IDEA

Innovations Deserving
Exploratory Analysis Programs

Highway IDEA Program

Operational Tests of the Conservation Traffic Control Load Switch

Final Report for Highway IDEA Project 26

Prepared by:
Gregory A. Filbrun
Conservation Load Switch, Inc.
Westerville, Ohioois

November 1996

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA) PROGRAMS MANAGED BY THE TRANSPORTATION RESEARCH BOARD (TRB)

This NCHRP-IDEA investigation by Conservation Load Switch, Inc. was completed as part of the National Cooperative Highway Research Program (NCHRP). The NCHRP-IDEA program is one of the three IDEA programs managed by the Transportation Research Board (TRB) to foster innovations in highway and intermodal surface transportation systems. The other two IDEA program areas are TRANSIT-IDEA, which focuses on products and results for transit practice, in support of the Transit Cooperative Research Program (TCRP), and ITS-IDEA, which focuses on products and results for the development and deployment of intelligent transportation systems (ITS), in support of the U.S. Department of Transportation's national ITS program plan. The three IDEA program areas are integrated to achieve the development and testing of nontraditional and innovative concepts, methods, and technologies, including conversion technologies from the defense, aerospace, computer, and communication sectors that are new to highway, transit, intelligent, and intermodal surface transportation systems.

For information on the IDEA Program contact IDEA Program, Transportation Research Board, 500 5th Street, N.W., Washington, D.C. 20001 (phone: 202/334-1461, fax: 202/334-3471, http://www.nationalacademies.org/trb/idea).

IDEA PROJECT FINAL REPORT
Contract NCHRP-94-ID026

IDEA Program
Transportation Research Board
National Research Council

November 1996

OPERATIONAL TESTS OF THE CONSERVATION TRAFFIC CONTROL LOAD SWITCH

Prepared by:
Gregory A. Filbrun
Conservation Load Switch, Inc.
Westerville, Ohio

CONSERVATION TRAFFIC CONTROL LOAD SWITCH

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This project describes the results of operational tests of the new conservation traffic control load switch (CTCLS Model 20867) developed under NCHRP-IDEA Project 8 by Conservation Load Switch, Inc. (CLS, Inc.) of Westerville, Ohio. The CTCLS has been designed to prolong the life of the incandescent lamps used in traffic signals. Depending on the voltage set point selected by a Department of Transportation (DOT), the CTCLS has the ability to extend lamp life by four times. The CTCLS Model 20867 will significantly reduce maintenance personnel's exposure to hazardous situations and will produce appreciable reductions in traffic-lamp maintenance expenditures.

DESCRIPTION AND METHOD OF OPERATION OF THE CONSERVATION TRAFFIC CONTROL LOAD SWITCH

The CTCLS Model 20867, a microcomputer that functions as a load switch, was designed to extend the life of incandescent traffic lamps by four times, providing significant savings to DOTs in maintenance expenditures. The load switch is the last possible access to the alternating current (AC) line voltage prior to reaching the lamp filament coil. By applying this technology to the load switch, there is no interference or damage to other critical components in the signal cabinet. The load switch is the only interchangeable component in the signal cabinet which provides the ease of replacement with maximum control over the AC line voltage. This is accomplished through three distinct features:

- Soft-Start: During the normal operation of an incandescent lamp, molecules of tungsten are constantly evaporating, which causes a notch, or weak spot, to develop on the tungsten filament coil. When AC is applied to a cold filament, an in-rush surge of 8-10 times normal load resistance occurs to the tungsten filament coil, causing stress to any notch or weak spot, which ultimately breaks the filament coil, and the lamp fails. The soft-start feature of the CTCLS Model 20867 softens this in-rush current or stress on the filament coil. The soft start, or the gradual increase of the initial AC voltage, preheats the filament coil over a period of 45 msec which is not perceptible to the human eye.

- Regulation: The Model 20867 regulation feature accomplishes two different functions. First, the microprocessor utilizes advanced series of algorithms to soften or cushion the voltage fluctuations, absorbing a substantial portion of the shocks and peaks that occur in all normal AC line voltage. This fluctuation is another leading cause of incandescent lamp failure. Second, the regulation feature regulates the AC line voltage down to a preset voltage point by looking at the AC line voltage 120 times per second and adjusting the AC applied to the lamp. This aspect of the regulation feature substantially cools the burning temperature of the lamp and slows the tungsten evaporation, which prolongs the life of the filament coil by reducing the development of the notches or weak spots on the coil. To obtain the maximum lamp-life benefits from the Model 20867, with the Institute of Transportation Engineers (ITE) standard for lumen output is specified at 1750 lumens, the CTCLS requires that a higher rated luminous output lamp be used to meet ITE specifications.

- Fail-Safe: When compared to a conventional load switch, the CTCLS Model 20867 provides an additional safety feature. In the unlikely event of microprocessor failure, the CTCLS Model 20867 reverts the unit back to a conventional on-off load switch through a built-in fail-safe, which helps to ensure uninterrupted traffic flow. The mechanical packaging is same as the standard National Electrical Manufacturers Association (NEMA) traffic control load switches. The connector and housing are exactly the same as existing units to ensure that no retro-fit will be required.

ACCOMPLISHMENTS

Two hundred CTCLS Model 20867 units were produced and distributed to 100 DOT and municipal signal laboratories throughout the country to:

1. Verify test results.
2. Complete all normal and customary testing of a traffic control load switch/tri-switch-pak to assist in the certification and specification processes.
3. Obtain recommendations for additional features.
4. Introduce the device to the DOT and municipal signal laboratories and obtain their feedback on its performance.

RESEARCH PROGRESS

PROBLEM STATEMENT

Burnt-out traffic lamps can prove to be more than just an inconvenience to motorists. The replacement of burnt-out lamps also causes considerable expense to state and regional DOTs. In addition, maintenance personnel are unnecessarily exposed to dangerous situations in order to perform the replacement. There is a need for a device or technology that would extend the life of traffic lamps, reduce maintenance expenditures, and reduce the exposure of personnel to dangerous situations. For the device to be useful, it must be compatible with the majority of existing hardware and meet all applicable standards for traffic-controlling equipment. The device also should be cost-effective to the end users.

RESEARCH APPROACH

CLS, Inc. contacted over 100 DOTs and municipalities to participate in this study. A mailing package was designed which included a six-week study questionnaire with verification testing steps intended to cover all functions of a traffic control load switch, a product description, NEMA Certification of Conformance, worksheets and specification sheets. CLS, Inc. then fabricated 200 test/production units to be used in this operational testing.

After the production units were assembled and tested, a number were sent to the DOT signal laboratories participating in this study, while a number of units were retained for additional testing.

Following are descriptions of the tests performed by the participating DOTs and municipalities, and their comments and feedback on the use and performance of the switch system.

Part One: Inside Signal Lab Testing and Review

Step 1:

Examine pin 11 in your cinch connector in the signal cabinet in which you plan to conduct this study and identify whether or not it has been assigned as an AC Common/AC Neutral as specified by NEMA. Note: The Conservation Traffic Control Load Switch's Microprocessor requires an AC Common/Neutral to operate. If pin 11 is properly assigned, proceed to step 2. Otherwise, remove the white cap on the side of the CTCLS unit housing and plug in the AC Common/AC Neutral feed wire to the CTCLS external port and attach to AC Common/AC Neutral.

Comments and Observations:

Both pin 11 and the AC Common/Neutral external port in all cases provided the necessary AC Common/ Neutral feed required.

Step 2:

Insert the CTCLS into the signal cabinet in the cinch connector and verify that the CTCLS unit is mechanically compatible with the signal cabinet.

Comments and Observations:

Mechanically compatible in all NEMA Cabinets. However, a housing adjustment is required for the 170 cabinets to accommodate the track/modular configuration.

Step 3:

Apply AC and examine the blue microprocessor fail-safe light-emitting diode (LED) on the CTCLS unit to ensure that the AC Common/AC Neutral is connected properly and that the microprocessor and fail-safe are functioning. This is indicated by the heartbeat (blinking of the blue LED). If the blue LED is not blinking, do not continue. Contact CLS, Inc. for advice

Comments and Observations:

Satisfactory results in all cases with properly connected AC Common/Neutral.

Step 4:

Optional fail-safe operations test: Temporarily disconnect the AC Common/Neutral (pin 11), reset the signal cabinet and observe CTCLS unit cycle through all phases. Observe the unit function as a conventional load switch. Then reconnect the AC Common/Neutral and ensure the blue fail-safe LED is blinking.

Comments and Observations:
Fail-safe functioned correctly in all cases.

Step 5:

Optional: With the CTCLS unit inserted, apply 10 amps through the unit for each of the three phases (red, yellow and green) to verify load capacity, and record results.

Comments and Observations:
Unit functioned as specified and designed and carried the 10 amp load without failure in all cases.

Step 6:

Optional: With the CTCLS unit inserted, apply normal AC input, let the unit cycle through all three phases and verify switching capabilities.

Comments and Observations:
Unit switched as specified and designed in all cases. However, there was one unit that had a bad component which failed; this was a manufacturing problem as opposed to a design problem.

Step 7:

Optional: Test the CTCLS unit with as many different types of conflict monitors as practical for compatibility. Note results. (Please record model and type numbers.)

Comments and Observations:
Unit was tested with solid state devices; Saftron 210sa, 210c, 210s; Traffic Sensor Corp 210; LMN 12E, TCT; EDI NSML, NSM 12L, 210S, 210N; PDC CM 82 12; Econolite NSM; Peak 1200; and Guardian NM12G, LCD12P, which all functioned correctly. The Peak EL series monitors required a voltage set point adjustment and the EDI SSM12LEP and NSM require research into a software adjustment. (It appears that these monitors do not read voltage-only digital sampling).

Step 8:

Optional: With the CTCLS unit inserted and cycling, verify regulation feature by attaching a Quality True RMS Voltage meter to first the red lamp AC output and record voltage output. Repeat this with the yellow and green recording the voltage output for each. (Please use a Quality True RMS Voltage Meter only; if an accurate True RMS voltage meter is unavailable, skip this step).

Comments and Observations:
The voltage fluctuation of a conventional load switch ranged from 3.65 VAC to 9.12 VAC; the CTCLS unit consistently held the voltage within an average of .3 VAC of the voltage set.

Step 9:

Optional: With the CTCLS unit inserted and cycling, attach a Quality True RMS Voltage meter to the AC input and record input voltage to verify regulation feature. (Please use a Quality True RMS Voltage Meter only; if an accurate True RMS voltage meter is unavailable, skip this step).

Comments and Observations:
The line voltage fluctuation ranged from 3.65 VAC to 9.12 VAC.

Step 10:

Optional accelerated lamp-life extension capabilities test of the CTCLS unit:

This step requires the procurement of two GE General Electric BBA No.1, 3-hour photo floods. These lamps are available at most local photo or camera stores. Important: These lamps are not manufactured to the same quality as we are accustomed; the lamp life varies widely from lot to lot and even lamp to lamp. When evaluating results and comparing the lamp-life extension, it is important to compare the CTCLS's actual lamp life with the actual control lamp's life as opposed to rated life. If lamps are purchased at the same time, they will presumably be from the same lot and of comparable quality.

Part one: Control lamp switching burn test

Set-up: Turn the applied AC to the signal cabinet OFF, and insert a conventional load switch. Apply AC and with a stop watch, adjust the signal controller timing to: Green lamp burn time or on state equaling 60 seconds, red and yellow combined burn time or on state equaling a total of 90 seconds. Test the timing again with a stop watch to ensure a 60-second burn followed by a 90-second cool down time. After verification of this timing, turn the applied AC to the signal cabinet OFF, and insert the BBA-No.1 3-hour photo flood into the green lamp socket in the signal head or test set. (If using a signal head, leave lens cover open.) Use test lamps or conventional traffic lamps in the red and yellow sockets.

Begin: Apply normal AC input and note the start time. During this burn, attach a True RMS Voltage meter to the green lamp output on the signal cabinet bar and record AC output. (Please use a Quality True RMS Voltage Meter only; if an accurate True RMS voltage meter is unavailable, skip this step.) Allow lamp to switch on and off until failure (this test will take approximately 5-7.5 hours or 2-3 hours of actual burn time); record time of lamp failure and length of burn; remove lamp and save for comparison purposes. Later, be sure to return the lamp to the original package and clearly mark package #1 full AC and the burn times.

Part two: CTCLS regulated lamp switching burn test:

Set-up: Turn the applied AC to the signal cabinet OFF, and insert the CTCLS unit. Apply AC, and use a stop watch to ensure that the timing is the same as in part one. (Green lamp burn time or on state is to equal 60 seconds, and the red and yellow combined burn time or on state is to equal a total of 90 seconds.) With a stop watch, test the timing to ensure a 60-second burn followed by a 90-second cool down time. After verification of this timing, turn the applied AC to the signal cabinet OFF, and insert a BBA-No.1 3-hour photo flood into the green lamp socket in the signal head or test set (if using a signal head, leave lens cover open); use test lamps or conventional traffic lamps in the red and yellow Sockets.

Begin: Apply normal AC input and note the start time. During this burn, attach a True RMS Voltage meter to the green lamp output on the signal cabinet bar and record AC output. (Please use a Quality True RMS Voltage Meter only; if an accurate True RMS voltage meter is unavailable, skip this step.) Allow lamp to switch on and off until failure (approximately 20-30 hours or 8-12 hours of actual burn time); record time of lamp failure and length of burn; remove lamp and save for comparison purposes. Later, be sure to return the lamp to the original package and clearly mark package #2 Regulated AC and the burn times. Record results.

Average range of results of the accelerated lamp-life test from the participants:

Control lamp burn time: 395-470 minutes
CTCLS Model 20867 lamp burn time: 1480-1720 minutes
Dividing the CTCLS lamp's total burn time by the control lamps' total burn time range results in lamp-life extension of 3.14-4.35 times.

Comments and Observations:
In all cases, the CTCLS unit extended the lamp life of the test lamps. Comments included: lamps visually appeared to be of equal light intensity, build-up on inside of lamps was equivalent upon lamp failure for both the control lamp and the CTCLS test unit lamp.

Part Two: Optional Field Testing and Functioning

Step 1:

Install the CTCLS in a field signal cabinet located close to the signal lab. Ensure that the signal head which is driven by the CTCLS has the enclosed three Hytron 185A21 lamps installed in it. Run the unit in the field for 30 days, periodically checking the functioning (at least once a week). Check fail-safe and note voltage at different times of the day with a True RMS Voltage Meter. Please note results.

Comments and Observations:

Week One: Functioned correctly; held voltage within .03 VAC of set point.
Week Two: Functioned correctly; held voltage within .03 VAC of set point. One unit failure due to bad component.
Week Three: Functioned correctly; held voltage within .03 VAC of set point.
Week Four: Functioned correctly; held voltage within .03 VAC of set point.

In two cases, a minor light intensity change was observed during heavy surges due to the microprocessor correcting applied voltage.

The following is a summary of the additional questions responses.

Q: Did you find the unit perform as well as a conventional load switch?
A: Yes

Q: Did you find the unit perform as expected?
A: Yes

Q: Were you satisfied with the unit in the lab testing?
A: Yes

Q: Were you satisfied with the unit in the field testing?
A: Yes

Q: What action are you recommending as a result of this review?
A: Unit is being added to the approved products list; unit is being referred for new products evaluation; unit is being recommended for further evaluation.

Following are some important suggestions and comments:

Do you have any recommendations, comments, suggestions or ideas for additional features which could or should be added to this unit or future models?

a. Adjust the voltage set point higher to allow a voltage regulation within the normal 3-6 volt fluctuation range to allow for the use of existing lamps while still extending the lamp life. (This has been accomplished through a software adjustment, and will provide for a 1.5 to 2.0 lamp-life extension)
b. Very impressed with the regulation feature and the unit's ability.
c. Unit housing modification required to conform to the Model 170 modular design.
d. Unit appears to function very well with the LEDs; very smooth light output; working in combination with the LEDs and incandescent in the same signal head, this could provide for substantial maintenance expense reductions
e. Suggest price reduction to be more competitive with current solid state units. (Unit pricing was set on an extremely small quantity production run; the price on future runs will be dramatically reduced).

RESULTS

Thus far, this research has been very successful. CLS, Inc. began with an idea for a much-needed device and has translated it into a viable product, the CTCLS Model 20867 Solid State Load Switch. Most of the objectives and goals of this project have been realized, and very encouraging feedback has been received by the DOTs and municipalities that participated in this operational testing.

All lab testing confirmed the design and yielded expected results.

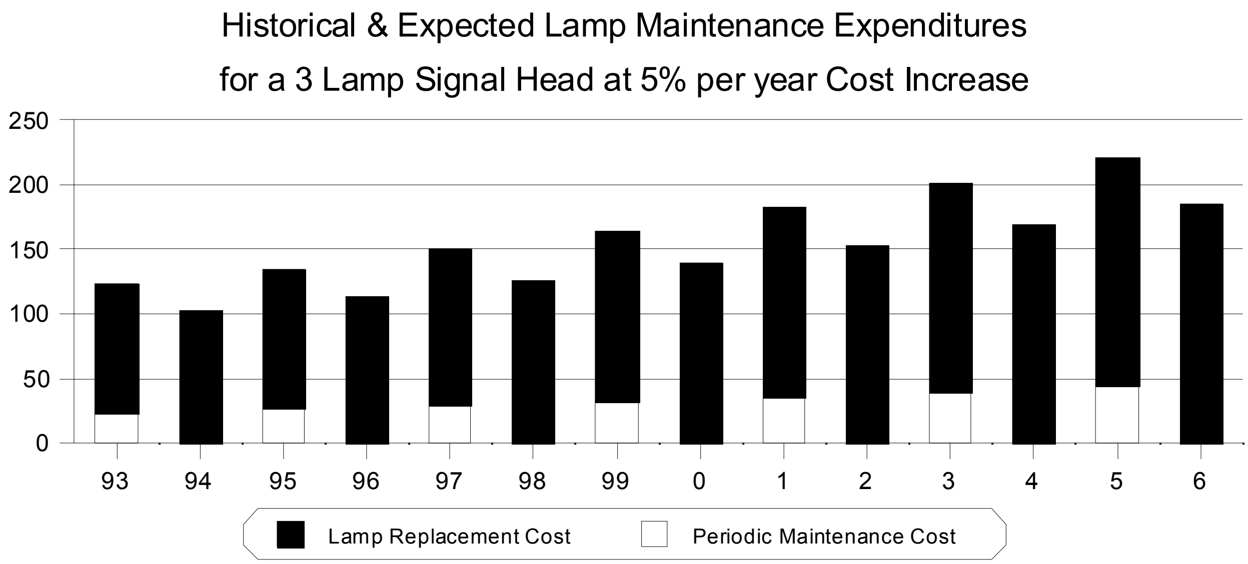
Initial responses from the participating DOTs and municipalities suggested that there was some problem with the CTCLS's ability to operate in conjunction with two conflict monitors. However, after communicating with the respective DOTs and municipalities, it was found that the monitors in question do not have the ability to read RMS voltage (which will require a software change for those DOTs and municipalities), or their low voltage alarm set points were higher than the CTCLS regulation set point. In order for the unit to function properly, it was necessary in one case to reprogram the test unit voltage regulation set point higher than the conflict monitor's low voltage alarm set point. Also, in at least one case where a lab test unit failed, it is suspected that the testing lab overloaded the unit.

CONCLUSIONS

Overall, the project has been a success. Communication with the DOTs and municipalities has indicated their significant interest in the CTCLS.

This study has demonstrated the potential of the CTCLS. However, while the AC Common/Neutral external feed port functions correctly, it may be able to be adjusted to eliminate the feed wire for cabinets not wired to NEMA specifications

In conclusion, it has been confirmed that the CTCLS has several immediate benefits. First, this product will dramatically reduce maintenance personnel's exposure to hazardous and potentially deadly situations by reducing the frequency of exposure. Second, if this load switch were installed for the 1986 FHWA estimate of 2,000,000 signal heads nationwide, it would save a conservative minimum of 6,000,000 lamps per year, assuming there are three lamps per signal head. Multiply this number by the average lamp replacement cost of $30.00 to obtain a conservative, nationwide, annual savings of $180,000,000 (Figure 1). Note: Current 1994 industry estimates run as high as 4,500,000 signal heads nationwide, which would equal potential nationwide maintenance savings of $450,000,000. Therefore, the capital that would normally be required to maintain and service the traffic lamps could be redirected to other important highway-related projects and areas.



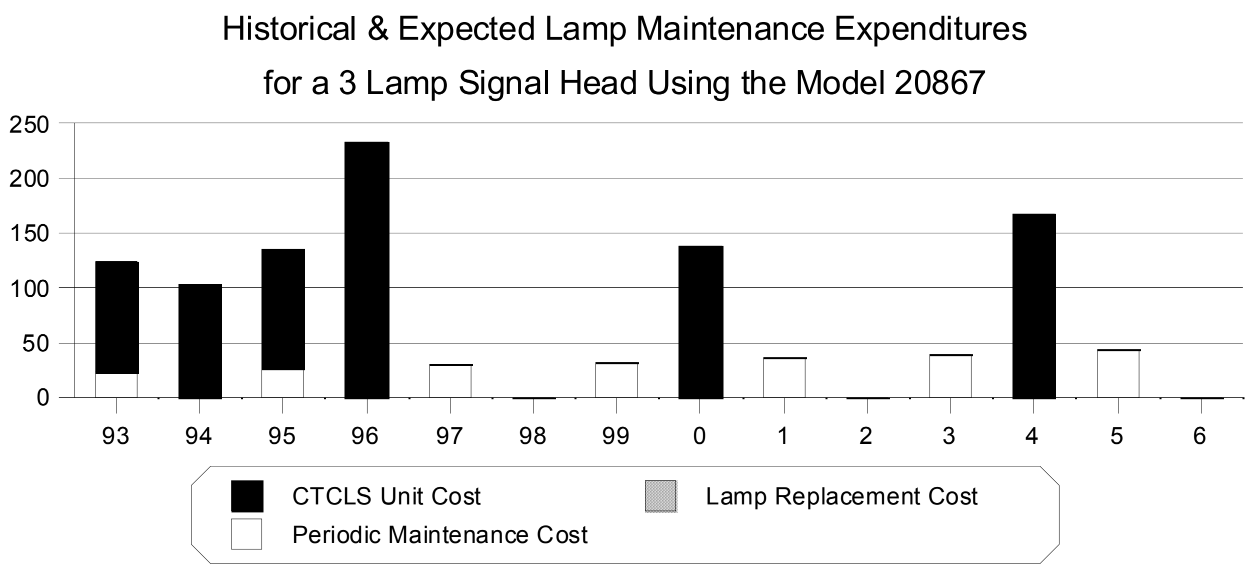


FIGURE 1 Comparison of lamp-maintenance expenditures. Both graphs are based on a 1995 lamp-replacement expense of $38 per lamp with a 5% increase per year, and CTCLS unit cost of $119. Bi-annual periodic maintenance is shown as well.