board Bulletin, 1957. Highway Research Board. No 146, pp 51-55.

ABSTRACT: studies have been reported on determination of effect of illumination of a roadway upon the night time accident rate. By careful analysis of traffic accident records, it is possible to show that accident rates at night are decreased as a result of improved lighting conditions. By examination of traffic accident reports received from the traffic section of the Chicago Park District, it is possible to show graphically the value and importance of higher levels of street lighting in reducing the night time accident rate. Various before and after diagrams are shown. These indicate the fatal and non-fatal night accidents that were saved as the result of improved lighting. Factors that would cause a variation of the night time accident rate are traffic volume and level of illumination. It is concluded that in a period of less than 5 years, the complete cost of relighting all boulevards would be balanced by the savings in night time accidents.

ACCESS: Available at the VDOT Research Library, Call No. TA 1001.5 .T7 no. 146

Effectiveness of Highway Arterial Lighting. Design Guide

CITATION: M. S. Janoff, B. Koth, W. McCunney, et al. , 1977. Franklin Institute. Pg. 177-p.

ABSTRACT: This research was undertaken to evaluate the cost-benefits of arterial lighting treatments in terms of traffic safety and energy use. As a result, a Design Guide has been developed to assist potential users in conducting cost-benefit analyses of lighting changes at specific locations. This Design Guide provides instructions for using a computer program to determine visibility on arterial streets and a method for conducting a cost-benefit analysis of new and upgraded lighting systems. In addition to this Design Guide, a Final Report (FHWA-RD-77-37) has been prepared to summarize the results of this research. The results have shown that arterial streets with high population density, in CBD areas, with low visibility have higher accident potential than arterial streets with low population density, in Other areas with high visibility. Regression equations have been developed which predict dry, nighttime accident potential based on population density, area type and visibility. In addition, the results have also shown that more cost beneficial lighting systems can be designed using HPS rather than Mercury luminaires.

ACCESS: Available at the VDOT Research Library, Call No. TE 228 .E32 1977 v.1

The Effects of Reducing Continuous Roadside Lighting to Conserve Energy: A Case Study

CITATION: S. H. Richards. , SAFE J., 1979. SAFE Association; SAFE Association. Vol. 9, No. 1, Pg. p.-24-26.

ABSTRACT: In early 1973, the continuous roadway lighting on the main lanes of Interstate 35 through Austin, Texas, was reduced by approximately 50 percent as a power-saving measure in response to a critical area energy shortage. Analyses of accident data revealed that this reduction in roadway lighting significantly increased the frequency, rate, and severity of nighttime accidents in the affected freeway sections. The most notable increases were associated with a sharp rise in nighttime rear-end and pedestrian-related accidents. The cutback in roadway lighting saved approximately 450,000 KWH of electrical power per year, enough to maintain 20 all-electric homes of average size for the same time period. In terms of energy cost savings to the City, this reduction amounted to \$25,000 per year. In addition, a savings of \$1,250 per year in lamp replacement costs was achieved through the cutback. However, accident cost increases after the lighting reduction were conservatively estimated to be just under \$17,000 per year. Public reaction to the lighting cutback, generally speaking, was apathetic. The findings of this study were forwarded to the City of Austin in 1975 and, last year, full use of the roadway lighting on Interstate 35 was resumed. Although positive energy conservation gains were made through the lighting cutback, these gains were offset by a measurable decrease in motorist safety.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Energy Conservation Through the Use of More Efficient Outdoor Lighting

CITATION: Anonymous , Public Works, 1980. Thomson Publications South Africa Proprietary Ltd; Public Works Journal Corporation. Pg. p.-48-50.

ABSTRACT: Factors affecting the efficiency of street lighting systems and the advantages of high pressure sodium lamps are reviewed.

ACCESS: Available at the VDOT Research Library, periodicals section.

Energy Considerations in Fixed and Vehicular Lighting

CITATION: Anonymous , Transportation Research Circular, 1981. Transportation Research Board. No. 228, Pg. 9-p.

ABSTRACT: National concern has been focused on energy consumption and conservation. While energy consumption resulting from operation of fixed and vehicular lighting represents only a minute percentage of United States energy use, every effort should be made to reduce consumption by these factors as well as others involved in this national effort. Over the past several years, a substantial number of papers have been presented concerning energy efficiencies and benefits of fixed roadway lighting. Comparatively speaking, practically no papers have discussed the energy efficiencies of vehicular lighting systems. It is the purpose of this report to summarize the results of past studies relating the energy consumption and benefits of fixed roadway lighting and vehicular lighting. The emphasis of this circular will be on the current benefit status of these two modes of roadway lighting with recommendations for implementation of the most energy efficient system.

ACCESS: Available at the VDOT Research Library, Call No. TA 1001.5 .T68 no.228

Energy Efficiency Arrives at the Pittsburgh Tunnels

CITATION: Ken Thorton and Chris Peterson. , APWA Reporter, 2008. American Public Works Association. Vol. 75, No. 7, Pg. pp-66-67.

ABSTRACT: This article is a case study of the implementation of energy efficient ventilation systems in Pittsburgh tunnels. Due to the age of the tunnels, the ventilation systems were expensive to maintain and run. The Pennsylvania Department of Transportation (PennDOT)

volunteered for the Strategic Environmental Management Program (SEMP), which investigated the environmental effects of all divisions, and led to the purchase of the new tunnel fan motors. The new motors use fewer amps, and have infinitely variable speeds instead of just high, medium, and low. The speed is also automatically adjusted depending on carbon monoxide levels. These new fans have saved PennDOT \$215,000 per year by cutting energy demands and repair costs. ACCESS: Available at the VDOT Research Library, periodicals section.

Energy Management in Municipal Street Lighting

CITATION: Anonymous , 1977. Massachusetts Department of Community Affairs; Department of Housing and Urban Development. Pg. 100-p.

ABSTRACT: This report presents strategies to reduce the energy used in street lighting and, at the same time, reduce or stabilize the cost of street lighting to municipalities. Note: Sponsored in part by Department of Housing and Urban Development, Washington, DC. Office of Policy Development and Research.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Evaluation of Inorganic and Organic Light-Emitting Diode Displays for Signage Application

CITATION: Pratibha Sharma and Harry Kwok. , Appearing in: Sixth International Conference on Solid State Lighting, 2006. International Society for Optical Engineering, Bellingham WA, WA 98227-0010, United States. San Diego, CA, United States. Vol. 6337, Pg. 63371.

ABSTRACT: High-brightness, inorganic light-emitting diodes (LEDs) have been successfully utilized for edge-lighting of large displays for signage. Further interest in solid-state lighting technology has been fueled with the emergence of small molecule and polymer-based organic light-emitting diodes (OLEDs). In this paper, edgelit inorganic LED-based displays and state-of-the-art OLED-based displays are evaluated on the basis of electrical and photometric measurements. The reference size for a signage system is assumed to be 600 mm \times 600mm based on the industrial usage. With the availability of high power light-emitting diodes, it is possible to develop edgelit signage systems of the standard size. These displays possess an efficacy of 18 lm/W. Although, these displays are environmentally friendly and efficient, they suffer from some inherent limitations. Homogeneity of displays, which is a prime requirement for illuminated signs, is not accomplished. A standard deviation of 3.12 lux is observed between the illuminance values on the surface of the display. In order to distribute light effectively, reflective gratings are employed. Reflective gratings aid in reducing the problem but fail to eliminate it. In addition, the overall cost of signage is increased by 50% with the use of these additional components. This problem can be overcome by the use of a distributed source of light. Hence, the organic-LEDs are considered as a possible contender. In this paper, we experimentally determine the feasibility of using OLEDs for signage applications and compare their performance with inorganic LEDs. Passive matrix, small-molecule based, commercially available OLEDs is used. Design techniques for implementation of displays using organic LEDs are also discussed. It is determined that tiled displays based on organic LEDs possess better uniformity than the inorganic LED-based displays. However, the currently available OLEDs have lower light-conversion efficiency and higher costs than the conventional, inorganic LEDs. But, signage panels based on OLEDs can be made cheaper by avoiding the use of acrylic sheet and reflective gratings. Moreover, the distributed light output and light weight of OLEDs and the potential to be built inexpensively on flexible substrates can make OLEDs more beneficial for future signage applications than the inorganic LEDs. Note: Compilation and indexing terms, Copyright 2008 Elsevier Inc.; T3: Proceedings of SPIE - The International Society for Optical Engineering.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Evaluation of Light-Emitting Diode Lamps: A Report to the City of Albuquerque

CITATION: M. Brown. , Appearing in: Solid State Lighting and Displays, Proceedings of the SPIE - The International Society for Optical Engineering, 2001. SPIE-Int. Soc. Opt. Eng. San Diego, CA, USA. Vol. 4445, Pg. 49-59.

ABSTRACT: Sandia assessed white LED lamps for parking lot, security and bike path lighting for the City of Albuquerque. Powering these lamps with photovoltaics was of particular interest to the city. Eight commercially available lamps were tested; one was AC and all others were 12-volt DC. Because DC-only photovoltaic systems do not regulate output voltage, a 12-volt nominal photovoltaic system can see a voltage range from 10.5-15.3 volts. Therefore, the LED lamp must be specified for the DC voltage range expected with a photovoltaic system. We found several failed lamps at the high voltage range of our test, which is below voltages that can be seen in the field. In addition, LED lamps need to be more powerful and cost competitive, and temperature and lifetime issues need to be addressed in order to be more widely useful with photovoltaic systems for illumination applications. We concluded that presently available white LED lighting powered by photovoltaics could be considered for bike path lighting applications where the area is remote, or for security lighting in areas that are difficult to access. We do not recommend LED lamps for much larger flux levels such as parking lot lighting at this time.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Evaluation of Light-Emitting Diodes for Signage Applications

CITATION: J. P. Freyssinier, Yutao Zhou, V. Ramamurthy, et al. , Appearing in: Third International Conference on Solid State Lighting, Proceedings of the SPIE - The International Society for Optical Engineering, 2004. SPIE-Int. Soc. Opt. Eng. San Diego, CA, USA. Vol. 5187, No. 1, Pg. 309-17.

ABSTRACT: This paper outlines two parts of a study designed to evaluate the use of light-emitting diodes (LEDs) in channel-letter signs. The first part of the study evaluated the system performance of red LED signs and white LED signs against reference neon and cold-cathode signs. The results show a large difference between the actual performance and potential savings from red and white LEDs. Depending on the configuration, a red LED sign could use 20% to 60% less power than a neon sign at the same light output. The light output of the brightest white LED sign tested was 15% lower than the cold-cathode reference, but its power was 53% higher. It appears from this study that the most efficient white LED system is still 40% less efficient than the cold-cathode system tested. One area that offers a great potential for further energy savings is the acrylic diffuser of the signs. The acrylic diffusers measured absorb between 60% and 66% of the light output produced by the sign. Qualitative factors are also known to play an important role in signage systems. One of the largest issues with any new lighting technology is its acceptance by the end user. Consistency of light output and color among LEDs, even from the same manufacturing batch, and over time, are two of the major issues that also could affect the advantages of LEDs for signage applications. To evaluate different signage products and to identify the suitability of LEDs for this application, it is important to establish a criterion for brightness uniformity. Building upon this information, the second part of the study used human factors evaluations to determine a brightness-uniformity criterion for channel-letter signs. The results show that the contrast modulation between bright and dark areas within a sign seems to elicit the strongest effect on how people perceive uniformity. A strong monotonic relationship between modulation and acceptability was found in this evaluation. The effect of contrast seems to be stronger than that of spatial frequency or background luminance, particularly for contrast modulation values of less than 0.20 or greater than 0.60. A sign with luminance variations of less than 20% would be accepted by at least 80% of the population in any given context.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Evaluation of Roadway Lighting Systems Designed by Small Target Visibility (STV) Methods

CITATION: B. Green, O. Culvacı, S. Senadheera, et al. , 2002. Vol. REPT017048; TX97017048; PB2003103794,

ABSTRACT: The project's objective is to evaluate the design of roadway lighting systems by the Small Target Visibility (STV) method and determine if it is indeed a practical, worthwhile design methodology and should be adopted by the TxDOT. This evaluation will compare STV to current design methods and assess the potential liability associated with making the change. The project consists of seven tasks. The first is to conduct a comprehensive, international review to identify roadway lighting issues and their relationship to accident reduction potential. The review will also include a search for risk management and tort liability issues that relate to the subject. Tasks 2, 3, and 4 involve the development of experiments to establish a benchmark of empirical data from which to evaluate STV and compare it with current design methods. Task 5 is the synthesis of the first four tasks into a formal plan of experiments and the conduct of those experiments directed by the Project Director. Task 6 consists of further experimental work as well as detailed analysis of the impact of STV on the Department's lighting design program, and a recommendation of STV standards language and design and construction tolerances. Task 7 is a comprehensive final report.

ACCESS: Available at the VDOT Research Library, Call No. TE 228 .E9384 1998

Evaluation of Solar Powered Median Markers

CITATION: Research in progress, start date: 2005/7/1, end date: 2008/1/31. Organization: Oregon Department of Transportation. Project Manager: Ross, June H., june.h.ross@odot.state.or.us

ABSTRACT: This project is being undertaken to evaluate the potential for future use of solar powered markers on raised medians on the Oregon Highway System. The markers are intended to provide an additional tool to guide drivers. The proposed research will determine if solar powered markers perform as designed over a period of time when exposed to rain, snow, fog, sun light, etc. The results of the research will help the Oregon Department of Transportation (ODOT) determine if the use solar powered median markers should be considered in Oregon.

ACCESS: http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/2007/FHWA-OR-RD-08-07.pdf

Evaluation of Solar-Powered Raised Pavement Markers

CITATION: June H. Ross, Eric W. Brooks and Carl K. Andersen. , 2008. Oregon Department of Transportation; Federal Highway Administration. Pg. 84p.

ABSTRACT: An evaluation of a limited number of solar-powered raised pavement markers (SRPMs) was conducted to determine if this type of marker would be more visible than retroreflective markers in some situations on Oregon highways. SRPMs typically use Light Emitting Diodes (LEDs) that are powered by solar cells. Some markers have retroreflective surfaces as well. The Oregon Department of Transportation, Research Unit, performed preliminary tests which included environmental tests (extreme temperatures, immersion), optical performance tests, and observation tests. Selected markers were sent to the Federal Highway Administration's Photometric and Visibility Laboratory (PVL) at the Turner-Fairbank Highway Research Center in McLean, Virginia for additional evaluation. A series of tests was performed to measure both the LED signal and the retroreflected light. It was found that each type of marker had significant shortcomings, so the project was terminated prior to field trials being performed.

ACCESS: http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/2007/FHWA-OR-RD-08-07.pdf

Experiences With ELV Traffic Systems

CITATION: Keith Manston. , Traffic Engineering and Control, 2007. Hemming Group Ltd, London, SW1V 2SS, United Kingdom. Vol. 48, No. 8, Pg. 343-345.

ABSTRACT: Recent developments in LED signals, resulting in lower power consumption and increased reliability, have allowed the development of a new generation of traffic control systems offering Extra Low Voltage (ELV) to be used for all on-street signals and related equipment. This paper reviews the benefits of using ELV 'on-street' and discusses the results of the first ST900 ELV trial installations, installed earlier in the summer. It concludes that despite some minor limitations when very long cable runs are required, the experience to date has been very positive. Note: Compilation and indexing terms, Copyright 2008 Elsevier Inc.

ACCESS: Available at the VDOT Research Library, periodicals section.

Freeway Accidents and Illumination

CITATION: P. C. Box. , Highway Research Record, 1972. Highway Research Board. No. 416, Pg. p.-10-20.

ABSTRACT: the findings of a study of freeway accidents and illumination are reported. The time during which ambient light conditions are such that typical roadway illumination would have an effect was found to be from 15 min after sunset to 15 min before sunrise. Lighted freeways were found to have lower (better) night-day accident ratios than unlighted ones. The lighted freeways with the lowest illumination, averaging 0.6 horizontal footcandles maintained, had the best accident ratio. This corresponds to an initial illumination design level of about 1.0 hfc. A wide variation was found in average illumination between adjacent pairs of luminaires along specific freeway sections. This was found to be principally a result of differences in individual lamp output. The variations of hfc averages and uniformity are so great as to cast doubt on the real value of these elements in lighting design calculations.

ACCESS: Available at the VDOT Research Library, Call No. TA 1001.5 .T71 no. 416

'Greening' America's Garages... With Light!

CITATION: Peter Kelly. , Parking Today, 2007. Bricepac, Incorporated. Vol. 12, No. 10, Pg. pp-24-26.

ABSTRACT: This article describes the correct implementation of commercial lighting in multi-level parking structures. A number of factors that impact decisions on this type of lighting are discussed, including: energy efficiency of the lighting, maintenance costs, environmental benefits, and safety improvement. A few lighting methods that are not appropriate for this type of application include: high-pressure sodium, due to its coloration; metal halide, because of the glare produced by its high-intensity discharge (HID); and induction lighting fixtures, because of the expense and glare. Also tested were light emitting diode (LED) fixtures and vapor-tight fluorescent fixtures. This last type was found to be the best system given the criteria put forward above. High-quality vapor-tight fixtures were found to be resilient across temperature ranges, have a low-impact environmental impact, and offer high, crisp light quality. The author predicts that these lighting fixtures will remain popular until another technology surpasses it.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Ground-Up Analysis Resulted in New Lamp and Luminaire Design To Floodlight 7-Million Plaza at International Airport

CITATION: Anon. , Electrical Construction and Maintenance, 1958. National Electrical Contractors Association, New York, NY, United States. Vol. 57, No. 4, Pg. 96-98.

ABSTRACT: Design and equipment of New York airport's parking and roadway illumination system, reversing normal design procedure; objectives of plan were initially established as starting points,

then desired results were obtained by determining "unknown quantities"; approach led to development of new 1500-w mercury vapor lamp, new luminaire and unique 75-ft high tripod pylon.

ACCESS: Available through Interlibrary Loan to VDOT employees.

High Mast Lighting Impact on Driver's Visibility, Traffic Performance and Illumination Costs

CITATION: V. A. McCullough, R. A. Shannon and A. KETVIRTIS. , Illuminating Engineering Society, Journal of, 1984. Illuminating Engineering Society. Vol. 14, No. 1, Pg. p.-379-395.

ABSTRACT: In 1975, the Ministry of Transportation and Communications, Ontario erected the first high mast lighting installation in Ottawa consisting of 46-30 m assemblies. When the cost analysis was carried out it was found that the high mast system was almost twice as expensive as that of conventional lighting normally consisting of 15 m mounting heights. As a result of this experiment conclusions were drawn at that time that high mast lighting could not be justified for economic reasons. Based on the above reasons, the Ministry has carried out an exhaustive study to determine the cost effectiveness of high mast lighting considering driver's visibility and traffic performance. The experience of high mast lighting in various countries is considered and conclusions are drawn on its advantages and disadvantages as compared with conventional lighting. Where an economic analysis of high mast vs. conventional lighting indicates that a break-even situation exists, high mast lighting should be used because it provides higher quality illumination and the possibility of a lower accident rate.

ACCESS: Available through Interlibrary Loan to VDOT employees.

High-Luminance LEDs Replace Incandescent Lamps in New Applications

CITATION: D. L. Evans. , Appearing in: Light-Emitting Diodes: Research, Manufacturing, and Applications, Proceedings of the SPIE - The International Society for Optical Engineering, 1997. SPIE-Int. Soc. Opt. Eng. San Jose, CA, USA. Vol. 3002, Pg. 142-53.

ABSTRACT: The advent of high luminance AlInGaP and InGaN LED technologies has prompted the use of LED devices in new applications formerly illuminated by incandescent lamps. The luminous efficiencies of these new LED technologies equals or exceeds that attainable with incandescent sources, with reliability factors that far exceed those of incandescent sources. The need for a highly efficient, dependable, and cost effective replacement for incandescent lamps is being fulfilled with high luminance LED lamps. This paper briefly described some of the new applications incorporating high luminance LED lamps, traffic signals and roadway signs for traffic management, automotive exterior lighting, active matrix and full color displays for commercial advertising, and commercial aircraft panel lighting and military aircraft NVG compatible lighting.

ACCESS: Available through Interlibrary Loan to VDOT employees.

An Illuminating Experience: Suppliers Shed Spotlight on R&D to Develop Reliable LED Products for Rail Applications

CITATION: Jeff Stagl. , Progressive Railroading, 2008. Trade Press Publishing Corporation. Vol. 51, No. 2, Pg. pp-26, 28, 30-31.

ABSTRACT: This article describes ways in which railroads are using light-emitting diode (LED) lamps, and how they would use more of them if they were specifically developed for railroad use. Because LEDs last up to 10 times longer than incandescent bulbs, they are being used in a number of devices, from signals to passenger-car tail markers to blue safety lights. Some railroads have reservations about LEDs, primarily because they have over-estimated their longevity. Railroads want LEDs that can be field-tested, that aren't susceptible to "phantoms"—a situation that occurs when sunlight or a locomotive headlight reflects off the lamp making them appear to

be lit when they are not—and do not washout color-wise from the sunlight. The article relates that in response, one manufacturer has developed an LED wayside signal made especially for rail applications, while another company is also supplying specialized wayside signals to the railroad market. It is currently developing white LED products to illuminate stations and the interior of passenger cars.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Illumination of Buildings and Urban Areas

CITATION: Benjamin Evans. , Appearing in: *Passive and Low Energy Ecotechniques*, 1985. Pergamon Press, Oxford, Engl. Mexico City, Mex. Pg. 161-171.

ABSTRACT: Cheap energy and the fluorescent lamp released designers from concerns about windows and daylighting-necessitated space configurations during the 1950s. With the sudden energy situation change came renewed interest in daylighting. Strategies for lighting design have focused on architectural changes. New glazing materials are in development which will effectively and selectively transmit, reject, or distribute radiant energy. Perhaps the greatest recent achievements have been in the control and distribution of electric energy for lighting which have tremendously increased the potential for using light more effectively. All this has led to heightened concerns for, and increased research into, biological phenomena associated with lighting to provide better understanding of work performance and productivity. Safety and security needs have prompted additional research and equipment improvements directed toward better lighting of highways and intersections and urban-blighted areas.

ACCESS: Available through Interlibrary Loan to VDOT employees.

The Impact of Public Lighting on Voltage Distortion in Low Voltage Distribution Systems

CITATION: E. Bompard, E. Carpaneto, G. Chicco, et al. , *IEEE Trans.Power Del.*, 2001. Institute of Electrical and Electronics Engineers Inc. Vol. 16, No. 4, Pg. 752-757.

ABSTRACT: Harmonic distortion has become a main concern in electric distribution systems during the last years. Several public utilities are experiencing harmonic problems on their networks and some of them started to monitor the situation of the MV and LV distribution networks. Recently, the operation of the MV and IN networks of the AEM-Torino (the city utility) has been investigated with several on-site measurements. The survey led to the observation of a step increase in voltage distortion on LV feeder when the city street lighting is switched on and, vice versa, a sudden decrease when it is switched off. This phenomenon can be mainly traced back to the resonance, under certain conditions, between the capacitance of the capacitors for the improvement of the lamps power factor and the inductance of the MV/LV transformer. This work investigates the phenomenon both from a theoretical point and with laboratory and field tests. Some possible remedies and their practical implementation to reduce harmonic distortion are discussed.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Improved Roadway Illumination: Information Resource

CITATION: Anonymous , 2005. Society of Automotive Engineers.

ABSTRACT: Headlamps should illuminate the traffic scene ahead of the vehicle in such a way that the driver can operate the vehicle safely and in a relaxed manner. At the same time, negative effects on drivers of other vehicles, pedestrians and other people should be minimized. Various technical parameters such as beam pattern, mounting height, headlamp aiming, and source spectrum can be tuned to find the necessary compromise. The physiology of the vision system under specific night time conditions strongly influences these factors and how headlamps can be best optimized for visibility and comfort. The SAE Improved Roadway Illumination task force collected and reviewed relevant research on these topics. This document is a comprehensive

summary of this information. The goal is to enable lighting experts, advocacy groups, and non-experts (journalists, consumer organizations, car drivers) to better understand the benefits and tradeoffs of improved roadway lighting with modern headlamp technology. It should be noted that all studies can not be included in this report, but the intent of this document is to provide the reader with a representative sample of the existing research as a starting point. Further, this document can be updated in the future to reflect new research findings.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Innovation With Regard to Highway Lighting: The TX Project

CITATION: L. de Lamalle. , *Revue E*, 1991. Vol. 107, No. 3, Pg. 32-9.

ABSTRACT: Several years' co-operation among private-sector manufacturers of street lamps and luminaires has led to a development giving more efficient light distribution over a longer period with lamp-post spacing extended to 90-100 m over appropriate carriageway surfaces. The criteria considered are average brightness at ground level, longitudinal uniformity in each traffic lane, average and transverse uniformities, and dazzle limitation. Reasons for early adoption of low-pressure sodium vapour lamps are set out. Modifications in pursuit of energy economy are related to Belgian Government measures aimed at cost-cutting with minimal impact on safety. Calculation and measurement of a 'threshold increment' quantifying dazzle from light sources within the field of vision are discussed. The innovative luminaire is illustrated and described with reference to its optical system, lamp and power supply circuit. Possible modulation according to traffic density is considered, but doubt is cast on its economic value. The annual running cost of the installation is estimated at 58% of that of a conventional one, whose performance is tabulated for comparison.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Key Technologies for Solid State Lighting

CITATION: Yi Luo, Yanjun Han and Keyuan Qian. , Appearing in: 2006 IEEE LEOS Annual Meeting Conference, 2006. IEEE. Montreal, Que., Canada. Pg. 2.

ABSTRACT: This report reviews the packaging and application technology of high power white LEDs including the lower thermal resistance and high reliable packaging of a group of LEDs, unsymmetrical three-dimensional optical system research based on non-image optics and the actual optical system design (such as street lamp) with luminous intensity distribution.

ACCESS: Available through Interlibrary Loan to VDOT employees.

LED = Lower-Cost Lighting : Lighting the World With Self-Contained Solar LED Airport and Obstruction Lights

CITATION: D. Green. , *Airports International Magazine*, 2005. Key Publishing, Limited. Vol. 38, No. 1, Pg. p.-40-41.

ABSTRACT: This article looks at the Light Emitting Diode as a solution to airport lighting. It explains the problem of low cost lighting at airports and lists data on unlit airports and existing companies manufacturing LED-based systems focusing on Carmanah. The article discusses the advantages of solar powered lights, focusing on renewability, extremely low cost, and low maintenance and installation costs. The article then gives an example of a solar power LED system.

ACCESS: Available through Interlibrary Loan to VDOT employees.

LED Blinks in the Spotlight

CITATION: Lindsay Audin. , *Eng.Syst.*, 2007. Business News Publishing Co., Troy, MI 48084-4904, United States. Vol. 24, No. 5, Pg. 32.

ABSTRACT: New light fixtures using light-emitting diodes (LED) hold great potential but some

early models are unable to meet some of the expectations. LEDs are used in all around such as instrument lights, exit signs, traffic lights, decorative and novelty lighting. The lifetime of LED is 50,000 to 100,000 hours and they are extremely sturdy. They may be fitted into many shapes and their color can be varied over a wide range. Researchers are using tightly packed white LEDs inside standard light fixtures such as over-the-counter, task, and downlights. Several designs have come under scrutiny for failing to provide claimed illuminating ability. One of the findings of the DOE tests is that light output dropped by over 20% as the fixtures warmed up after about two hours. Various LED related standards are being developed to guide fixture manufacturers to better quantify the characteristics of new fixtures.

ACCESS: Available through Interlibrary Loan to VDOT employees.

LED in Your Head : Paying Heed to the Signals

CITATION: Anders Anderson. , Traffic Technology International, 2000. UK and International Press; AutoIntermediates Limited. Pg. p.-57-60.

ABSTRACT: This article is presented as a cartoon storyboard promoting the use of light emitting diodes (LEDs) in traffic signals.

ACCESS: Available at the VDOT Research Library, periodicals section.

LED Market Shines, But Prices Continue to Drop

CITATION: Anonymous , Purchasing, 2003. Cahners Publishing. Vol. 132, No. 12, Pg. 11, 14, 16.

ABSTRACT: Light emitting diodes (LEDs) are one of the bright spots in the semiconductor industry. Demand for LEDs continues to grow as they are used more in cell phones, automobiles, traffic signals and outdoor signs. The good news for buyers is that despite growing demand, prices for LEDs will continue to fall. Buyers can expect a 10-15% drop in LEDs made with aluminum indium gallium phosphide (AlInGaP) and a 15-20% drop in tags for LEDs that use indium gallium nitride (InGaN). More cell phones are equipped with color liquid crystal displays (LCDs) which use LEDs for display backlighting and keypads. Mobile phones account for about 40% of the total high brightness LED in market. However, it's not just cell phones that are driving LED demand.

Automakers are using more LEDs. In fact, some suppliers say LEDs will replace incandescent lights completely in cars. More LEDs are being designed into cars for both interior and exterior applications. In the late 1990s LEDs were used in instrument panels to light the speedometer, odometer and other gauge displays. In a few years, automakers will use LEDs for turn signals and front headlights. Besides lower total cost, automakers are using LEDs for signature styling.

Besides traffic lights, cars and phones, LEDs will be used more in planes, homes and businesses.

The Challenge is to reduce the cost of LEDs. Suppliers are looking to reduce the cost by making the LED more efficient.

ACCESS: Available through Interlibrary Loan to VDOT employees.

LED Road Illumination Communications System.

CITATION: S. Kitano, S. Haruyama and M. Nakagawa. , Appearing in: VTC 2003-Fall, 2003. IEEE. Orlando, FL, USA. Vol. 5, Pg. 3346-50.

ABSTRACT: In intelligent transport systems (ITS) with a purpose to decrease traffic accidents, vehicle information and communication system (VICS) has been in practical use in Japan. It is expected to place light emitting diode (LED) illumination into practical use as a future light source. Also in road illumination, utilization of the LED illumination is considered. We propose a visible light communication system, which uses LED road illumination. First, we propose the shape of the LED road illumination, which fulfills the standard specification of road illuminations in Japan. We can change the light source of the existing road illumination by using the proposed LED illumination. Next, we consider carrying out vehicular communications using this LED road

illumination. It was proven that vehicular communications is possible through numerical analysis and excelled the present VICS system in using LED road illumination.

ACCESS: Available through Interlibrary Loan to VDOT employees.

LED Shakedown: Lower LED Power Requirements Defer Expensive Upgrades and Reduce Maintenance

CITATION: C. McCormick. , Airports International Magazine, 2004. Key Publishing, Limited. Vol. 37, No. 5, Pg. p.-14-15.

ABSTRACT: This article reports on how the Vancouver International Airport Authority (YVRAA) and Transport Canada have approved Light Emitting Diode (LED) lights for use on taxiways. LEDs are still not approved for use on runways as they don't meet the required light intensities. LEDs can help reduce energy requirements and costs, as well as increase the reliability of aeronautical ground lighting. On the average, use 30-40% of the power that an incandescent light uses. In addition, LEDs are known for their longevity. While tungsten-filament light bulbs need to be replaced every two years, LEDs typically have a replacement interval of five years. The article also discusses some of the standards in place for taxiway and runway lighting at Canadian airports.

ACCESS: Available through Interlibrary Loan to VDOT employees.

LED to Safety

CITATION: Karl Eigentler. , Traffic Technology International, 2005. AutoIntermediates Limited. Pg. pp-106-109.

ABSTRACT: Road safety initiatives discussed at the European Commission include a goal of cutting fatalities by 50 percent by the year 2010. Tunnel safety is one area that is receiving attention from intelligent transportation systems. Most tunnels were not built with pedestrian safety and escape routes in mind, and recent experiences with major fire disasters are causing agencies and policymakers to rethink ways to improve conditions. Visual guidance systems using LEDs are showing promise in reducing risks. They are installed in modules that are interconnected and linked to a control unit. This article reports on the first scientific study to include the visual effectiveness of visual guidance using LEDs, which are also used to instruct drivers about clearances, safe speeds and changing conditions that they should adjust to. LEDs mounted in the road are also used to guide traffic. The article describes installation and placement under different conditions and the need for robust modules to withstand extreme temperatures from events like fires.

ACCESS: Available at the VDOT Research Library, periodicals section.

LEDs as Light Source: Examining Quality of Acquired Images

CITATION: R. Bachnak, J. Funtanilla and J. Hernandez. , Appearing in: Machine Vision Applications in Industrial Inspection XII, Proceedings of the SPIE - The International Society for Optical Engineering, 2004. SPIE-Int. Soc. Opt. Eng. San Jose, CA, USA. Vol. 5303, No. 1, Pg. 99-107.

ABSTRACT: Recent advances in technology have made light emitting diodes (LEDs) viable in a number of applications, including vehicle stoplights, traffic lights, machine-vision-inspection, illumination, and street signs. This paper presents the results of comparing images taken by a videoscope using two different light sources. One of the sources is the internal metal halide lamp and the other is a LED placed at the tip of the insertion tube. Images acquired using these two light sources were quantitatively compared using their histogram, intensity profile along a line segment, and edge detection. Also, images were qualitatively compared using image registration and transformation. The gray-level histogram, edge detection, image profile and image registration do not offer conclusive results. The LED light source, however, produces good images for visual inspection by an operator. The paper will present the results and discuss the usefulness

and shortcomings of various comparison methods.

ACCESS: Available through Interlibrary Loan to VDOT employees.

LEDs Brighten For Car, Outdoor Apps

CITATION: Gina Roos. , Electronic Engineering Times, 2006. CMP Media LLC, Manhasset, NY 11030, United States. No. 1446, Pg. 67-72.

ABSTRACT: The advantages offered by the improvement in the performance of ultrahigh-brightness or high-power LEDs are discussed. Optophotonics manufacturers are targeting exterior and interior automotive applications with bright LEDs which offer higher operating temperatures, high power ratings. It also offers longevity and the ability to withstand shock and vibration. High brightness and small packaging are also growing requirements in automotive interior lighting. Vishay Intertechnology has introduced super bright red LEDs for exterior automotive applications and traffic signals. The company has also upgraded its existing TLM series with the new RoHS-compliant VLM series of high intensity surface-mount LEDs. The fully integrated LED backlight or light guide assemblies are suitable for various reasons which include GPS and DVD systems, portable DVD players and other daylight-readable displays used in cars and minivans.

ACCESS: Available through Interlibrary Loan to VDOT employees.

LEDs in Light-Emitting Highway Devices in Maryland

CITATION: J. P. Young and T. Hicks. , ITE J., 2003. Institute of Transportation Engineers. Vol. 73, No. 4, Pg. p.-32-36.

ABSTRACT: Light-emitting diodes (LEDs) are an attractive alternative to incandescent lamps in highway devices because of their low power consumption and potential longevity. The Maryland State Highway Administration's (MSHA's) methodology for testing and approving these devices needed to address certain public safety and economic issues before permitting their use. This article discusses some of the issues that confronted the MSHA as it engaged in the consideration of LEDs for use on Maryland roads.

ACCESS: Available at the VDOT Research Library, periodicals section.

LEDs Lighten the Energy Load

CITATION: R. Allan. , Electronic Design, 2007. Penton Media Inc. Vol. 55, No. 14, Pg. 55-6.

ABSTRACT: LEDs offer longer life and greater efficiency than those other technologies, which is why they're seeing rapid adoption in buildings, parking lots, plants, streets, stadiums, airports, and other large facilities. The U.S. Department of Energy (DoE) is putting some muscle (read: funding) into this growth with its solid state lighting (SSL) plan, which spans the years 2000 to 2020. The program consists of core technology research, product development, and commercialization support activities. Progress on the white-light LED front is moving faster than originally anticipated. Based on the U.S. government's Energy Star ratings, the use of efficient solid-state lighting all over the U.S. (where it has been shown to be profitable) would cut the nation's demand for electricity by more than 10%. This translates into a \$17 billion savings in energy costs and pollution reduction of 202 million metric tons of carbon dioxide-the equivalent of taking 15 million cars off the road.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Let There Be Light [Gallium Nitride LED]

CITATION: G. Zorpette. , IEEE Spectrum, 2002. IEEE. Vol. 39, No. 9, Pg. 70-4.

ABSTRACT: The incandescent light bulb rolled back the night around the start of the 20th century. The gallium nitride LED will light the way in the 21st. The development of the gallium nitride

(GaN) LED, made it possible to get white light from a semiconductor. GaN LEDs are already quietly transforming specialized illumination, including architectural and stage lighting, indoor and outdoor accent lighting, traffic and railway signaling, commercial and retail signs and displays, and outdoor illumination on bridges, walkways, gardens, and fountains. Lumen for lumen, white LEDs cost roughly 100 times as much as an incandescent bulb. Not to worry, say researchers. Not only will they get the cost down, they are going to dazzle us with devices that will be 10 times as efficient as an incandescent and will last 100 times as long. By mixing light from LEDs of different colors, the devices will provide 1000 shades of white-or any hue under the sun-at the twist of a dial.

ACCESS: Available through Interlibrary Loan to VDOT employees.

LED Lighting to Replace Overhead Lighting

CITATION: Research in progress, start date: 2004/4/1, end date: 2009/4/1. Organization: Colorado Department of Transportation. Project Manager: Outcalt, Skip, skip.outcalt@dot.state.co.us

ABSTRACT: Colorado state law requires lighting methods to minimize light pollution caused by overhead lighting at highway interchanges. During reconstruction of two structures on I-25 in Trinidad, the overhead luminaire lighting will be replaced by light-emitting diode (LED) lights mounted on the barriers adjacent to the highway rather than on poles above the structures. Over a 5-year period, the LED lighting will be evaluated for effectiveness in delineating the highway and interchanges associated with the structures. Costs, ease of installation and maintenance, and durability of the LED lighting components will also be evaluated. Accident data will be gathered during the study and compared with a like time period before installation of the LED lighting. Other projects will be added to the study as they become available.

ACCESS: Research underway.

The Light Fantastic

CITATION: Cordula Carlin. , New Electronics, 2006. Findlay Publications Ltd, Horton Kirby, Kent, DA4 9LL, United Kingdom. Vol. 39, No. 20, Pg. 19-20.

ABSTRACT: The growing significance of light emitting diodes (LED), which are being used for lighting torches, bicycle lamps, car stoplights, and traffic lights, are discussed. Some of the advantages of LEDs include their better optical efficiency and they emit light in one direction. Another advantage of the LEDs is that they help in selecting the color of light when required. They also possess a long service life as their brightness reduces over a period of time. LEDs are being preferred over other sources of light in applications where long service life and high efficiencies are required. They are also environmentally friendly, operate from low voltage, and require less maintenance. Intensity and tone of light can be configured using LEDs and modulated manually or by computer. Architects, designers, and advertisers can them to set moods and to change them with a cycle adapted to the presence of sunlight. Note: Compilation and indexing terms, Copyright 2008 Elsevier Inc.

ACCESS: Available through Interlibrary Loan to VDOT employees.

"The Light For The 21st Century" National Project Based on White Light Emitting Diode (LED) Lighting Technology

CITATION: T. Taguchi. , Transactions of the Institute of Electronics, Information and Communication Engineers C, 2001. Inst. Electron. Inf. & Commun. Eng. Vol. J84-C, No. 11, Pg. 1040-9.

ABSTRACT: "The light for the 21st century" national project, which is based on white light-emitting diode (LED) lighting technology, has started from 1998 in Japan. The outline and purpose of this

project are introduced. In order to develop efficient lighting sources using high-brightness white LEDs, four research programmes have been carried out. Basic illumination characteristics of two types of white lighting sources using phosphor-coated blue or ultraviolet (UV) LED are discussed in detail. We have shown that the white LED street lamp and sign panel are confirmed to provide a brightness and an illuminance distribution that clearly exceed that displayed by the incandescent blue or the fluorescent lamp.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Light Sources 2004 - Proceedings of the 10th International Symposium on the Science and Technology of Light Sources

CITATION: Anonymous , Appearing in: Light Sources 2004 - Proceedings of the Tenth International Symposium on the Science and Technology of Light Sources, 2004. Institute of Physics Publishing, Bristol, BS1 6BE, United Kingdom. Toulouse, France. Vol. 182, Pg. 671.

ABSTRACT: The proceedings contains 271 papers from the conference on the Light Sources 2004- Proceedings of the Tenth International Symposium on the Science and Technology of Light Sources. The topics discussed include: LEDs a challenge for lighting; low-pressure mercury-free plasma light sources: theoretical and experimental perspectives; some aspects of the interface between fluorescent lamps and electronic gears; acoustic resonance in HID lamps; high performance optical spectroscopy: applications and opportunities in lamp diagnostics and new concepts for roadway lighting. Note: Compilation and indexing terms, Copyright 2008 Elsevier Inc.; T3: Institute of Physics Conference Series.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Light Work

CITATION: Mike Farish. , Engineering, 2005. Gillard Welch Ltd, Solihull, B93 0LL, United Kingdom. Vol. 246, No. 3, Pg. 42-44.

ABSTRACT: Hella, German-based multinational automotive systems manufacturer, is in the process of developing automotive lighting systems that can automatically react to changing road conditions. In a concept car based on a BMW 7 Series, the LEDs are not being used as main beam headlights but as parking lamps. The achievement of the capabilities such as high beam, highway light, country road light and town light, with LED technology is packaged together by Hella under the title Advanced Frontlighting System. The company is confident that light-based systems for detecting the range of other vehicles will ultimately win out over those using radio waves.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Lighting in Finland

CITATION: E. Paivarinne. , Illuminating Engineering Society -- Transactions, 1958. Vol. 23, No. 3, Pg. 163-171.

ABSTRACT: General course of lighting development during last few years and its influence upon local conditions; principles which led to practical solutions in lighting of schools, offices, streets, hospitals, etc; details of installations and lighting fittings; decorative fittings, and controlled light distribution. (See also - discussion p 171-3).

ACCESS: Available through Interlibrary Loan to VDOT employees.

Lighting the Way for Sustainability

CITATION: Marilyn Burtwell. , Highways, 2004. Alan Limited, Rochester, United Kingdom. Vol. 73, No. 5, Pg. 12-13.

ABSTRACT: The importance of street lighting which is influenced by a number of factors such as lamp color, road surface luminance, glare and observer age is discussed. Better understanding of

light sources together with technical developments have led to a gradual improvement in the performance of lighting systems. The emergence of metal halide discharge lamps with ceramic arc tubes has led to a new generation of efficient light sources with high color rendering indices (CRI). It is predicted that reductions in energy utilization by a factor of 2 and overall maintenance costs due to the lower wattage lamps will lead to significant cost savings.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Lighting the Way To a Low-Energy Future

CITATION: Gordon Routledge. , IEE Rev, 2002. Institution of Electrical Engineers. Vol. 48, No. 5, Pg. 21-25.

ABSTRACT: Solid-state lighting (SSL) using light-emitting diodes (LED) was discussed. SSL offered benefits in public and commercial signs, signalling, lighting and the automotive sector. The light output beam was found to be cool and contained no ultra-violet frequencies in LED. The parameters important while discussing white light were the colour-rendering index (Ra) and the correlated colour temperature (CCT). The LED was expected to halve lighting related electricity demand.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Lower Your Lighting Costs- Save the Planet

CITATION: Donald R. Monohan. , Parking Today, 2006. Bricepac, Incorporated. Vol. 11, No. 11, Pg. pp-20-21.

ABSTRACT: In this article the author discusses the role of lighting in energy consumption for parking structures. In addition to saving money due to better efficiency, there are further tax benefits for such improvements, as the article explains. With a suitable retrofit, it is possible to save up to 40 percent of a standard system's electrical output. One design that is particularly efficient is that of fluorescent lights with high-frequency electronic ballasts in lieu of both metal halide or sodium fixtures. Although fluorescent lights have tended to lose up to 50 percent of their output at temperatures around 32 degrees, recent studies have shown that vapor tight fluorescent fixtures can be used in weather conditions down to 10 degrees with as little as a 20 percent reduction in efficacy. An additional benefit the article describes is the consequent reduction in greenhouse gasses that such a reduction would precipitate.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Luminance Requirements for Lighted Signage

CITATION: J. P. Freyssinier, N. Narendran and J. D. Bullough. , Appearing in: Sixth International Conference on Solid State Lighting, Proceedings of the SPIE - The International Society for Optical Engineering, 2006. SPIE - The International Society for Optical Engineering. San Diego, CA, USA. Vol. 6337, Pg. 63371-1.

ABSTRACT: Light-emitting diode (LED) technology is presently targeted to displace traditional light sources in backlighted signage. The literature shows that brightness and contrast are perhaps the two most important elements of a sign that determine its attention-getting capabilities and its legibility. Presently, there are no luminance standards for signage, and the practice of developing brighter signs to compete with signs in adjacent businesses is becoming more commonplace. Sign luminances in such cases may far exceed what people usually need for identifying and reading a sign. Furthermore, the practice of higher sign luminance than needed has many negative consequences, including higher energy use and light pollution. To move toward development of a recommendation for lighted signage, several laboratory human factors evaluations were conducted. A scale model of a storefront was used to present human subjects with a typical red channel-letter sign at luminances ranging from 8 cd/m² to 1512 cd/m² under four background

luminances typical of nighttime outdoor and daytime inside-mall conditions (1, 100, 300, 1000 cd/m²), from three scaled viewing distances (30, 60, 340 ft), and either in isolation or adjacent to two similar signs. Subjects rated the brightness, acceptability, and ease of reading of the test sign for each combination of sign and background luminances and scaled viewing distances.

ACCESS: Available through Interlibrary Loan to VDOT employees.

M27 Trial of Highway Noise Barriers as Solar Energy Generators

CITATION: D. R. Carder, K. J. Barker, TRL Limited, et al. , Appearing in: Published project report,; PPR178, 2006. TRL Limited. Wokingham, Berkshire. Pg. 49.

ABSTRACT: Renewable energy technologies are likely to become more important as other energy sources become depleted and the cost of power generation using fossil fuels rises. Renewable sources of energy have considerable potential for increasing security of supply and reducing CO₂emissions although, in most cases, they require significant initial investment. This report describes a full scale trial to recover solar energy using photovoltaic noise barriers installed on the M27. In addition to the electrical performance of the system, whole life costs studies were undertaken to assess the benefits of a wider implementation of the technology. Any impact on driver behaviour due to the presence of a visible technology adjacent to the highway was also investigated, as were the implications on reflected noise levels of using a photovoltaic barrier as opposed to a conventional noise barrier.

ACCESS: Available at the VDOT Research Library.

Making Spaces

CITATION: Mike Sharp. , Highways, 1996. Alad Ltd., Rochester, Engl. Vol. 64, No. 5, Pg. 33.

ABSTRACT: Maidstone County in Kent was able to solve its problem of providing adequate and cost effective parking facilities to motorists with the VMS signage system. The VMS system uses state-of-the-art LED technology to provide numeric readouts of the spaces remaining in up to five of the main town center car parks. The LED approach ensures long life, low maintenance system with low initial capital outlay. The signs are linked to the car parks by license exempt radio and a central control computer manages the system. Each car park is color coded and additional static signs use the color code to direct drivers to their chosen car park via routes which address the need to make better use of the small, less well-known car parks.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Modern Photonics for Improved Highway Safety

CITATION: M. R. Cates and S. W. Allison. , Appearing in: Proceedings of the 50th International Instrumentation Symposium, 2004. ISA - Instrumentation, Systems, and Automation Society, Research Triangle Park, NC 27709, United States. San Antonio, TX, United States. Vol. 451, Pg. 133-136.

ABSTRACT: The developments done on modern photonic devices for improving highway safety are discussed. The development of an enhanced road stripping or vehicle marking using logn-persistence phosphors (LPP) is also discussed. The advantages of application of ultraviolet light-emitting diode (LED) technology for enhanced visibility of headlight systems are also discussed. Results show that LPPs suspended as pigment in standard acrylic paint can be used in conjunction with standard stripping paint to generate stripping that has afterglow properties activated by daylight.

ACCESS: Available through Interlibrary Loan to VDOT employees.

A New Concentrator-Collimator Lighting System Using LED Technology

CITATION: A. Garcia-Botella, D. Vazquez and E. Bernabeu. , Journal of the Illuminating

Engineering Society, 2000. Illuminating Eng. Soc. North America. Vol. 29, No. 2, Pg. 135-40.
ABSTRACT: A new concentrator-collimator lighting system based on LED technology has been developed. Using an array of LEDs as source, this device makes it possible to obtain an integrated light beam with high intensity level and desired divergence, in a compact geometry with small output area. It has low consumption and long lifetime. This makes it applicable in a variety of fields where quasi-monochromatic light and narrow angular distributions are needed, like road safety lighting.

ACCESS: Available through Interlibrary Loan to VDOT employees.

New Lighting and Sensing Technologies

CITATION: Nick Palmen. , Automotive Industries AI, 2007. Automotive Industries, Versailles,, KY 40383, United States. Vol. 187, No. 6, ABSTRACT: OSRAM Opto Semiconductors is working with an array of lighting and sensing technologies to make vehicles and streets safer. Active safety has become important in the automotive industry and the suppliers strive to develop technologies that not only make vehicles safer but help them avoid accidents. OSRAM Opto Semiconductors, Inc., supports the drive for active safety with a variety of lighting and sensing technologies that alert drivers to dangerous situations inside and outside a moving vehicle. OSRAM Opto Semiconductors is also a leader in the field of Photonics and is Renowned for its Light Emitting Diodes (LED). Most of the vehicles in the market had a five-star safety rating indicating that advancements in Passive safety have reached a saturation level.

ACCESS: Available through Interlibrary Loan to VDOT employees.

New Lighting Demands Play Increasingly Important Role in Parking Facilities

CITATION: A. Liao. , Parking Today, 2004. Bricepac, Incorporated; Bricepac, Incorporated. Vol. 9, No. 5, Pg. p.-24-25.

ABSTRACT: New demands on lighting fixtures are spurring new designs. One of the more influential developments is the call for "dark sky" fixtures that do not add to light pollution in the night sky. Energy efficiency and pedestrian safety are two other imperatives driving new designs. Higher light levels do not necessarily satisfy all these demands, because the higher levels require higher wattage, which translates into higher energy demands, which also require higher light standards, leading to spillover. The high glare that can result does nothing to enhance security and in fact can make it less safe. Keys are uniformity of design and placement with an eye to traffic flow patterns. For enhanced low-wattage effective brightness, metal halide is proving more popular than low- and high-pressure sodium lamps. New types of LED are also promising; they combine LEDs with reflectors to project light and lead to even longer lamp life.

ACCESS: Available through Interlibrary Loan to VDOT employees.

New Mexico Experiments With Solar Powered Highway Signs

CITATION: Anonymous, TRANSAFETY REPORTER, 1988. TranSafety, Incorporated; TranSafety, Incorporated. Vol. 6, No. 10, Pg. p.-8.

ABSTRACT: The New Mexico State Highway Department has begun to use solar powered highway signs in locations where electricity is not available. They have installed two overhead signs employing solar power on Interstate 25 near Cochiti Pueblo, south of Santa Fe. The illumination is provided by solar battery systems with photovoltaic cells. The batteries are stored inside concrete wall barriers below the signs and are accessible for maintenance from frontage roads. Other solar powered uses being considered by the highway department are ramp lighting, sensing and telemetry systems, and street lights in remote areas.

ACCESS: Available through Interlibrary Loan to VDOT employees.

New York Looks Ahead With LED Street Light

CITATION: Carl Gardner. , Lighting Journal (Rugby, England), 2006. Institution of Lighting Engineers, Rugby, CV21 2PN, United Kingdom. Vol. 71, No. 4, Pg. 22-24.

ABSTRACT: New York based lighting designers have designed a street light by using the light emitting diode (LED) as an effective light source. The state-of-art LED source used for street light is imaginative, cost-effective, and meets the strict technical performance standards. The advantages of LED luminaire component includes lower maintenance cost, lower waste disposal, low UV-radiation effects, low power consumption, and better color rendition. LRD is used extensively in exterior lighting instruments, such as traffic lights, signage boards, and street signs. The use of high output LEDs, with state-of-art lens optics, allowed considerable design flexibility and the ability to make the luminaries small and compact. LED drivers are mounted within a compartment at the base of the pole, which offers time, cost, and maintenance saving advantages. Several automobile manufacturers have announced the LED technology, as a standard for daytime running headlights in 2006 models.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Oleds: A New Technology for Lighting and Displays

CITATION: P. Destruel, J. Farene, P. Jolinat, et al. , Appearing in: Tenth International Symposium on the Science and Technology of Light Sources, 2004. Inst. of Phys. Toulouse, France. Pg. 135-41.

ABSTRACT: In this paper, we present an updated status of the research on organic LEDs and the recent developments in their applications. The first part is devoted to the electrical and optical processes involved in the production of light. Then organic electroluminescence is presented with its specific characteristics. The next paragraph describes the technologies used in the fabrication and the structural design of the devices, in relation with the different classes of organic luminescent materials. Finally, the structure of realizations such as a white light-emitting device is analyzed. Some of the current and future commercial products using these LEDs are presented for the use in different fields such as lighting, sign and video displays. ACCESS: Available through Interlibrary Loan to VDOT employees.

Optical Analysis of an 80-W Light-Emitting-Diode Street Lamp

CITATION: Kai Wang, Xiaobing Luo, Zongyuan Liu, et al. , Optical Engineering, 2008. Society of Photo-Optical Instrumentation Engineers. Vol. 47, No. 1, Pg. 013002-1.

ABSTRACT: Optical analysis is critical to the evaluation of a light-emitting diode (LED) street lamp, especially when the lamp is still in its early stage of development and applications and when optimization is needed for making use of unique characteristics of LEDs. In this study, optical analysis of an 80-W LED street lamp was conducted. Experimental research on such a lamp was first undertaken. The results demonstrated that the average illumination was about 8.25 lx and the total uniformity was 0.364 for a 20-m-long and 10-m-wide test area at a height of 8 m, which is acceptable for the current standard for a submain road. Numerical simulation was also conducted; the feasibility of the numerical model was proven by comparison of the simulations with the experimental data, which will be used for future optimization study and other novel designs of the optical system of street lamps. Through the simulations and the corresponding analysis, it was found that the tested 80-W LED street lamp had reasonable performance in average illumination, but multiple shadows existed, which would need to be removed in future designs. Improvements are suggested to reduce the number of optical elements, to reduce the lamp's volume, and to enhance the illumination performance. Two design methods for LED street lamps are summarized, based on the optical analysis.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Optimal Design of Solar LED Street Lamp Lighting System

CITATION: Wei Chen, Hui Shen, Kong-Xian Ding, et al. , Zhongshan Daxue Xuebao/Acta Scientiarum Natralium Universitatis Sunyatseni, 2005. Journal of Zhongshan University, Guangzhou, China. Vol. 44, Pg. 95-98.

ABSTRACT: On the basic of completing the Chinese first solar LED street lamps project at Zhuhai, to pursue reliability and economy of solar street lamp systems, the systems were optimally designed from four aspects: light source, charging controller circuit, optimum tilt angle of photovoltaic module, sizing of photovoltaic module and storage battery. As a result, the LED light source and direct-coupling charging controller are very good choices for solar street lamp systems, at the same time, by the method of scientific calculation, the optimum tilt angle of photovoltaic module, sizing of photovoltaic module and storage battery were discussed, too. At the last, the method and conclusion in this paper can also be used to help the design of other solar street lamp systems.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Optimising Lighting Installation

CITATION: M. Bonomo. , AEI, 2003. AEI-Assoc. Elettrotec. & Elettron. Italiana. Vol. 90, No. 4, Pg. 33-40.

ABSTRACT: This paper presents a comprehensive review of lamp and lighting development. The scope for energy saving in the estimated 8,300 MWh, energy consumption in domestic lighting, representing 30% of the Italian lighting load is identified. The operating characteristics of fluorescent and incandescent lamps with and without halogen is compared. Current practice in industrial, commercial and public lighting systems is summarized. The properties of high-pressure sodium and other street lamps are presented. The progress in LED technology as applied to public lighting is described. Notes that 10% of worldwide energy is devoted to illumination with an aggregate annual consumption of 30,000 MWh.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Optimising the Use of LEDs in Signs and Signals for Visually Critical Applications

CITATION: K. M. Conway, Yunjan He, P. R. Boyce, et al. , Appearing in: Proceedings of International Commission on Illumination LED Workshop and Symposium, 1997. Commission Int. L'Eclairage. Vienna, Austria. Pg. 26-30.

ABSTRACT: Spurred by a need for energy efficiency, a market trend has begun in the US toward the use of light emitting diodes (LEDs) in signs and signals for visually critical applications. We summarize research on exit signs for commercial buildings, 1993 to the present which compares light sources, active input power and visual performance characteristics, and present an exit sign performance specification used in a voluntary federal product labeling program. We discuss concerns with LEDs, such as light output degradation over time under normal building operating conditions, and visibility of LED products for persons with color defective vision. We recommend five activities for the improving the visual and energy effectiveness of signs and signals illuminated by LEDs.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Pedestrian and Motor Vehicle Traffic Control Practices for Light Rail Transit Innovations In New Light Rail Transit System, Barcelona, Spain

CITATION: Jose I. Farran. , Appearing in: Transit - Intermodal Transfer Facilities and Ferry Transportation; Commuter Rail; Light Rail and Major Activity Center Circulation Systems; Capacity and Quality of Service, Transp.Res.Rec., 2006. National Research Council, Washington, DC 20007, United States. No. 1955, Pg. 56-61.

ABSTRACT: The focus of this paper is to provide an informative summary on innovative pedestrian and motor vehicle traffic control designs and practices that have been applied to the recently opened light rail system in Barcelona, Spain. In April 2004 Barcelona, the capital of the Catalunya region, opened a completely new light rail system to expand and support its extensive subway, bus, and commuter rail system. Known locally as the Trambaix and Trambesos, these two light rail lines operate within a broad range of urban environments, both on street and in semiexclusive rights-of-way. Accommodating light rail in these multiple environments while maintaining or improving safety has led local transportation planners and engineers to use a variety of innovative traffic control practices to manage conflicting movements with LRVs and to provide motorists, as well as pedestrians and bicyclists, with better information on which to base their decisions. This paper, based on the author's site visits and technical discussions with local planners and engineers, summarizes these practices and identifies those that could have the greatest potential for implementation in the United States.

ACCESS: Available through Interlibrary Loan to VDOT employees.

The Potential for Reduced Lighting on Roadways

CITATION: M. S. Janoff, L. K. Staplin and J. B. Arens. , Public Roads, 1986. Federal Highway Administration; Federal Highway Administration. Vol. 50, No. 2, Pg. p.-33-42.

ABSTRACT: A summary is presented of a Federal Highway Administration (FHWA) study to determine if roadway lighting can be reduced or eliminated during nighttime periods when traffic density is much lower than design capacity, without significantly reducing driver ability to safely and effectively control the vehicle. The study consisted of the following tasks: review of the literature; development of a conceptual model of visibility needs and the identification of alternative reduced lighting techniques; determination of the costs, potential energy savings, and legal implications; and the determination of the effect of such techniques on driver detection of simulated roadway hazards under actual traffic conditions. The study found that technology exists for implementing all of the identified reduced lighting techniques with benefit-cost ratios greater than 1.0 for all but the most complex techniques. It was also found that driver detection performance decreased under each reduced lighting technique. It is noted that legal problems may result with the use of reduced lighting techniques. **ACCESS:** Available at the VDOT Research Library, periodicals section.

A Primer on LED Technology for Large-Display-Based Applications

CITATION: Antoine De Ryckel. , Inf Disp, 2007. Society for Information Display, San Jose, CA 95112-4006, United States. Vol. 23, No. 3, Pg. 14-18.

ABSTRACT: Light emitting diodes (LED) have captured a major portion of the market and are presently the dominant technology for the largest sun-light readable displays, despite some challenges related to power consumption, heat loading, and display formity over lifetime. LED technology is used in applications that requires a large format bright-visualization tool. The two effective business models for supporting LED display include a model that would realize the financial return on investment (ROI) and the model that uses the LED display to maximize the visibility of corporate brands or enhance the customer experience. LED display is assembled by linking smaller modules together, and this modular system makes LED display suitable for any type of installation. LED technology has proved to be effective by combining high brightness, flexibility, and picture quality for the display of full-color graphics or video in sporting arenas, highways, shopping malls.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Photovoltaic-powered overhead guide sign lighting system : final report : January 15, 1989 : submitted to Florida Department of Transportation, Tallahassee, FL

CITATION: James P. Dunlop and Florida Solar Energy Center. , 1989. Florida Solar Energy Center. Cocoa, Fla.

ABSTRACT: Photovoltaics, the technology of converting sunlight to direct-current electricity, has become a viable option for many remote and atypical electric power requirements. This project, sponsored by the Florida Department of Transportation and the Florida Governor's Energy Office, demonstrates an attractive application for a photovoltaic-powered energy system to operate a lighting system for an isolated overhead highway guide sign."--p.1./ "Prepared for Florida Department of Transportation"--cover./ Report: FSEC-CR-242-89; Other Titles: Contract report ;; photovoltaic-powered overhead guide sign lighting system : final report : FSEC-CR-242-89; Responsibility: James P. Dunlop

ACCESS: Available through Interlibrary Loan to VDOT employees.

Reduced Freeway Lighting

CITATION: M. S. Janoff and N. L. Zlotnick. , Lighting Design and Application, 1985. Illuminating Engineering Society. Vol. 15, No. 8, Pg. p.-35-42.

ABSTRACT: The paper discusses various systems that have been employed to reduce roadway lighting, their costs, benefits, and potential legal problems that must be addressed. Two general types of systems were identified: 1) older and oil-embargo related systems, such as extinguishing the lighting on all or part of specified roadways during various time periods and 2) modern systems that are controlled by special ballasts, electronic sensors and controls, and computers. It is concluded that under both the common law and state Tort Claims Acts, the specter of liability is present for a municipal entity which seeks to reduce or eliminate lighting on its highways during periods of low traffic density. Any municipal agency which undertakes such a program will be well advised to do so only after extensive scientific research and study.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Relating Design, Economic Analysis, and Energy Conservation Techniques In Highway Lighting

CITATION: R. A. Smith and G. Goguen. , Lighting Design and Application, 1975. Illuminating Engineering Society. Vol. 5, No. 6, Pg. p.-40.

ABSTRACT: The relationship of design, economics, and energy conservation techniques for various interchange configurations (cloverleaf, diamond, half-cloverleaf and trumpet) is analyzed using four types of light sources (mercury vapor, metal halide, high-pressure sodium, and low-pressure sodium). The cost elements were grouped in three parts: maintenance, power, and capital costs. Amortizing the capital cost over 20 years at 8 per cent interest provides a comparison of the yearly costs and the light source efficiency for each design. Energy cost is analyzed to determine the effect on the total cost when there are variations in the power rate. The most economical source using the power rate applicable to New Brunswick does not remain the same when the power rate approaches 10 cents/kWh. The cost of high-mast lighting is compared with conventional lighting using high-pressure sodium as the light source. Although less expensive than mercury, it was found to be more costly than any of the three other sources. Full-partial lighting designs installed in the Province of New Brunswick are analyzed to determine power savings and their effect on highway safety. This method permits the majority of highway lighting to be turned off after a certain hour in the night, determined by highway accident and traffic flow rates. It was found that up to 36 per cent of power savings can be achieved. The full-partial lighting design for a new expressway will be described, which the authors feel can be easily applied to many existing lighting designs throughout the country. The possibility of using vehicle-activated illumination on

future roadways is discussed.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Relationship between Illumination and Freeway Accidents. Project 85-67

CITATION: P. C. Box and W. A. Alroth. , 1971. Illuminating Engineering Research Institute. Vol 66, No 5, PP 365-393.

ABSTRACT: the objective was to determine the optimum design illumination level and uniformity needed on urban freeways, as related to accident rates. Data were collected from a wide variety of freeways, and compared by using the ratio of night/day accident rates per million vehicle miles. The tabulations included other factors, such as roadway elements, weather, driver age, and types of accidents, which would allow subsequent analysis as separate research. Conclusions are presented concerning daylight threshold, night traffic, lighting warrants, illumination values, lighting depreciation, roadway elements, driver age, data acquisition, and recommended future research.

ACCESS: Available through Interlibrary Loan to VDOT employees.

The Relationship Between Visibility and Traffic Accidents

CITATION: M. S. Janoff. , Illuminating Engineering Society, Journal of, 1978. Illuminating Engineering Society. Vol. 8, No. JAN19, Pg. p.-95-104.

ABSTRACT: No abstract provided. Note: M.S. Janoff ... Illustrated Includes Bibliographical References Illuminating Engineering Society Journal Of The Illuminating Engineering Society.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Replacement of Fluorescent Lamps With High-Brightness LEDs in a Bridge Lighting Application

CITATION: J. W. Curran and S. P. Keeney. , Appearing in: Sixth International Conference on Solid State Lighting, Proceedings of the SPIE - The International Society for Optical Engineering, 2006. SPIE - The International Society for Optical Engineering. San Diego, CA, USA. Vol. 6337, Pg. 633719-1.

ABSTRACT: There are many advantages that LEDs offer for use in general illumination. The use of LEDs in certain applications can provide improved energy efficiency. For example, in traffic lights in the United States, LED technology has taken over the market not only because of the energy savings as compared to standard incandescents, but also because of the reduced maintenance costs associated with bulb replacement and improved reliability. With useful lifetimes exceeding 40,000 hours or more, today's high flux LEDs can provide illumination solutions with replacement periods of 8 to 10 years or more. This paper will examine a bridge roadway lighting feasibility study which the authors' company recently undertook. The application required the LED units to reproduce the photometric performance of 64-inch (1.625 m) fluorescent lamps. In addition, the LED units were required to survive a harsh, outdoor marine environment with an expected lifetime of 7 years or more. To achieve these results, a number of design elements were studied including: optimum heat dissipation in a sealed enclosure, ease of installation, and design of power supplies having expected lifetimes to match the LED light engines. Results of these studies will be discussed as well as illustrations of the designs chosen.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Replacement of Fluorescent Lamps With High-Brightness Leds in a Bridge Lighting Application

CITATION: John W. Curran and Shawn P. Keeney. , Appearing in: Sixth International Conference on Solid State Lighting, 2006. International Society for Optical Engineering, Bellingham WA, WA

98227-0010, United States. San Diego, CA, United States. Vol. 6337, Pg. 633719.

ABSTRACT: There are many advantages that LEDs offer for use in general illumination. The use of LEDs in certain applications can provide improved energy efficiency. For example, in traffic lights in the United States, LED technology has taken over the market not only because of the energy savings as compared to standard incandescents, but also because of the reduced maintenance costs associated with bulb replacement and improved reliability. With useful lifetimes exceeding 40,000 hours or more, today's high flux LEDs can provide illumination solutions with replacement periods of 8 to 10 years or more. This paper will examine a bridge roadway lighting feasibility study which the authors' company recently undertook. The application required the LED units to reproduce the photometric performance of 64-inch (1.625m) fluorescent lamps. In addition, the LED units were required to survive a harsh, outdoor marine environment with an expected lifetime of 7 years or more. To achieve these results, a number of design elements were studied including: optimum heat dissipation in a sealed enclosure, ease of installation, and design of power supplies having expected lifetimes to match the LED light engines. Results of these studies will be discussed as well as illustrations of the designs chosen.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Roadway Lighting: An Investigation and Evaluation of Three Different Light Sources

CITATION: I. Lewin, P. Box and R. E. Stark. , 2003. Vol. REPT522; FHWA AZ03522; PB2004100097.

ABSTRACT: Nighttime visibility has been shown to be influenced by the lamp type used for roadway lighting, because the lamp's spectral output can influence sensors in the retina that are active at night. The report investigates the nature of these spectral effects and provides an in-depth review of available knowledge. It also addresses lighting levels and their relationship to driver safety. Three candidate lamp types have been analyzed in terms of technical characteristics and associated costs. This involves factors such as the efficacy with which the sources produce light, lamp life, and maintenance characteristics. Ideal lighting designs have been performed using the three sources for identical road sections, and initial and operating costs have been calculated, to assist in contrasting the difference between the sources. Two research plans have been developed for further investigations. One is a major project of field experimentation to determine relationships between visibility, safety, lighting level and lamp type under practical driving conditions. The other is based on using roadway sections lighted by the three sources respectively for the collection of accident data.

ACCESS: Available at the VDOT Research Library, Call No. TK 4188 .L494 2003 or online at http://www.azdot.gov/TPD/ATRC/publications/project_reports/PDF/AZ522.pdf

Roadway Visibility Using Minimum Energy

CITATION: D. M. FINCH. , Transportation Research Record No. 855, 1982, Pg. p.-7-16.

ABSTRACT: The basic requirements for nighttime roadway visibility are reviewed, and a table of recommended values for roadway lighting of city streets is presented. The values are based on five classifications of streets and a separate category for intersections. The primary standard of measurement is roadway luminance, but illumination and glare values are shown as parallel requirements. The recommended values for roadway lighting are less than the current American Standard Practice (RP-8, 1978) values but have more stringent quality specifications. Thus, it is shown that vision on roadways can be equal to or better than current practice and energy use can be appreciably reduced, by as much as 50-60 percent in some cases. Data for a study project in Portland, Oregon, are reviewed to demonstrate that the recommendations are achievable and that energy and cost reductions are practical. (Author). Note: This paper appeared in Transportation

Research Record No. 855, Visibility and Operational Effects of Geometrics.
ACCESS: Available at the VDOT Research Library, Call No. TA 1001.5 .T71 no. 855

Safety Effects of Reducing Highway Illumination for Energy Conservation

CITATION: Christopher M. Monsere and Edward L. Fischer. , Appearing in: Transportation Research Board 87th Annual Meeting, 2008. Transportation Research Board. Pg. 14p.

ABSTRACT: In 2001, Oregon's governor responded to a perceived future energy shortage in the Pacific Northwest by directing all state agencies to reduce power consumption by 10 percent. After review of power saving opportunities, the Oregon Department of Transportation (ODOT) elected to include selective illumination reductions on Oregon interstate highways as part of their energy saving strategy. The illumination reductions occurred at 47 interchanges and along 6.03 miles of interstate highway between October 2001 and April 2002. The reductions consisted of full to partial interchange lighting, partial plus to partial interchange lighting, or lineal modifications. The study evaluated the changes in safety performance using crash, geometry, weather, and volume data from years 1996 to 2005 with an empirical-Bayes observational before-after evaluation. The study found a 3.47 percent increase (4.65 standard deviation) in total night crashes where full interchange lighting was reduced to partial lighting. Injury night crashes, however, were found to decrease by 11.38 percent. For interchanges where illumination was reduced from partial plus to partial, a 35.24 percent decrease in total night crashes was found. A 28.95 percent increase in total night crashes (18.21 standard deviation) on sections where the lineal lighting was modified was found. Weighing all evidence, the research concluded that a decrease in safety performance occurred on the lineal freeway sections and at full to partial lighting locations. An observed decrease in safety performance was not found at the partial plus to partial lighting modifications.
ACCESS: Available at the VDOT Research Library, Call No. CD-ROM TA 1005 .N382

A Sensor Integrated Ultra-Long Span LED Street Lamp System

CITATION: Kai Wang and Sheng Liu. , Appearing in: 2007 8th International Conference on Electronic Packaging Technology - ICEPT '07, 2007. IEEE. Shanghai, China. Pg. 568-70.

ABSTRACT: As the LED's lumen efficiency increases rapidly in recent years, many new LED illumination applications are emerging. Based on the analysis of LED's characteristics, our optimization scheme and design methods for LED street lamps were proposed. A unique street lamp with ultra-long span and high total uniformity was designed as an example. The simulation results demonstrated that the road light utilization efficiency was 85% and the total uniformity was 0.52 for a 100x30 square meters test area at the height of 20 meters, which was much better than the current standard for the main road, proposing a challenging to the current standard with high pressure sodium lamps. Various sensors integrated with the LED street lamps were also discussed as the mainstream design concept for the next-generational LED street lamps.
ACCESS: Available through Interlibrary Loan to VDOT employees.

Sensor-Friendly Vehicle and Roadway Systems

CITATION: P. Griffiths, D. Langer, J. A. Misener, et al. , Appearing in: Rediscovering Measurement in the Age of Informatics, 2001. IEEE. Budapest, Hungary. Vol. 2, Pg. 1036-40.

ABSTRACT: Sensor-friendly vehicle and roadway systems consist of complementary signal sensor and reflector or transmitter technologies, which provide information about the threat of a collision. These technologies can be composed into cooperative collision avoidance systems, which can supplement or replace single vehicle-based systems. Experiments were run on the four most promising technologies to determine their performance and reliability; the four technologies were passive license plates with enhanced radar return, roadside obstacle-mounted radar-reflecting corner cubes, fluorescent paint for lane and obstacle marking, and light emitting diode brake-light

messaging. These technologies all focus on improving the signal-to-noise ratio of the collision avoidance sensor. We believe that experimental results indicate that further proof-of-concept refinements are needed, but in general these systems represent technologically sound, cooperative vehicle-roadway components and that sensor friendly systems could eventually translate into a significant benefit in terms of lives saved.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Signage in the Digital Age

CITATION: Clifton Stroud. , Airport Magazine, 2006. AAE Service Corporation, Incorporated. Vol. 18, No. 6, Pg. pp-22-25, 28.

ABSTRACT: When airport managers are choosing flight information display systems and directional signs, they are looking for the sharpest, most visible and readable displays available at a reasonable cost. This article discusses the unique signage needs of airports and how new products that incorporate plasma screens, liquid crystal display (LCD) and light emitting diode (LED) technology can meet these needs. LED signs are a popular choice, especially for outdoor applications, because of their long life expectancy and visibility in bright sunlight. LCD technology is an acceptable alternative to LED displays in inside, smaller venues. Plasma screens are good for applications such as video, but they lack sharpness from side angles and they suffer from image burn-in. A scrolling color, backlit display sign can be used to generate advertising revenue for the airport.

ACCESS: Available through Interlibrary Loan to VDOT employees.

A Smart Lighting Choice for Parking Areas

CITATION: Kevin Orth. , Parking Today, 2007. Bricepac, Incorporated. Vol. 12, No. 10, Pg. pp-30-31.

ABSTRACT: In this article the author discusses the merits of light-emitting diode (LED) based lighting solutions for parking areas in contrast with the standard high-intensity discharge (HID) solutions such as high-pressure sodium and metal halide. Only recently has LED been able to compete with HID lighting in terms of the strength of the light intensity. LED offers advantages such as little maintenance, energy savings, robust performance under extreme weather conditions, and instant restriking after power interruption. Another advantage of LED is that even if one of the diodes fails, there is no need to replace the entire fixture. Only upon a large percentage of failures do the fixtures need replacing. As LEDs are solid-state with no moving parts, they also provide an in-principle reliability over technologies that are less solidly constructed.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Solar Powered Highway Sign: Final Report

CITATION: Robert L. Hayden, Werner Hutter, Colorado, et al. , Appearing in: Report / Division of Transportation Planning, State of Colorado ;; no. 80-9; Variation: Colorado.; Division of Transportation Planning.; Report ;; no. 80-9. 1980.

ABSTRACT: Not available.

ACCESS: Available at the VDOT Research Library, Call No. TE 228.3 .H39 1980

Solar Powered Lighting for Overhead Highway Signs

CITATION: Research in progress, Start date: 2006/8/28, End date: 2008/8/15, Source Organization: University of Arkansas, Fayetteville. Principal investigator: Patangia, Hirak, hcpatangia@ualr.edu

ABSTRACT: The purpose of the present research is to design and develop a solar powered lighting

system for overhead highway signs with a view to improving night visibility, driving conditions, and highway safety. Two systems will be developed and tested: one system will utilize regular fluorescent tube lights for shining light on the sign, and the other system will employ Electroluminescent (EL) fibers to highlight the letters in the sign and/or the boundary of the signboard. The engineering aspect will involve designing a highly efficient dc to ac inverter at 60 Hz for fluorescent system and at 1 KHz for the EL system. An improvement in inverter efficiency will allow use of more compact solar panels and reserve energy for rainy or cloudy weather conditions. The inverter signal quality will be similar to that of utility supply (reduced harmonics) for extended life of the fluorescent tubes as well as EL fiber. The system will incorporate a power management controller to adjust the lighting effect to compensate for weather conditions for days with inadequate solar charging. Both the systems will be tested outdoor in a highway environment, and their performance will be closely monitored. A group of volunteers will be recruited to determine their perceptions concerning any benefit to traffic safety due to the overhead lighting.

ACCESS: Research underway.

Solar Street Light

CITATION: S. Nakanishi, K. Matsumura, H. Mori, et al. , Sharp Technical Journal, 2005. Sharp Co. No. 93, Pg. 54-8.

ABSTRACT: Most of the conventional solar street lights using 20 W fluorescent lamps as light sources were expensive. Their market prices were between 1,000,000 to 1,500,000 yen. We have developed two types of solar street lights with special high-luminance white LED lamps and realized low price of nearly 500,000 yen. To apply the controlled direct current at the LEDs, the life time was expected to become about 15 years. Due to the low energy consumption of less than 10 W, a photovoltaic module size was able to be smaller and we realized the slim pole solar street light which the controller and the batteries were all set in.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Street Lighting: Past, Present and Future

CITATION: G. H. Wilson. , Light and Lighting, 1942. Illuminating Engineering Society, London, England. Vol. 35, No. 6, Pg. 71-72.

ABSTRACT: Considerations of visibility have led to study of effects of road surface reflectivity on brightness distribution; importance of siting post positions so that satisfactory distribution of brightness is obtained; sodium and mercury lamps; future of street lighting.

ACCESS: Available through Interlibrary Loan to VDOT employees.

A Study of the Benefits of Suburban Highway Lighting

CITATION: Illuminating Engineering, 1969, Vol 64, No 4, PP 359-363.

ABSTRACT: the effectiveness of highway lighting in reducing automobile accidents was determined. Figures are given for accidents, injuries, and deaths during the year prior to the installation of lighting and for the two-year period after lighting was installed. After the installation of highway lighting, accidents were reduced 22 per cent and injuries were reduced 39 per cent per million vehicular miles. A discussion of costs is included.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Summary of Current Status of Knowledge on Rural Intersection Illumination

CITATION: Martin E. Lipinski, G. C. Meador, A. L. Gilbranson, et al. , Highway Research Record, 1970. Highway Research Board. No. 307,

ABSTRACT: the purpose is to review the status of knowledge as of June 1968 regarding roadway

illumination at rural at-grade intersections and to summarize current practices. Over 300 references have been reviewed. From this review of literature and the results of a survey of current practices, it was determined that very few research studies pertaining to illumination problems at rural at-grade intersections have been conducted; but the need for such work has been shown by the interest states and other organizations indicated in their replies to survey questionnaires. The scarcity of developed programs of intersection illumination across the country substantiates the need for standard lighting programs and warrants for these rural problem areas. Background information on the extent of current practices in the area of rural at-grade intersections was obtained by survey questionnaires sent to 49 state highway departments and various other organizations and industries concerned with roadway lighting problems. Replies indicated that very few programs were in operation but that there was a widespread interest in roadway illumination programs.

ACCESS: Available at the VDOT Research Library, Call No. TA 1001.5 .T71 no. 307

Survey of Advanced Front Lighting System (AFS) Research and Technology. Assessment of Headlamp Glare and Potential Countermeasures

CITATION: Y. Akashi, J. Van Derlofse, J. Watkinson, et al. , 2006. United States. Pg. 108.

ABSTRACT: The goal of advanced front lighting systems (AFS) is to actively control headlamp beam patterns to meet the dynamic requirements of changing roadway geometries and visibility conditions. AFS is being rapidly introduced worldwide due to its attractive styling aspects and potential safety benefits. However, before AFS becomes more aggressively implemented, it is necessary to better understand the impacts of AFS on drivers, other vehicles, and pedestrians. To achieve this understanding, this survey investigated comments on AFS from the NHTSA database (Docket 13957), reviewed relevant literature, and held a phone conference with automobile and headlamp manufacturers for industry feedback. The detailed results of the survey are described in this report. This survey led to a general conclusion that, although a significant number of studies on AFS have been done, due to inconsistency in metrics used and lack of information on experimental procedure and scenarios, further research is still needed to quantify the effectiveness of AFS. In order to evaluate AFS technology, it is important to first identify the appropriate visibility, glare, and safety metrics and test methods. Second, based on these common metrics and test methods, examine the effectiveness of AFS compared to other vehicle forward lighting systems. Based on these findings, two tasks are proposed as future NHTSA research: (1) identify appropriate metrics, performance measures, and test scenarios for AFS; and (2) develop an AFS prototype for evaluation.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Switch To Energy-Efficient Lighting, Lower Wattages Saves Highway Dollars

CITATION: Anonymous , Better Roads, 1977. James Informational Media, Incorporated. Vol. 47, No. 9, Pg. p.-20-32.

ABSTRACT: Several states across the country recently have initiated energy conservation measures by switching to high pressure sodium lamps and reducing lighting levels in some areas without compromising traffic safety, while at the same time coming up with some impressive cost savings that somewhat ease the tight budget situation. The article reports on a poll recently conducted among various highway departments to determine what specifically is being done in their areas to conserve energy through highway lighting techniques and equipment.

ACCESS: Available at the VDOT Research Library, periodicals section.

Syracuse Street Lighting: Defensive Decision-Making By a City Faced With Escalating Energy Costs

CITATION: D. D. Roberts. , 1977. Syracuse University Research Corporation; Department of Energy. Pg. 25-p.

ABSTRACT: As an urbanized public function, municipal street lighting is a \$420 million yearly industry. Installation of energy-efficient lamps (e.g., high-pressure sodium) may result in a 60% decrease in energy required by earlier technologies, but utilities (the owners of most street lighting systems) are slow to convert. Niagara Mohawk Power Corporation owns and operates the system in Syracuse, New York. Rates had been low until 1973. But by 1974, Niagara Mohawk estimated it needed a 42% increase in street-lighting rates. With an increase of \$300,000 in 1975, city officials began tentatively to consider options, the main one being to purchase the system. Options to buy street lighting systems in neighboring cities had been defeated by popular vote. Some calculations showed that by acquiring the system, a net loss of income to the city of Syracuse would result. A program to install the HPS lamps was implemented, but to date only 241 lamps have been installed. The technical innovation was more involved than was anticipated. (ERA citation 03:040919).

ACCESS: Available through Interlibrary Loan to VDOT employees.

Talking LEDs

CITATION: Carl Gardner. , Lighting Journal (Rugby, England), 2004. Institution of Lighting Engineers, Rugby, CV21 2DZ, United Kingdom. Vol. 69, No. 5, Pg. 14-20.

ABSTRACT: Carl Gardner, lighting Journal editor talked to Keith Scott, the director of Market Development at Lumileds, about the future potential of light emitting diodes (LED), particularly in the field of public lighting. Keith Scott said that they have decided not to put a whole lot of further effort into Luxeon V but to concentrate on new high power packages. He says that the reality of an LED is that it's much like the old mercury vapor lamp, that is it will run and run and run, but the output will just continue to drop and drop. He adds that the motion detector or things like that could be linked quite easily with LEDs.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Testing and Evaluation of the Solar Panel Sign Support System

CITATION: D. L. Bullard, R. P. Blight, W. L. Menges, et al. , 2001. United States. Pg. 92.

ABSTRACT: The purpose of this series of tests is to verify the performance of the pedestal sign installation when attached to the ground with a helical type screw-in foundation anchor assembly and equipped with the solar power (photovoltaic) hardware necessary to operate flashing signal beacons. Additionally, wind load analysis was also performed to determine the strength of the installation under extreme wind conditions. A pedestal base sign installation equipped with photovoltaic equipment and attach to the ground with a helical type screw-in foundation anchor assembly successfully met the evaluation criteria set forth in National Cooperative Highway Research Program (NCHRP) Report 350. The installation was fabricated using a Pelco (model SP 1014 TX) square cast aluminum traffic signal base with a 114 mm (4.5 in) outside diameter x 3.96 m (13 ft) long spun aluminum pole. Attached to the pole was a 16 mm x 1.2 m x 1.2 m (0.625 in x 48 in x 48 in) plywood warning sign with the bottom of the sign height 2.1 m (7.0 ft). In addition, a 305 mm (12.0 in), LED lamp, flashing yellow signal beacon was mounted directly above the sign panel. A 1429 mm x 654 mm x 89 mm (56.3 in x 25.7 in x 3.5 in) solar panel weighing 235.8 N (53 lb) was attached atop the support.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Thermal Analysis of an 80 W Light-Emitting Diode Street Lamp

CITATION: X. Luo, T. Cheng, W. Xiong, et al. , IET Optoelectronics, 2007. IET. Vol. 1, No. 5, Pg. 191-6.

ABSTRACT: Light-emitting diode (LED) street lamps rely heavily on successful thermal management, which strongly affects the optical extraction and the reliability/durability of the LED lamp. A thermal analysis of an 80 W LED street lamp was done. Sixteen thermocouples were used to measure the temperatures at 16 different positions of the street lamp. The results demonstrated that the temperature of the frame and the heat sink of the 80 W LED street lamp remained stable at about 42°C after several hours of lighting at a room temperature of 11°C, and the bulk material resistance of the heat sink could be neglected. Numerical simulation was also used to analyse the temperature distribution of the lamp. The reliability of the numerical model was proven by a comparison of simulation results with the experimental data. Through simulations and the corresponding analyses it was found that the tested 80 W LED street lamp would have poor reliability at an environment temperature of 45°C.

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TRANSPORTATION & ROADWAY LIGHTING - Night Rider - Under The Cover Of Darkness, Ron Gibbons And His Team Of Lighting Researchers Aim To Develop New Standards And Practices On Virginia Tech's Well-Traveled "Smart Road"

CITATION: Anonymous , Lighting design + application : LD + A, 2004. Vol. 34, No. 2, Pg. 35.
Note: Additional Info: Illuminating Engineering Society of North America, Alt Journal: Key Title: Lighting design & application Preceding Title: Lighting design & application.
ACCESS: Available through Interlibrary Loan to VDOT employees.

TRANSPORTATION & ROADWAY LIGHTING - Seeing the Big Picture - The lighting community must think in terms of "roadway visibility" rather than "roadway lighting," while taking a systems approach to design

CITATION: Anonymous , Lighting design + application : LD + A, 2004. Vol. 34, No. 2, Pg. 27.
Note: Additional Info: Illuminating Engineering Society of North America, Alt Journal: Key Title: Lighting design & application Preceding Title: Lighting design & application.
ACCESS: Available through Interlibrary Loan to VDOT employees.

Turning The Tide in Adelaide : Adelaide's Southern Expressway Highlights Another Application for Led Technology

CITATION: Anonymous , ITS international.Vol.6, issue 4, 2000. Pg. p.-50.
ABSTRACT: This article discusses the use of light emitting diode (LED) technology for road markings in Adelaide, Australia. LED lights fitted to the road surface are able to provide drivers with positive lane guidance.
ACCESS: Available at the VDOT Research Library, periodicals section.

Unidirectional Lighting of Double Carriageway and One-Way Roads

CITATION: J. S. Smyth. , Surveyor and Municipal and County Engineer, 1948. Vol. 107, No. 2954, Pg. 479-481.
ABSTRACT: Factors which led to installation of unidirectional lighting system on two-lane and single-lane roads; among advantages is saving in power consumption, avoiding bright road surfaces and clearness with which junctions are seen; examples of conventional and unidirectional lighting shown in illustrations. Before Assn Pub Lighting Engrs.
ACCESS: Available through Interlibrary Loan to VDOT employees.

Use of LED or Other New Technology to Replace Standard Overhead and Sign Lighting (Mercury and/or Sodium)

CITATION: Patrick J. Szary, Ali Maher, Michael Strizki, et al. , 2005. Rutgers University,

Piscataway; New Jersey Department of Transportation; Federal Highway Administration. Pg. 138p.
ABSTRACT: The New Jersey Department of Transportation (NJDOT) has an increasing concern that the quality and energy use for roadway lighting is outdated. The current lamps and energy usage is based on old practices and technologies. To research the state-of-the-art, NJDOT has contracted Rutgers/Center for Advanced Infrastructure and Transportation. The main issues to be addressed include: 1) Introduce the existing and latest technologies in roadway lighting, and evaluate the current and proposed alternatives (taking into consideration illumination, visibility, maintenance, spectral power distribution, lumen depreciation, mean life, and color rendering). In addition, the research team is to provide NJDOT with the field verification on two key issues: visibility and color rendering, which are implemented on sodium and white light sources. 2) Present the life cycle cost analysis (LCCA) on the introduced technologies and compare them to current lamps used in street lighting (High Pressure Sodium), with the proposed alternatives. Thus, the study will provide not only the most cost effective alternative to using High Pressure Sodium in roadway lighting, but also the most practical. Based on the research, white light sources demonstrated superior light quality. QL, Icetron, Restrike HPS, and LEDs were all shown to be equivalent or superior in light quality based on Lumen Effective Multiplier (LEM). Also, based on the LCCA the QL, Icetron, Restrike HPS, and LEDs had superior cost savings. However, QL, Icetron, and LEDs may not meet current light distribution specifications, which are currently being revised on a national level. In summary, Restrike HPS lamps are recommended for immediate implementation; whereas QL, Icetron, and LEDs should wait for acceptance on a national level. In some situations where lighting is not specifically governed by the specifications, and NJDOT would like to further evaluate the technologies, QL type lamps are recommended for implementation.

ACCESS: <http://www.state.nj.us/transportation/refdata/research/reports/FHWA-NJ-2005-029.pdf>

Use of Solar Energy for Lighting Of Overhead Guide Signs, Roadway Lighting, and Intersection Traffic Signals. Final Report

CITATION: J. E. Upchurch, P. E. Russell and E. F. McBrien. , 1989. Arizona State University, Tempe; Arizona Department of Transportation; Federal Highway Administration. Pg. 73-p.

ABSTRACT: The principal objective of this study was to demonstrate the technological and economic feasibility (or lack thereof) of photovoltaic powered systems for overhead guide sign lighting, roadway lighting, and traffic signalization. A preliminary technical and economic feasibility study concluded that the first two applications were feasible, but that full-scale traffic signalization was not. In lieu of full-scale traffic signalization, the project developed a system to power flashing warning lights. Photovoltaic systems were designed, constructed, field tested and evaluated for overhead guide sign lighting, roadway lighting, and powering of flashing warning lights. All these systems were found to be dependable and economical for application at remote sites where a conventional power supply is not available. In addition, previous research has shown that roadway lighting can have a safety benefit at remote locations which have a high nighttime accident rate and that flashing warning lights have a safety benefit.

ACCESS: Available at the VDOT Research Library, Call No. TE 228 .U63 1990

Using LEDs in Large Area Displays

CITATION: Terry Klein. , New Electronics, 1987. Vol. 20, No. 8, Pg. 44-45.

ABSTRACT: During the past decade, advances in light emitting diode technology and the availability of low-cost computing power have combined to make the production of large area LED signs commercially viable. Present technology enables each point in a continuous field of lamps to be individually controlled. Modern displays can now approach the pixel density of a CRT, and the display can be interfaced with computer systems that are CRT oriented. The display has become a user friendly CRT emulator that can handle third-party software. State of the art of LED - based

display technology is outlined.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Visibility for Highway Guidance and Hazard Detection

CITATION: M. S. Janoff, L. K. Staplin, C. A. Bennett, et al. , 1987. Vol. TRBTRR1149; ISBN0309046599; PB89139539,

ABSTRACT: The 11 papers in the report deal with the following areas: Effect of alternative reduced lighting techniques on hazard detection; Characterizing discomfort glare from roadway lighting; Evaluation of headlamp systems for nighttime safety: their relationship to retroreflective traffic sign performance; Marine visibility research and development initiatives of the U.S. Coast Guard; Legibility of freeway guide signs as determined by sign materials; Contrast sensitivity, drivers' visibility, and vision standards; Effect of alternate population mixes on design eye locations in vehicles; Measuring wet-night delineation reflectivity; Use of reflectorization to reduce truck-trailer accidents; Driver lateral control performance as a function of delineation; Establishing a minimum functional reflectance for raised pavement markers. Note: Library of Congress catalog card no. 88-19555.

ACCESS: Available at the VDOT Research Library, Call No. TA 1001.5 .T71 no. 1149

Visibility Levels in Street Lighting: An Analysis of Different Experiments

CITATION: W. Dr. Adrian. , Journal of the Illuminating Engineering Society, 1993. Vol. 22, No. 2, Pg. 49-52.

ABSTRACT: In order to support recommendations on necessary visibility levels in roadway lighting, the results of experiments have been analysed. Dunbar and de Boer investigated when a target of a defined size and contrast could be seen under driving conditions. Janoff had a group of observers subjectively rate lighting quality. He then measured when a critical detail of a target - a protruding square - could be seen. The analysis of the underlying photometric data of those experiments led to the selection of visibility levels between 8-11 and 15 to perceive the form of the target at an average road luminance of 1 cd/m²@. A VL of 15 implies and 80 percent probability of perceiving the form. The results support the range of VL levels as suggested in the roadway lighting recommendations and reflect that VL is applicable as a measure of lighting quality.

ACCESS: Available through Interlibrary Loan to VDOT employees.

Visual Performance Under CMH And HPS Street Lighting at Different Power and Dimming Levels

CITATION: G. I. Crabb, TRL Limited, Great Britain, et al. , Appearing in: Published project report, ; PPR069, 2006. TRL Limited. Wokingham, Berkshire. Pg. 49.

ABSTRACT: Highly efficient light sources are under development to reduce the power consumption of lighting systems and hence greenhouse-gas emissions in line with the international Kyoto agreement. Preliminary calculations suggested that, within Europe, the expected annual energy savings could be around 10 terawatt hours (TWh), which corresponds to a reduction of at least 5 million tons of carbon dioxide (CO₂) emissions. Such systems, applied to street lighting, should simultaneously produce benefits in road safety, energy efficiency and the visual quality of outdoor lighting schemes. The earlier European 'NumeLiTe' (Numerical Light for Technology) project, in which TRL participated sponsored by the European Commission, the UK Department for Transport and the UK County Surveyors Society, aimed to prove the feasibility of an optimal and energy efficient outdoor city lighting scheme. This utilised broad spectrum 'white' light intended to match the needs of the human visual system better than conventional street lighting, when performing tasks essential to road users. This project was designed in the light of this earlier project to

investigate the feasibility of using CMH and HPS lamps of significantly lower power than used in the NumeLiTe project. Moreover, because of the complexity of the human visual system and the road user's task, evidence was needed to confirm that reduced illumination would not have any adverse effect on road user behaviour and road safety. The results did not show any visual performance benefit from the use of the CMH lighting for traffic streets, but provide some evidence that it may be safe to reduce lighting levels, in traffic streets normally lit to higher levels, to 0.5cd/m² during the quieter period of the night, as permitted by current standards. Dimming to this lower level, using either type of lamp, should be free of any significant degradation in visual performance, and allow potential energy savings to be realized.
ACCESS: Available at the VDOT Research Library.

Well-Lit Directions: Architectural Lighting Could Be the Most Effective Way of Illumination

CITATION: Raymond Grenald. , Roads & Bridges, 2006. PSA Group LLC. Vol. 44, No. 3, Pg. pp-60-62.

ABSTRACT: A well-lit bridge can be a beautiful sight at night. This article describes the various types of lighting that can be employed, as well as which type works best in specific situations. The author describes four different approaches lighting designers utilize when illuminating bridges. These include the "historical precedent" model, which entails restoration of existing historic fixtures; a more straightforward illumination model for floodlighting the bridge structure; a theatrical approach that includes visual projections onto the bridge or the use of colored floodlights; and architectural lighting which is a combination of the straightforward illumination model and the theatrical model. Constraints in lighting design include building codes, site conditions, spill light, glare control and budgets. Sustainability and maintainability are also important issues.

ACCESS: Available at the VDOT Research Library, periodicals section.

A White LED Low-Mounted Luminaire, Using the All-positive Contrast Concept based on Car Headlights

CITATION: A. Walkling. , Lighting Journal (Rugby, England), 2004. Institution of Lighting Engineers. Vol. 69, No. 1, Pg. 24-25.

ABSTRACT: A white light emitting diode (LED) low-mounted luminaire was developed for road lighting applications using the all-positive contrast concept based on car headlights. A collimator for each LED was designed to achieve a symmetrical beam pattern to fulfill the glare control requirement. The glare effect caused by a fixed low-mounted installation was estimated by using the threshold increment (TI) method. The results show that light pollution can be minimized in the extreme, while providing additional visual guidance for increased driver visual comfort, which can affect road safety.

ACCESS: Available through Interlibrary Loan to VDOT employees.

White Power LED Lights the Way With a 160-Lumen Output

CITATION: R. Allan. , Electronic Design, 2006. Penton Media. Vol. 54, No. 26, Pg. 39-41.

ABSTRACT: A new white-light LED sports a 160-lumen luminous flux output level at a 700-mA dc forward current and 61-lumen/W efficacy level (white color temperature of 5000 K to 10,000 K). And that's about 33% brighter than its nearest competitor, says the LED's developer, Cree Inc. The XLamp 7090 XR-E series power LED also puts out 85 lumens at 350 mA. It is based on SiC wafer technology with an InGaN layer, this benchmark-setting device matches the output and efficacy levels of fluorescent lamps. The device is as efficient as fluorescent sources, making it a cost-effective alternative for a number of general illumination and backlighting applications.

Projected uses include flashlights, architecture, traffic signs, homes and offices, headlights, garage and warehouse low-bay illumination, and camera flash and projection displays.

ACCESS: Available through Interlibrary Loan to VDOT employees.

You Are My Sun Sign

CITATION: Anon. , *Highways*, 2005. Alad Limited, Rochester, ME2 1BY, United Kingdom. Vol. 75, No. 2, Pg. 38-39.

ABSTRACT: The use of solar powered light emitting diode (LED) road sign's in the UK is helping in avoiding of accident. The country's first solar powered road signs - the Solagen SAS 600 - was installed at a busy junction on the A38 near Watts Cottage, Burlescombe, Tiverton, in December 2004. The Solagen SAS 600 solar powered permanent installation was found to be fit as it was neat and completely independent with no energy costs and low maintenance. Such signs alert drivers of the potential hazards, and warn them to take action before it is too late and also help in bringing down the number of accidents.

ACCESS: Available through Interlibrary Loan to VDOT employees.