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AN INTERIM REPORT ON A STUDY OF ROADWAY LIGHTING SYSTEMS

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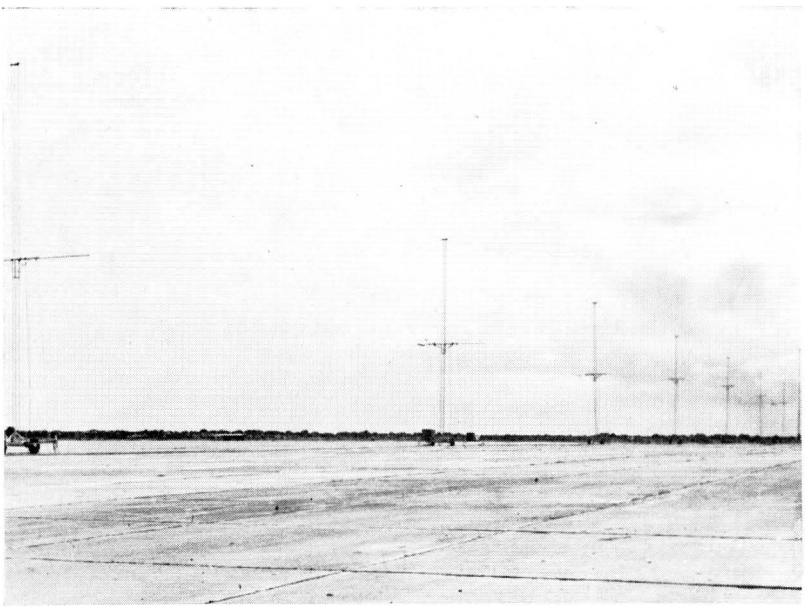

Cooperative Research Program of the
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U. S. Department of Commerce, Bureau of Public Roads

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An Interim Report on a Study of Roadway Lighting Systems

by
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In 1964, the Texas Transportation Institute, in cooperation with the Texas Highway Department and the U. S. Department of Commerce, Bureau of Public Roads, initiated a research project devoted to establishing definite criteria for the design of economical and functional roadway lighting that provides a safe and comfortable visual environment for night-time driving. An essential phase in the accomplishment of this goal is the definition of the relationships among visibility, visual comfort, brightness patterns, light distributions, and the configuration of the lighting system. This report presents the results of a study

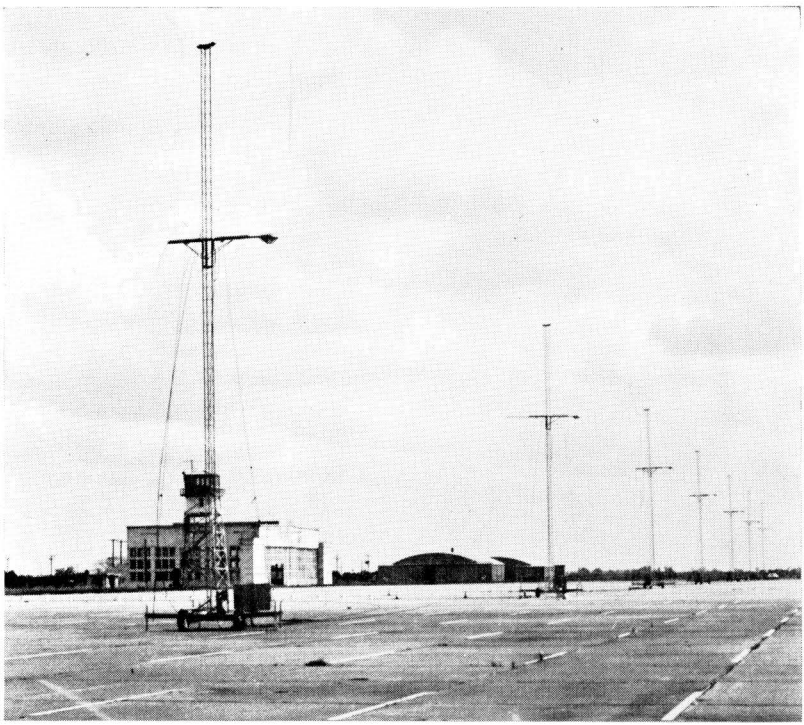


Figure 1

of the effects of the system configuration on the resultant distribution of light on the roadway.

Test facilities were developed at the Texas A&M University Research Annex with which a representative section of roadway lighting could be simulated with complete flexibility in selection of system configuration. Roadway luminaires were mounted on ten 60-foot mobile towers which could be adjusted and maneuvered to provide various mounting heights and spacings of the luminaires (Figure 1). These towers were arranged on a large paved area approximately 500' wide by 3500' long where a grid system was laid out with ten-foot longitudinal grid line intervals and 12.5-foot transverse grid line intervals.

The light distributions of the lighting systems were determined by measurements made at each grid point using an SL-480A light meter, cosine corrected to give light intensity in horizontal footcandles.

Commercially available 400-watt and 1000-watt, Type III mercury vapor luminaires were used in this study. Three 400-watt luminaires were obtained from each of four manufacturers, and three 1000-watt luminaires were obtained from each of three manufacturers. The lamps used in all luminaires were those available on state contract. They were clear mercury vapor lamps with outputs of 21,500 and 57,000 lumens for the 400-watt and 1000-watt units, respectively.

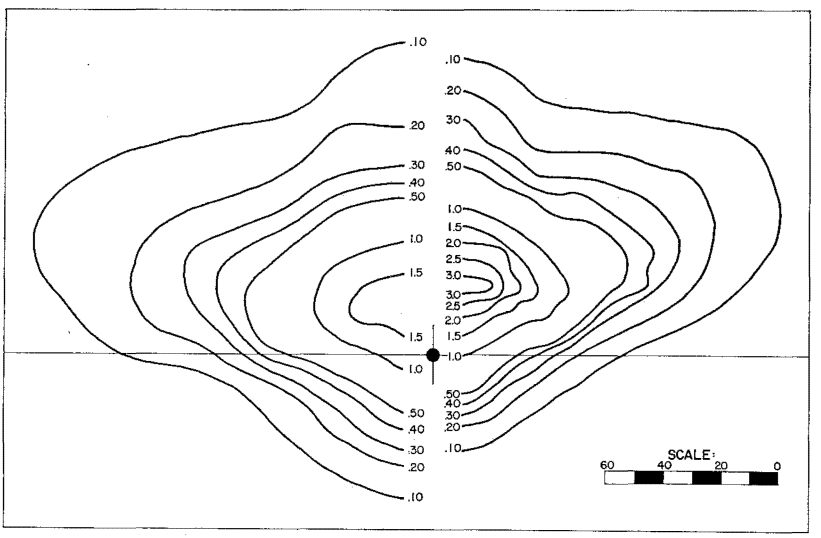
The experiment design provided a determination of the light distribution for one-side lighting systems and median or dual mounted lighting systems using the three luminaires from each manufacturer. The following outline summarizes the experiment design for each manufacturer:

I. One-Side Lighting Systems.
   A. 400-watt luminaires.
      1. Mounting heights—30, 40, 45, and 50 feet.
      2. Longitudinal spacings—100, 120, 140, 160, 180, 200, 210, 220, 230, 240, and 250 feet.
   B. 1000-watt luminaires.
      1. Mounting heights—50 and 60 feet.
      2. Longitudinal spacings—240, 260, 280, 300, 320, 340, and 360 feet.

II. Median lighting systems.
   A. 400-watt luminaires.
      1. Mounting heights—30, 40, 45, and 50 feet.
      2. Longitudinal spacings—100, 120, 140, 160, 180, 200, 210, 220, 230, 240, and 250 feet.
      3. Transverse spacing—10, 20, and 30 feet.

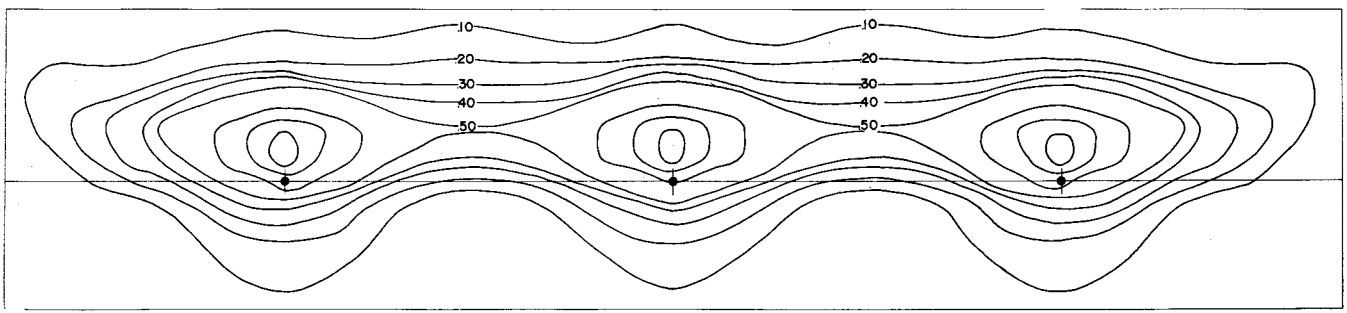
B. 1000-watt luminaires.
   1. Mounting heights—50 and 60 feet.
   2. Longitudinal spacings—240, 260, 280, 300, 320, 340, and 360 feet.
   3. Transverse spacing—10, 20, and 30 feet.

Considering this experiment design and the desirability of reducing the influence of the inherent variability among luminaires of the same description, the light distributions of nearly 1300 combinations would have to be measured. Since each combination would constitute one field study which would require several hours to complete, a means of simulating or synthesizing light distribution was developed using electronic computer techniques. This approach involved the combination of photometric data from individual luminaires to obtain the light distribution for a system of similar luminaires. Using this technique it was only necessary to collect field data for each individual luminaire at each of the mounting heights. To check the accuracy of the simulation procedure, a random sample was drawn from the synthetic systems developed. Each system in the sample was set up at the test site and photometric measurements were made. These data were then compared to those of the corresponding synthetic system. The differences found in comparing the actual systems with the synthetic systems were not appreciable.



40-FOOT MOUNTING HEIGHT 30-FOOT MOUNTING HEIGHT
ISO-FOOTCANDLE CURVE

Figure 2



LUMINAIRE 400 WATT TYPE III
MOUNTING HEIGHT 40'

ISO-FOOTCANDLE CURVE
ONE-SIDE LIGHTING

LONGITUDINAL SPACING: 200'
SCALE 0 20 40 60 80 100

Figure 3

Isofootcandle curves were plotted for each set of luminaires and for each of the synthetic systems utilizing a computer plotting technique commonly known as the UM plot routine. Also for each system the following photometric characteristics were computed for two, three, four, and five lane roadway widths:

1. Average illumination.
2. Maximum illumination.
3. Minimum illumination.
4. Largest of the ratios of maximum to minimum illumination on each lane.
5. Ratio of average to minimum illumination.

These values were computed based on the assumption that the luminaires were mounted over the edge of the roadway and adjusted to their maximum vertical adjustment (maximum vertical adjustment means that the luminaire was tilted upward on the street side as far as the luminaire mounting assembly would permit when mounted on a horizontal mastarm). The photometric characteristics were related by graphic interpretation to system configuration in order to illustrate the effects of configuration on the light distribution.

Summary of Results

The isofootcandle curves produced by the computer plotting technique provided a means of visualizing the effects of configuration on the light distribution. Figure 2 illustrates the increase in uniformity of illumination caused by raising a luminaire from a 30- to a 40-foot mounting height. Figure 3 shows the light distribution for a particular system. It is significant to note that

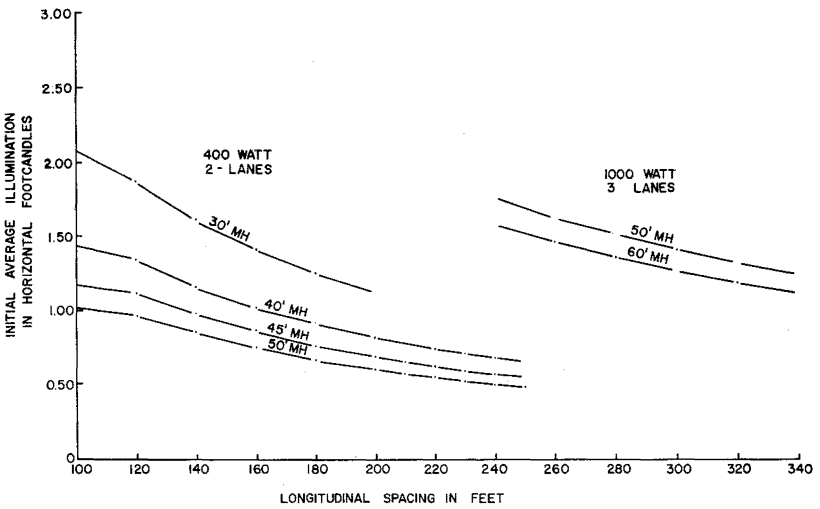


Figure 4

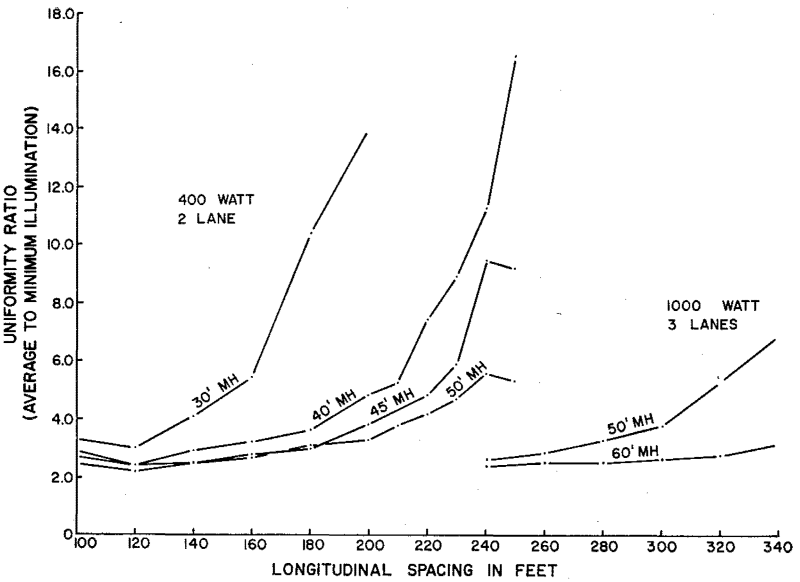


Figure 5

most of the contour lines within this system are essentially parallel to the traffic lanes, which indicates that the system provides uniform lighting for any particular lane.

The effects of system configuration on the resultant light distribution of a roadway lighting system can be summarized as follows:

1. The initial average illumination on the roadway was inversely proportional to the mounting height, longitudinal spacing, and transverse spacing of the luminaires, and to the width of roadway considered (Figure 4).

2. The uniformity of illumination on the roadway was directly proportional to the mounting height of the luminaires (Figure 5).

3. The systems of 1000-watt luminaires provided more illumination and greater uniformity than the 400-watt systems (Figures 4 & 5).

4. Differences in the amount and uniformity of illumination from luminaires of different manufacturers indicated that the optimum system configuration was dependent upon the luminaire used.

5. For higher mounting heights of luminaires, the effect of roadway width on uniformity of illumination was less (Figure 6).

6. Even though initial average illumination was inversely proportional to the mounting height of the luminaires, initial

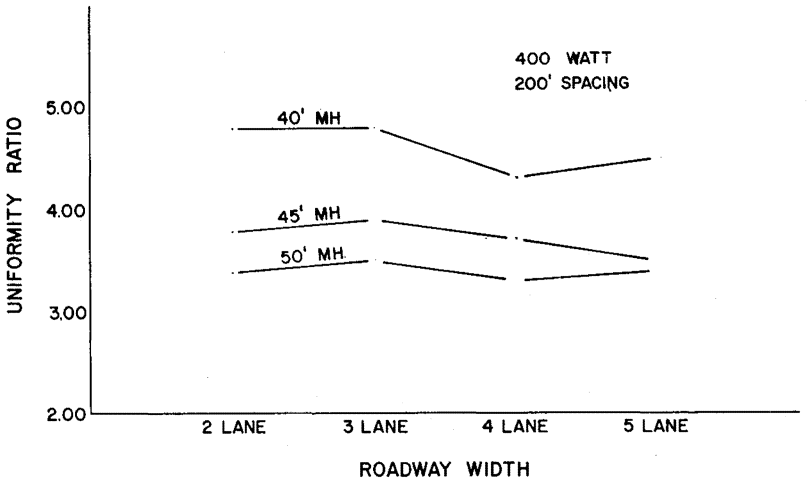


Figure 6

minimum illumination was directly proportional to the mounting height at the longer spacings and on wider roadways.

These results suggest that in order to design the most efficient lighting system to satisfy a given specification, consideration must be given to the relationships between the configuration of the lighting systems and the photometric characteristics being used as criteria.

This research has shown uniformity of illumination to be a very important factor in roadway lighting design. Visual evaluations of these systems have suggested that any reduction in visibility due to a lower average illumination can usually be more than compensated for by an apparent increase in visibility due to improved uniformity of illumination, as in the case of systems with luminaires at higher mounting heights. This research also suggests that adequate visibility can be obtained at lower average intensities than are currently specified in design criteria, and that more emphasis should be placed on the minimum amount of illumination and the uniformity such as by specifying a ratio of the maximum to minimum illumination.

To enable others to apply the photometric data obtained in this research, summary tabulations of the photometric characteristics for several different lighting systems have been prepared, and are furnished by the Texas Transportation Institute upon request. From these tables the engineer can readily select the designs that satisfy the given criteria for a particular lighting project. A cost comparison can then be made to determine the most economical of several systems providing acceptable photometric characteristics.