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Abridgment

Test of 400-W High-Pressure Sodium Vapor Lighting

Michael C. Belangie, Research and Development Unit, Utah Department of Transportation, Salt Lake City

At present, 400-W high-pressure sodium vapor (HPS) lamps are advertised as having an average life expectancy of 24 000 h, the equivalent of six years of operation. The cost in labor and equipment to replace a single lamp in Utah is about 90 percent of the initial cost of a 400-W HPS lamp.

Since both lamp and maintenance costs are rising rapidly, inferior lamp performance will place an unnecessary, unprogrammed cost on lighting maintenance programs. The results of this test indicate that manufacturer-supplied lamp mortality data should not be considered reliable (performances of between 35 percent and 50 percent were typical). These findings strongly suggest that users should develop and implement contractual mechanisms for enforcing performance specifications in regard to the advertised life of the lamp.

QUALIFICATIONS ON THE USE OF THIS REPORT

Substantial technological modifications have occurred since these lamps were manufactured. Therefore, the lamp mortality data described here are only applicable to the lamps and fixtures available from the manufacturers in late 1971 and early 1972 and in the lamp-and-fixture combinations used in this test. The direct application of these findings to lamps and fixtures currently being manufactured is therefore strongly discouraged.

However, until the manufacturers can unequivocally demonstrate that their products will perform as advertised, the user is fully justified in assuming that manufacturer-supplied lamp mortality data may be questionable.

BACKGROUND

HPS lighting was first used in Utah in 1968. During that year, contracts were let for more than 1400 lighting units; these were the initial elements in an installation that would number more than 6600 operational luminaires by 1977.

In 1977, 81 percent (5533 luminaires) of this system was composed of 400-W HPS units; the remainder of the system was composed of 250-W HPS (13 percent) lamps and either 400-W or 250-W mercury vapor units (6 percent). Since 1968, the advertised average life expectancy of the 400-W HPS lamp has increased from 6000 h (1.5 years) to 15 000 h (3.75 years) in 1971 and, most recently, in 1976 to 24 000 h (6 years).

In 1971, substantial concern over the costs resulting from the terms of utility maintenance agreements had surfaced within the Utah Department of Highways. The lack of hard data on the validity of the advertised increases in lamp life compounded the problem. This study was initiated to address both problems.

FINDINGS

Four test groups of 12 luminaires each were operated on a 10-h on, 2-h off continuous cycle for two years (14 360 h of operation) (1). Replacement of burnouts occurred during the first year of operation only. Figure 1 depicts the performance of each test group. Performance of each group has been divided into three categories:

1. Original: performance of the initial 12 operating lamps;
2. Original and replacement: performance of the original 12 operating lamps plus any replacements made during the course of the test;
3. Original, replacement, and infant: performance of the original 12 operating lamps plus any replacements, including lamps that burned out the first time they were energized (infant mortality).

Only one test group (Lamp B in Fixture X) performed without a single failure during the two-year test. The other three test groups all had failures. Lamp A in Fixture W had 9, 5 of which occurred in the first year and were replaced. Lamp D in Fixture Z had 12 failures, 4 of which occurred in the first year and were replaced. Lamp C in Fixture Y had 15 failures in the first year

Figure 1. Summary of lamp performance.

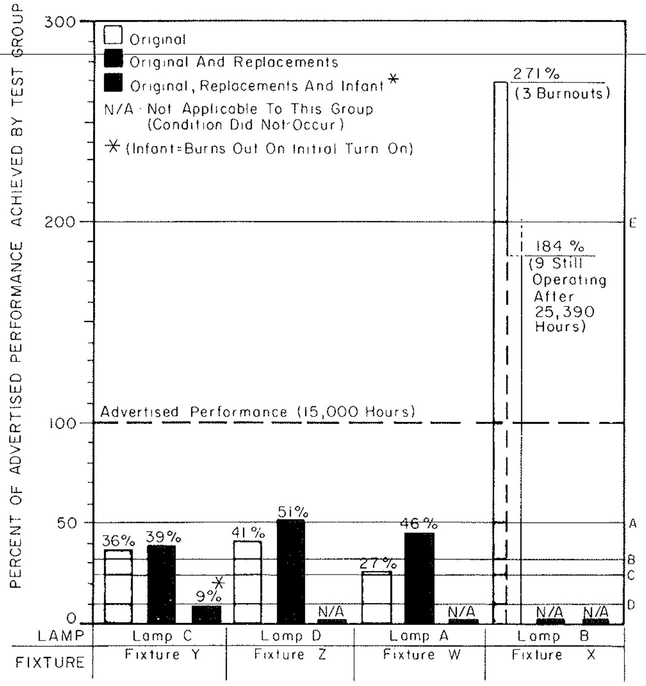
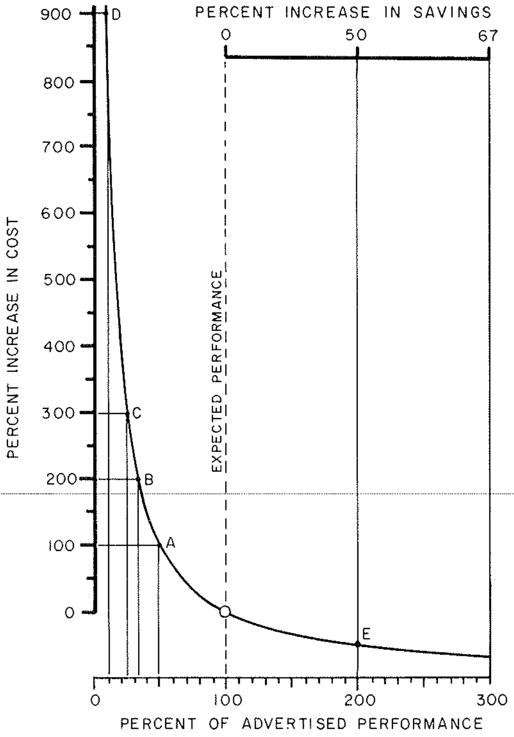


Figure 2. Estimated effect of lamp performance on expected costs (excluding cost of replacement lamp).



(7 infant mortalities and 8 during the course of the year). This test group was removed after 8380 h of operation. The other test groups, with the exception of Lamp B in Fixture X, were removed after two years. The remaining test group was placed on a regular 10-h on and 14-h off burning cycle and left in place. On April 1, 1977, 9 of the original 12 lamps were still burning. The total number of hours of operation for each of the 9 operating lamps on that date was 25 390 h.

Consistency of performance is a factor. Cycling (lamp going off and then restarting) occurred in all four test groups:

Lamp	Fixture	Occurrences
B	X	1
A	W	18
D	Z	51
C	Y	97

Most of the cycling occurred during the first summer of the test, during July and August. Both months were exceptionally hot; temperatures rarely fell below 27°C (80°F) and often exceeded 38°C (100°F). The second summer was comparatively mild. Cycling during this period was consistent with observed winter operation, and cycling principally occurred prior to failure.

Energy use remained fairly constant for the four test groups over the course of the two-year operating period; the average daily consumption per lamp was 0.45 kW·h (90 percent within 0.03 kW·h). For the first 18 months following the removal of the other three test groups, the remaining group consumed an average of 0.48 kW·h/day (95 percent within 0.02 kW·h). In the 19th month, consumption jumped 20 percent to an average of 0.58 kW·h/day (94 percent within 0.03 kW·h) and remained at that level until April 1977, when readings were discontinued.

Peak draw (power) increased steadily over the entire period. The average high 15-min draw per month (power billing) began at 0.46 kW. After 61 months of operation, it had increased to about 0.62 kW, an increase of 25 percent.

Observed light intensity (apparent lumen output) did not decline significantly over the course of the observations.

CONCLUSIONS

Lamp Mortality Data

Figure 1 is sufficient justification to question the reliability of the lamp mortality data supplied by the various manufacturers.

Group Replacement

Group replacement of lamps is a function of economics and performance. As the lamps age, the rate of burnouts increases. Since group replacement is less costly per unit than individual replacement, there is a threshold point (determined by rate of burnout and the alternative replacement costs) beyond which it is cheaper to replace by group than to continue with individual replacements.

The HPS lamp has a very small decrement in light output over the course of its life. This aspect of the lamp, in combination with an expected average lamp life of 24 000 h and the apparently unreliable manufacturer-supplied lamp mortality data, makes group replacement at this time a highly questionable practice.

Energy Use

Energy use increased modestly over the course of this study. However, it should be noted that this was a small installation that had an overhead power supply. The rates shown here should be considered to be somewhat lower than those that would be expected in a field installation.

Demand

Peak energy demand (power) may play a role in lighting costs in areas where penalties are placed on users who contribute to peak demand.

IMPLEMENTATION

Figure 2 indicates the effect of lamp performance on the expected cost of maintenance. Points A through E refer to the equivalent reference lines drawn on the right vertical of Figure 1. In a lighting system composed of lamps performing at 50 percent of advertised capability (reference line A in Figure 1) that were replaced at burnout with lamps of equivalent operational (as opposed to advertised) capability, the cost of maintaining the system would be 100 percent greater (point A in Figure 2) than the amount budgeted for the time period. In relating Figure 1 to Figure 2, it can be seen that the performance of the first three groups in Figure 1 could have raised the expected maintenance cost of a lighting system composed exclusively of those lamps and fixtures by 100-900 percent of the expected cost.

In considering the fourth group in Figure 1 (Lamp B, Fixture X) and relating reference line E in Figure 1 to point E in Figure 2, it would appear that this combination would yield substantial savings. However, if a group replacement policy that was based on the manufacturer's lamp mortality data had been in effect, then the indicated savings would not have been realized; the lamps would have been replaced in groups at approximately 92 percent of their advertised life (13 800 h). It must be noted that in 1977 no major lamp manufacturer recommended group replacement of HPS lamps.

It is apparent that the users must find some method to protect themselves from manufacturers of inferior products. The low-bid requirement, in an area such as lamp purchases, can cause a user to incur a substantial maintenance liability through the mandatory purchase of a less than satisfactory product.

The city of Seattle (2) and the state of Idaho (3) have used a life-cycle costing approach to implement a partial solution to this problem. Whether their approach is adequate is yet to be determined.

In order to achieve the savings indicated in Figure 2, group replacement that is based on manufacturer-supplied data must be eliminated in favor of either replacement after individual burnout or a group replacement system that is based on in-house data. The economic feasibility of the latter approach is questionable and needs to be evaluated before serious thought is given to its implementation.

The potential benefits of this study will be largely determined by the effectiveness of the steps taken by users to require performance at the level advertised.

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Abridgment

Pavement Inset Lights for Use During Fog

Frank D. Shepard, Virginia Highway and Transportation Research Council, Charlottesville

Reduced visibility as a result of fog presents a very hazardous condition on the highway because motorists are unable to readily observe pavement markings and signs and the movement of traffic. Afton Mountain, which is traversed by I-64, is often the site of such reduced visibility because of the low cloud cover on the mountaintop during rainy periods.

An acute awareness of the fog problem on Afton Mountain led to a decision by the Virginia Department of Highways and Transportation to install a lighting system that consists of pavement inset lights and low-level illumination lights to aid motorists during periods of fog. The installation was made on a 9.3-km (5.8-mile) section of highway that encompasses the top of Afton Mountain. Since fog often occurs on only a portion of the mountain, the installation was divided into three sections that represent the points observed to most often correspond with the fog patterns. Each section is controlled by two fog detectors, located at or close to the endpoints of the section, that are capable of detecting five levels of fog density. The intensity of the guidance lights within each section is controlled by the density of the fog at each detector.

The fog guidance system consists of unidirectional airport runway lights installed in the pavement edge line along each side of the roadway in both directions, spaced at 61-m (200-ft) intervals on tangent sections and 30.5-m (100-ft) intervals on curved sections. In addition to the white inset lights on the main line, amber lights are installed on one side of the off-ramps. Also, low-level illumination lights are installed on a short section of an on-ramp.

It was felt that the lighting system would help delineate the highway and thus lead to an improvement in traffic operations. However, it was not known how the system of lights would affect vehicle speeds, head-