Assisted Night Vision for Motorists in Highway Construction Zones: Phase I*

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FINAL REPORT

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1) Project Abstract

The goal of the project was to develop a low cost solution to provide active lighting along the length of jersey barriers in construction zones. The primary design requirement for such an application is energy efficiency of the lighting devices. The project investigates two different technologies for this purpose: Electroluminiscent (EL) technology and Light Emitting Diode (LED) technology. The EL technology is well known for its energy efficiency and ideally, the power consumption is very nearly zero. The EL requires a high voltage ac (typically 100V rms) at a frequency of few hundred hertz for its operation while the current draw is very small. The LED technology doesn't need such high voltage and can be easily operated from a 12V dc, however, the power requirement is higher. Since the lights are for outdoor usage, 12V batteries were used as the power source for both the systems. For driving the EL lamps, an efficient dc-ac inverter was researched and developed for the project, and the results relating to this new inverter design was published recently at the IEEE International Conference on Industrial Technology (ICIT'04). For the LED driver, Pulse Width Modulation (PWM) technique was employed to minimize power consumption. Both the systems were built and tested in the laboratory before deployment at the field site. The 12V batteries and the solar panels were selected to match the power calculations of the two systems. The wire harnessing for both EL and LED systems were assembled at a construction zone on HWY 270 in Hot Spring for field-testing the lamps under actual environmental condition. Fifteen LED lamps on one side and same number of EL lamps on the opposite side were installed on the barriers and each system was powered from a 12V battery. The batteries were charged in the daytime through two solar panels (15" x 19") with one dedicated to each battery. Electrical data were gathered starting last week of

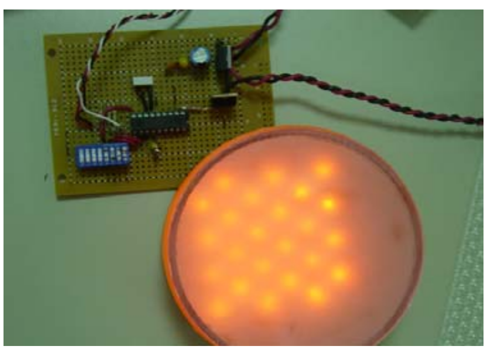
September through first week of December. An analysis of the data is included in the report. Both the technologies performed well electrically, and the enclosures for these lamps need further refinement to withstand the harsh conditions of ultra-violet (UV) rays, rain, and humidity.

2) Tasks Outlined in the Proposal

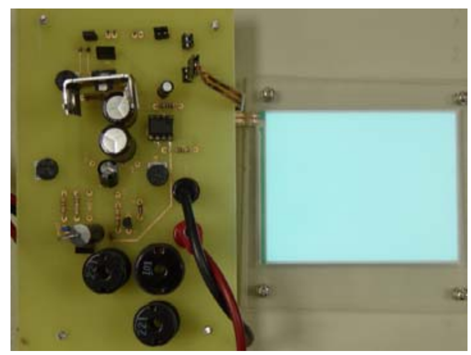
(a) Preparation of EL and LED lamp samples: September 2003 – November 2003
(b) Design of Power Source & Battery Charging: December 2003 – February 2004
(c) Construction Phase: March 2004 – April 2004
(d) Field Test and Instrumentation: May 2004 – August 2004
(e) Design Modifications and Report: August 2004

Task (a)

Preparations of EL and LED lamps were completed as scheduled: The following pictures are included to show details:



LED Lamp & Driver



EL Lamp & Driver

Task (b)

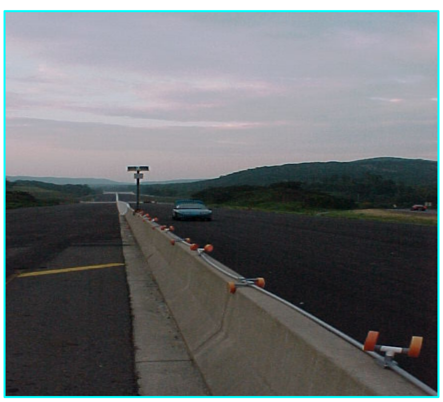
Sizing of battery source and solar panels were completed as scheduled.

Task (c)

Completed construction phase as scheduled. However, the advisory committee recommended a change in the color of the EL lamps. According to prevailing highway regulations, white color (original EL color) is not acceptable for barrier delineation and an orange color was recommended. This is not a readily available color for EL and the company supplying the EL lamps had to go through a new production cycle to develop EL materials with orange color. As a result, there was a delay in the completion of this phase and pushed out the timeline to July.

<u>*Task (d)*</u>

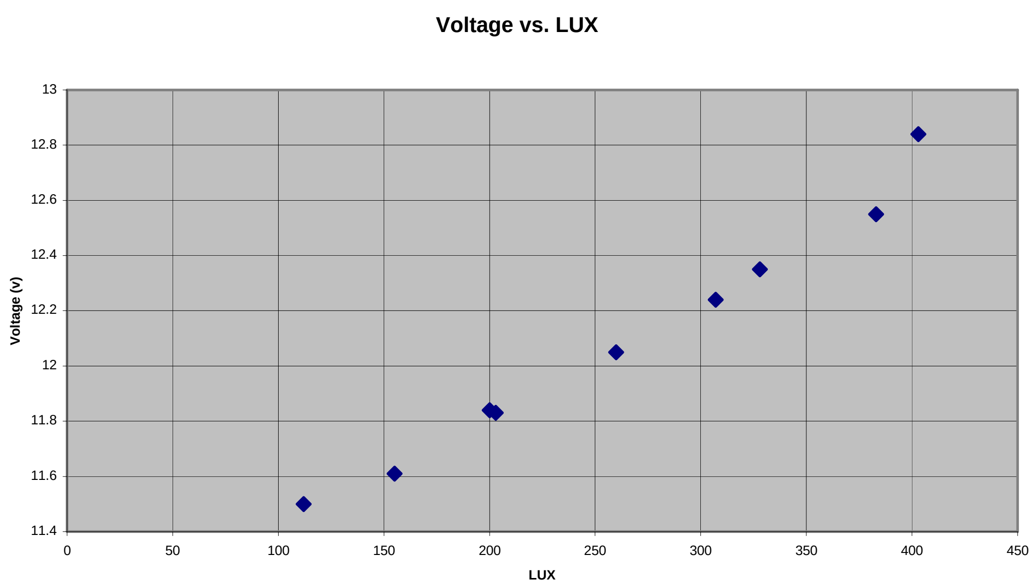
The start of the field test was delayed due to the reordering of EL lamps and also the time it took in identifying a suitable construction zone that would be safe for students to work, and not distract motorists with a new device on the road. HWY 270 in Hot Spring was the site selected for field-testing and it was a fairly safe site to work since there was no traffic immediately adjacent to the barrier. The assembly phase was completed beginning September, and results were monitored September through first week of December. The following field-site pictures give an overview of the installation:



The eastbound side of the barrier was used for LED lights and the EL lamps were hung on the westbound side. In the bottom right picture shown above, the housing underneath the two solar panels includes the drivers for both EL and LED lamps. The enclosure is waterproof, and conduits for electrical wiring were laid along the top of the barrier into the enclosure. This configuration required long conduits to install the lamps. In practical application, this could be a major problem unless the jersey barriers are pre-fitted with the conduits to run the wires. A solution to this challenge has been described in the implementation section of the report.

3) <u>Test Results</u>

Electrical data were collected for voltage, current, and brightness (LUX) on a weekly basis. Observational data were collected for the environmental (weather) effect on the devices. The following graph gives an overall view of the variation of brightness (LUX) with voltage averaged over nine weekly readings:



As expected, the brightness varied with battery voltage, and the battery voltage was a function of the solar power. The brightness dropped to little over 100 LUX when the weather was cloudy and rainy. We had more than a week of cloudy and rainy weather and even so, the battery voltage remained more than 11.4V to provide a brightness of 110 LUX. Along the barrier, there was some difference in LUX/lamp due to mismatching of lamps and also IR voltage drop along the wire harness. This would be more pronounced if the same driver were used to power a large number of EL or LED lamps. The current consumption of the EL system was considerably less than that of the LED, and this was expected. Even with higher power consumption, the LED system performed very well over the entire period of field-testing although the weather conditions underwent some extreme variations.

Outdoor Weather Effect

The test system was exposed to UV intense, humid, and rainy weather of the summer. Within two weeks, the effect of UV on the orange enclosures was visible, and the color was fading. Except for the enclosure, the LED lamps remained unaffected by UV radiation. The light intensity was not degraded due to UV effect. The EL system lamps appeared to suffer from weather exposure. It also happened that water got inside few EL lamps due to inadequate sealing. A sample of the orange EL lamp with weather effect was sent to the company that manufactured the EL sheets. The company's comments were:

We had conducted outside-test of amber color EL (4pcs) in 20days by IT9425A4 driver. We didn't find out any problem in the lighting area of amber color EL. I think the reason of this problem is temperature, humidity and unstable current voltage. So, I will start again the aging test with high humidity and temperature condition for checking the reliability. I will also check the high voltage test in 150V and 200V. After analysis of test, we will increase the reliability of amber color EL by increasing layer of EL structure or control of driver. It means we can continue to use the EL. We can also change from EL sheets to EL fiber, which itself is UV-resistant. It has been used outdoors for several years; it has no degradation of color, despite raining, because it is also double encapsulated by sheath. If we use EL fiber, we can coil it in a way to generate a spiral circle, which is still visible in foggy condition.

It appears from the comments of the manufacturing company that EL lamps are still usable and they are willing to improve their construction by adding more layers. Actually, the requirement of orange color has been a challenge for the company since this is not the natural color for EL lamps. It's the pigmentation that is affected by weather condition. However, EL fiber is UV resistant and that would be an alternate solution for the EL lamps.

4) Research Implementation

The original idea of the research proposal was to provide a distributed light on the jersey barriers for motorists to have a visual cue of the barrier profile. The EL lamps are ideal for this purpose since they produce a uniform light across its entire surface. Two or three lamps on each barrier were proposed for this purpose. As the project developed and was demonstrated to the AHTD advisory committee, it was pointed out that for barrier applications, only orange color is acceptable. It meant that the lamp would serve as an active light-emitting cautionary signal along the barrier. For such an application, one or two lamps per barrier would be sufficient. These devices would be visible from a distance and caution the motorists as they approach the construction zone. They would provide a higher level of safety in identifying the barrier profile to motorists under varying weather conditions compared to the passive reflectors that are currently used. The end products of the research are portable electronic lamps that can be deployed not only for barriers in construction zone, but also in any other situation where active warning signals are warranted.

5) <u>Design Modifications</u>

Few noteworthy lessons learnt from the field test are:

(a) Weather effect on the enclosures and lamps (EL).
(b) Layout of the wire harness for electrical power distribution.
(c) Time constraint due to unforeseen situations.

With lessons (a) and (b) in mind, design changes have been made in the construction of the final products. The EL lamps are to be constructed of EL fiber, which is known to be UV and humidity resistant. These devices are constructed in double encapsulated sheath making them rugged for outdoor applications. For quick and flexible installation of the lamps, we are experimenting with a self-contained lamp that includes a driver, automatic turn-on and off (depending on ambient light), battery pack, and a small solar panel. The solar panel has been sized to meet the electrical need for 3-4 days. With such a design, there is no need for long conduits, wiring layout, and the degree of electrical reliability is enhanced. Installation time will be reduced considerably, and the system will have the flexibility to be deployed for other applications. The following two pictures are prototypes of the current design:

Self-Contained LED Lamp with Solar Panel on Top

Self-Contained EL Fiber Lamp with Solar Panel on Top

If these models are approved by the AHTD advisory committee, we would like to employ them for the Phase II study. Since the Phase II plans include a large-scale study to evaluate motorists' perception of these barrier indicator lamps, we will need about 450 lamps for a mile with one lamp per barrier. Each lamp will have light emanating from two opposite sides to meet the needs for traffic flow on either side. To provide flexibility in time factor for construction/installation of the lamps and evaluation of data, a realistic estimate of end date for Phase II is June, 2006.

6) Summary Statement of Research Implementation

The research outcome of Phase I is ready for implementation. The cost of prototype of the new design is about thirty dollars in quantities of one or two. However, the cost in volume would be less than $10 per unit. The life of the units is expected to exceed 3-4 years. With advances in technology, the units should be upgraded on a timely basis to reflect the existing state of technology. With the design modifications to be incorporated in Phase II, the units would be usable in more applications than what was proposed in the initial research proposal.

Disclaimer Statement

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