ROADWAY LIGHTING: ILLUMINATION STUDY OF RTE. I-95, SHIRLEY HIGHWAY

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

This report is concerned with a study of the quantity and uniformity of the illumination on some selected sections of the roadway lighting on Rte. I-95 in Northern Virginia. The evaluation of the lighting was made to obtain data that could be used as a guide for the selection and design of future lighting systems or for possible modification of existing systems.

The illumination data were collected with a photometric recording system that was developed specifically for the study. This equipment, which is described in the report, is mounted in a vehicle such that data can be recorded while driving through the area being surveyed. These data were used to develop isofoot-candle diagrams which show the distribution of the illumination over the roadway area. In addition, average illumination levels and uniformity determinations were calculated from these data.

The results indicated that the main line lighting on Rte. I-95 was excellent and was generally well within the recommended design standards for uniformity and average maintained levels of illumination. The uniformity of the lighting on the loop type ramps having the lamp posts located on the inside of curvature was generally not good— although better on some ramps than on others. These and other inadequacies of the system are discussed in the report.

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INTRODUCTION

Prior to the energy crisis during 1973-74, there was an increasing trend toward the use of lighting on many urban and suburban highways and interchanges. Concurrent with this trend toward wider utilization of roadway lighting, a certain degree of interest in lighting technology and research evolved in the highway industry. At that time the Virginia Department of Highways and Transportation like many other state transportation agencies, became involved in the design and installation of roadway lighting on certain projects. As a result, considerable concern related to the warrants for highway lighting emerged on the national level, and research such as that by Walton and Rowan(1) and Rowan(2) was conducted. In addition to the interest related to the question of whether to light or not to light certain sections of roadway, highway engineers charged with the design of lighting developed an interest in the illumination levels and uniformity that were being provided by some of their initial designs. In an attempt to compile information on some of the designs in Virginia, a mobile illumination recording system was developed and measurements were taken on some lighted roadways in the populated eastern and northern regions of the state.

Subsequent to the initiation of the lighting study, the oil embargo and the consequent "energy crisis" had a marked effect on the operational aspects of the existing lighting installations. In the interest of conserving energy, all the existing lighting systems were reviewed with the main question being, Should the lighting be left on, turned off, or reduced? On Rte. I-95 in Northern Virginia, for example, the lighting was first reduced and then later turned off between interchanges for several months. While all of the lighting has now been turned back on, the effect of the energy crisis has been to place added emphasis on warrants for lighting installations on new highway construction projects. A lighting facility which will be a continuing user of costly energy and which will almost certainly be among the first to be eliminated in another energy shortage is not likely to be given high priority for funds. The existing shortage of highway funds and the effects of inflation are added restraining factors which make a decision to install lighting extremely difficult. Although the future for highway lighting appears uncertain, it is nevertheless important that some information be obtained relative to the effectiveness of existing lighting systems in Virginia. Such data may be helpful to designers and administrators in making decisions concerning future lighting installations or the warrants for lighting during possible energy shortage periods.

The first report on the study dealt with the lighting levels and uniformity on a section of Rte. I-264 in the Norfolk area.(3) The present report concerns illumination data taken on certain typical lighted areas of Rte. I-95 (Shirley Highway), Virginia's longest continuous section of highway lighting. An additional report on the Shirley Highway lighting will deal with the reduced levels of illumination during a six-month period during the energy crisis. A comparison of the accident experience before and after the lighting levels were reduced will be made. That phase of the study will be related to one of the more important warrants for lighting — namely, the reduction of the nighttime accident rate. Finally, an additional study of the illumination levels on a section of Rte. I-64 roadway south of the Hampton Roads Bridge Tunnel will be reported.

GENERAL FEATURES OF THE SHIRLEY HIGHWAY LIGHTING SYSTEM

Beginning slightly south of the Springfield interchange, continuous freeway lighting extends northward on Rte. I-95 to the "Mixing Bowl" area near the Pentagon. Most of this section of roadway lies between the Potomac River at the northern extreme and the Rte. I-495 (Washington circumferential) — Rte. I-95 interchange south of Washington. This section of roadway covers a distance of approximately 10 miles (16 kilometers).

A general cross section of the main roadway consists of 10 lanes — 4 northbound and 4 southbound with 2 reversible lanes in the center. Because of the complexity of the geometrics of the various interchanges and the access and exit ramps to the reversible lanes, a variety of lighting situations exist within the total length of the project. As a result several different luminaire mounting situations exist. In general, the lighting for the main line of the highway is provided by 1000 watt mercury luminaires mounted at a height of 50 ft. (15.24 meters), and having a 12 ft. (3.66m) mast arm. The lamp posts for these luminaires are positioned on the outside shoulders of the roadway and provide lighting for the reversible lane area as well as for the regular traffic lanes. Because of the various geometric configurations in the 9 different interchange areas, the lamp post locations on the main line do not conform to that generally described for the between interchange areas. Lighting on the interchange ramps is designed to meet the needs of the particular interchange configuration involved. Typical sections of the general roadway lighting situations were shown in an earlier paper.[4]

Overall, the Shirley Highway lighting project includes 400-, 700-, and between 1,000-watt mercury luminaires and 30-, 40-, and 50-ft. (9.14-, 12.19-, and 15.24m) mounting heights designed to specifically accomodate the illumination requirements of the different roadway areas. In addition, 250-watt mercury, wall type lighting fixtures are used in the bridge underpass areas.

PURPOSE AND SCOPE

In the design of roadway lighting systems certain minimum levels of illumination and certain uniformity ratios are provided. The AASHTO Informational Guide [5] and the American National Standard Practice[6] are usually used as guides for establishing the design standards for the various roadway classifications. While the quantity and quality of lighting have been provided for in the design of a particular installation it is desirable to take illumination measurements to determine if the design objectives have been obtained. Therefore, one of the objectives of the overall roadway lighting study is to determine the quantity and uniformity of the illumination provided by some of the lighting installations currently in service. These data have been obtained in the field at several sites— one being the Rte. I-264 site reported earlier.[3] The Rte. I-95 section is the second site that has been surveyed and is the subject of this report. The results of these type surveys will hopefully yield information that can be used as a guide for the selection and design of future lighting installations or for the potential modification of existing systems.

The size and length of the Shirley Highway lighting project limit the amount of data that can be presented. Since many of the lighting situations and roadway geometrics are quite similar, only some representative samples of the illumination data are presented and discussed in this report.

PHOTOMETRIC INSTRUMENTATION

Freeways that warrant lighting normally carry high traffic volumes. As a result, the collection of roadway photometric data under heavy, high speed traffic conditions after dark would present a hazardous situation. In addition, if adequate traffic controls were to be provided to facilitate the manual collection of data, some undesirable degree of hazard and impedance to nighttime traffic operations would result. In order to avoid these type situations, an illumination recording system which is mounted in a vehicle was developed for the study by the Cottrell Electronics Corporation of Richmond, Virginia. The system is designed to record variations in illumination levels on a continuous strip chart as the vehicle is driven down the roadway. The components of the equipment are portable and can be mounted in the vehicle in a short period of time and readily dismantled after data collection is complete.

The illumination recording system is composed of three general units. The first unit, shown in Figure 1, is composed of two Weston Model 856 type RRV selenium photovoltaic cells mounted on a wooden bracket. The photovoltaic cells consist essentially of a metal disc to which the light sensitive material is bonded, and is housed in a hermetically sealed metal case. The cells convert light energy into electrical energy without physical or chemical change and are designed for use under adverse as well as favorable conditions. Each cell is both cosine and color corrected as indicated by the RRV type designation. The bracket containing the cells is mounted to the roof of the car and held in place by both suction cups and straps.

At the illumination levels developed by most roadway lighting installations the current output of the photovoltaic cells is too low and must be amplified. Therefore, the signal from each cell is amplified by a Fairchild Model 725/LA line amplifier. The small amount of current needed is supplied by four 12-volt batteries. A typical battery that can be used for the equipment is an Eveready 732. Battery load test circuitry is supplied to check for weak battery conditions. A fifth battery, which can be used to supply current for the calibration lamp to be described later, is housed with the other batteries and the calibration and scale control switches in the unit shown in Figure 2. It should also be noted that the two light cells are connected to the amplifiers so that their responses are additive, with the sum representing the average total illumination at a point between the two cells. The right and left cell and sum switch controls are also contained in the portable unit shown in Figure 2.

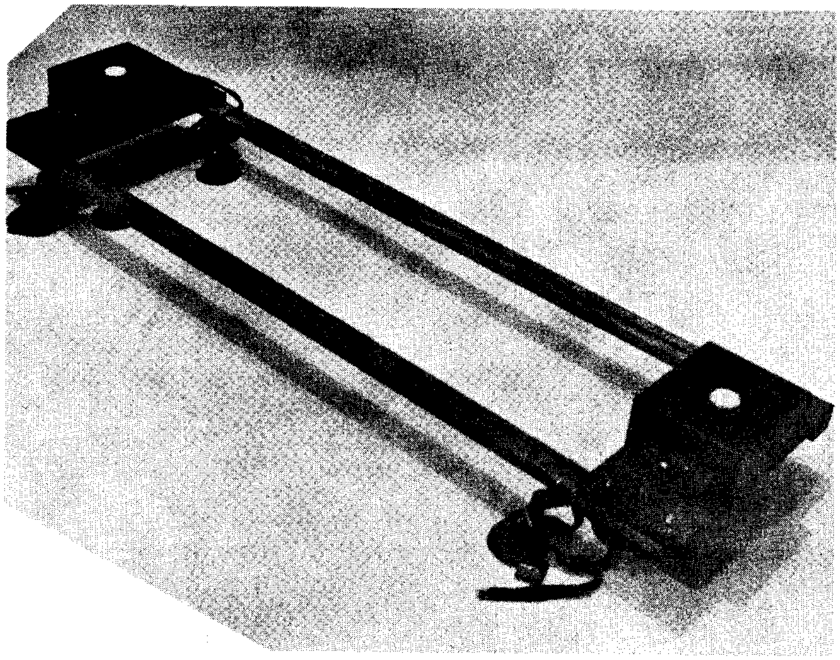


Figure 1. Photovoltaic cells mounted on a bracket which can be attached to the roof of an automobile.

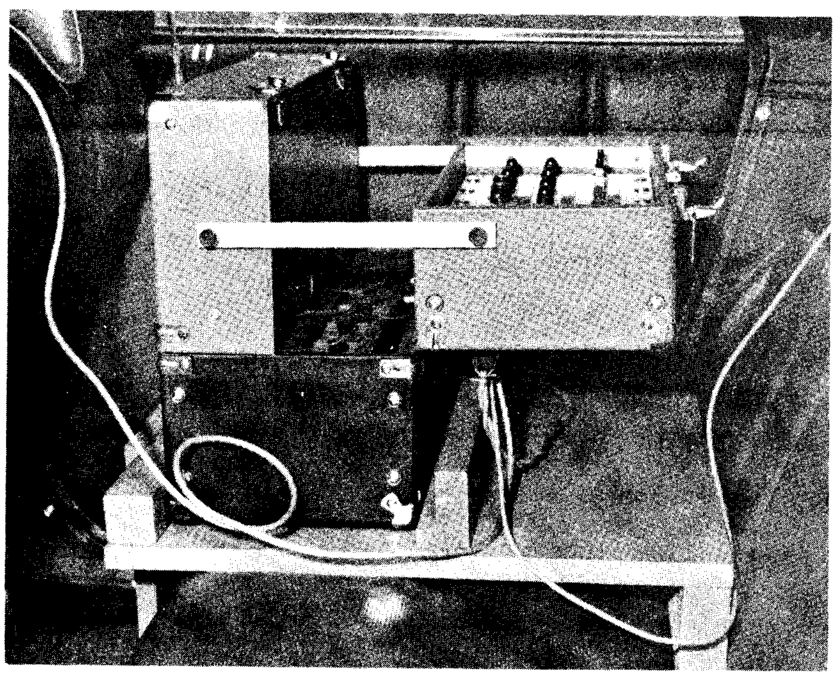


Figure 2. Portable unit containing calibration control switches and batteries.

The third portable unit contains an additional Fairchild 725/LA amplifier with power supplied by two additional 12-volt batteries, a battery load test scale, and an Esterline Angus A-601C strip chart recorder (Figure 3). The recorder is mechanically driven by a linkage that couples the strip chart drive gears to the speed odometer mechanism of the vehicle. Therefore, the strip chart drive is synchronized with the speed of the vehicle so that the major divisions on the data paper are proportional to the distance traveled on the roadway. Four drive gears are provided for the recorder so that different longitudinal distance scale factors are available. The equipment can be calibrated to record footcandle (fc.) levels on either a high or low scale- one being 10 times the other. Each scale can be changed by a multiple of 5.

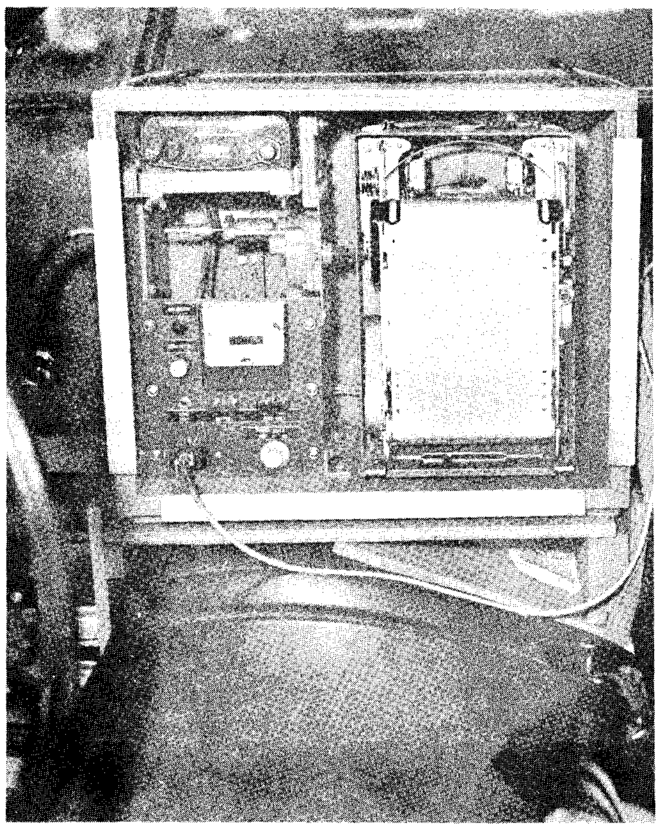


Figure 3. Portable unit containing the recorder. The strip chart drive linkage enters the unit on the left.

The photocells can be calibrated at the job site by using either the power from the 12-volt battery mentioned earlier or by using 120-volt A.C. and an A.C. transformer to supply current to a small variable control lamp. The lamp is mounted in a tightly sealed box that can be placed over a photometer sensor or probe, which in turn is connected to an amplifier unit (Figure 4). This unit is a Vactec model 3107 portable photometer. The variable control lamp can be adjusted to a predetermined level of illumination as indicated by the Vactec meter. When the desired level of light has been obtained, the lamp box is transferred to the main equipment photocells. Each photocell is then calibrated to read half-scale on the strip chart of the recorder. Thus, when both cells are in operation, the sum of the two signals will provide a full-scale reading on the recorder chart paper.

The complete installation of the illumination recording system is shown in Figure 5. Typical data tapes are shown later in Figures 9 and 10.

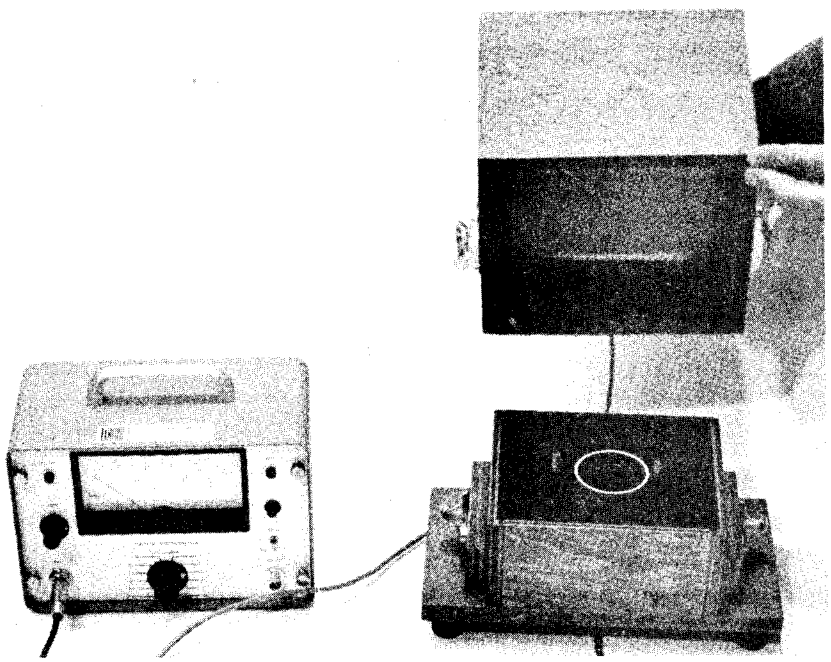


Figure 4. Control light source and meter used to calibrate the mobile illumination recorder.

Figure 5. Illumination recording equipment installed in a vehicle.

ILLUMINATION DATA

Considerable illumination data were initially collected on the main line of Rte. I-95. Since most of these data are similar, only some typical areas on the main line will be discussed. The areas that have been chosen lie mostly in the northern sector of the project, and were picked primarily because the lighting was initially turned on in this section when the illumination recording equipment became available for use. The lighting beginning south of the Springfield area to a point south of the Glebe Road interchange had been in operation for a number of months before the study began. Data from some of these areas are presented also.

Initially, illumination data were recorded over most of the distance of the main line of Rte. I-95 and reviewed. From these data, some typical roadway areas were chosen and the illumination levels recorded in each traffic lane and the reversible lanes and on the shoulders. Although these test runs were made through each of the lanes and ramps for which data were recorded, one run is all that is needed since the repeatability of the data recording equipment is excellent. Differences in the data obtained from several test runs over the same lane are small and can be attributed to the fact that it is impossible for the driver of the vehicle to position the car in the same lateral position each time he drives through a lane. Due to the fact that the dual photocells are spaced 4 ft.(1.22m) apart, each test run actually represents the average footcandles of illumination taken at two lateral positions within a lane. Therefore, one run through a lane can be considered as an average level of illumination within the lane. The isofootcandle diagrams presented in this report were developed from the average data obtained for the lane and shoulder test runs.

All of the data collected with the mobile illumination recording system represent illumination levels taken at a height of approximately 5 ft.(1.52m) above the pavement surface, whereas lighting is usually designed for illumination provided on the pavement surface. Since illumination varies inversely with the square of the distance from the light source,(7) the horizontal fc. of light measured on the pavement would differ in most instances from the values reported herein. The difference between the illumination on the roof of the car and that on the roadway surface is greatest directly beneath the light source and decreases as the distance between the luminaire and the point under consideration increases. Generally, the higher the mounting height of the luminaires, the less the relative difference between the levels of light on the pavement as opposed to those measured on the roof of the car. The overall uniformity, average order of magnitude, and the general distribution of the illumination, however, are representative of those at the pavement surface, although the data are recorded in a horizontal plane approximately 5 ft.(1.52m) above the pavement.

It is difficult to accurately estimate very low footcandle values from the strip chart record— particularly when the scale factor is reduced. In order to obtain more accurate data in the 0.01 to 0.10 fc.(0.11 - 1.08 lx) range, some spot readings were taken manually with the Vactec portable photometer. These data were used primarily for calculating the uniformity ratios discussed in more detail later.

RESULTS

One of the measures of the quality of a roadway lighting system is the uniformity ratio, which can be defined as the ratio of the average level to the minimum level of illumination at a given point within an area. The uniformity ratio is an important lighting factor since high ratios indicate substantial variations in the level of illumination. Frequent variations in illumination would require frequent changes in the eye adaptation mechanism, which is too slow to react to rapidly changing visual conditions. Uniformity can be determined from the data charts or from the isofootcandle diagrams by first determining the average level of illumination on a given area. If the isofootcandle diagrams are used, the various areas representing a certain illumination level can be proportioned to the total area involved to determine an average level. If the data charts (like those shown in Figures 13 and 14) are used, the area bounded by the continuous curve and the baseline can be determined by planimeter and converted to units of footcandle-feet (fc.-ft.) by using the appropriate scale factor. Thus, by multiplying the scale factor by the area in square inches and dividing by the length in ft., the average level of illumination in fc. for each test run can be obtained. If a number of lanes are involved, an overall average can be determined from the lane averages. The average fc. values are then divided by a typical minimum value for a given area to determine the uniformity ratio.

The illumination data that are evaluated in this report are representative of the various types of lighting situations that exist on the Shirley Highway projects. The following roadway sections will be illustrated using isofootcandle diagrams, strip chart data records, or a combination of both.

1. The transition zone south of the Springfield interchange where the lighting project begins.

2. A section of the main line of Rte. I-95 beginning north of the Rte. 495 interchange and extending northward to the Edsall Road interchange.

3. A section of the main line of Rte. I-95 lying north of the Glebe Road interchange.

4. Ramps on the Glebe Road interchange.

5. Several bridge underpass locations.

6. A ramp section of the Turkeycock Run access to the reversible lanes.

7. The overpass of Seminary Road over Rte. I-95.

Transition Zone

Although the roadway on the main line of Rte. I-95 is provided with 1,000-watt mercury luminaires, the transition zone in the north-bound lane (NBL) begins with six 400-watt(Type III cutoff) luminaires followed by four 700-watt(Type III semi-cutoff) luminaires all spaced at approximately 230 ft.(70.1 m) and mounted at a height of 50 ft.(15.24 m). The spacing between posts remains at 230 ft. (70.1 m) for the next 5 luminaires approaching the Springfield interchange, whereas those further to the north and lying between interchanges are spaced on the order of 150 ft.(45.72 m). In the south-bound lane (SBL) the transition zone spacing is the same, but the lighting ends with three 700-watt followed by three 400-watt luminaires at the southermost end of the lighted lane.

Isofootcandle diagrams for the transition zone are shown in Figures 6 and 7. These data were plotted from the data tapes and the isofootcandle lines developed by interpolation between plotted points where required. These particular lights had been in service for over a year when the initial measurements were taken. Therefore, the levels of illumination shown on the figures can be expected to be lower than those that would have existed initially. As can be noted from the diagrams, however, the highest level of illumination in the areas where luminaires are located only on the NBL was 1.35 fc.(14.53 lux[lx]) directly beneath a light source. The average level of illumination was 0.56 fc.(6.03 lx). Halfway between the luminaires the light levels dropped to the general range of 0.2-0.3 fc.(2.15-3.23 lx). Taking the section of roadway between the broken lines shown on Figure 6, the uniformity ratio on the NBL was 3.51:1. Although this was higher than the 3 to 1 ratio recommended in the American Standard Practice for Roadway Lighting,[6] it is probably relatively good for the lamp post spacing used.

On the opposite side of the road in the SBL (for traffic leaving the lighted area) the general lighting levels ranged between 0.1 - 0.2 fc.(1.08-2.15 lx) and averaged 0.11 fc.(1.18 lx). These levels were less than the 0.25 fc.(2.69 lx) minimum suggested by the standards[6] but were quite uniform at a 1.54:1 ratio.

Figure 7 shows the continuation of the isofootcandle diagram of Figure 6. Here the luminaires have 700-watt lamps in the NBL and the 400-watt lamps begin on the SBL. Considering the area between the broken lines shown in Figure 7, which includes only 700-watt lamps, the highest levels beneath the light sources were on the order of 3-4 fc.(32.29-43.06 lx) and the lows in the range of 0.30-0.40 fc.(3.23-4.31 lx). The overall average level of illumination was 1.28 fc.(13.78 lx)—slightly more than double that of the previous sector and very close to the desired standards.[6] The uniformity ratio was 4.12:1, which was not as good as that for the area discussed previously— which indicates that the luminaire spacing may be too great to cover the shoulder areas adequately. Also, lamp output could be slightly high, which would increase the illumination level in the vicinity of the lamp posts and in turn can cause poorer uniformity of the lighting. Since the standards suggest that the lighting level of an adjacent sector be one-half that of the preceding sector in transition zones, reduced output at the light source might improve the situation. From a practical viewpoint, however, the average illumination levels are only slightly more than double that of the previous sector and could be considered reasonably good.

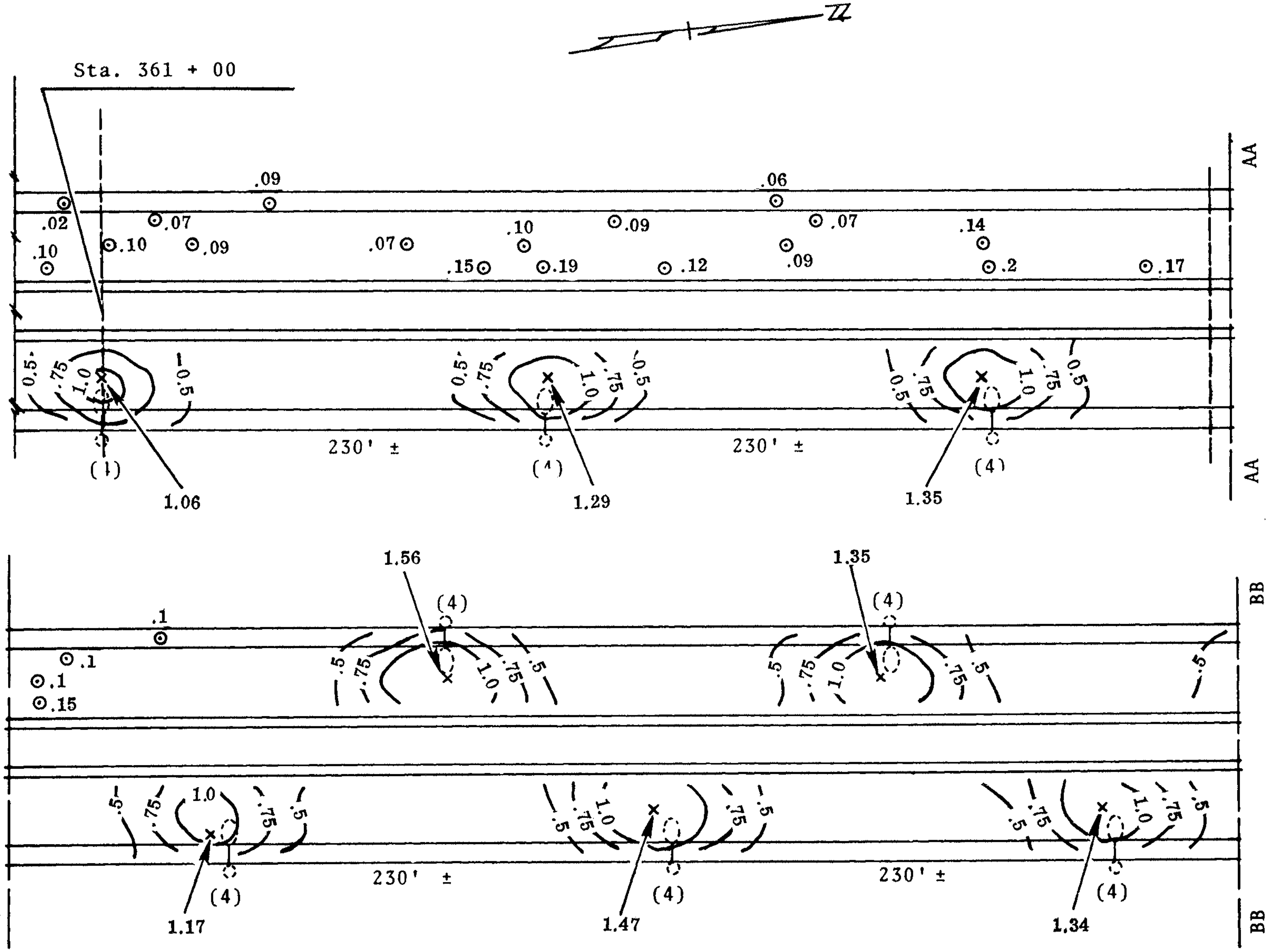
A second series of data were collected approximately 10 months after the initial measurements. The lighting patterns remained the same as those shown in Figure 6 and 7; only the levels of illumination had dropped, as would be expected. Comparisons of the average levels and uniformity ratios existing at the two periods are shown in Table 1. The uniformity ratios were reasonably consistent between the two time periods. Much of the difference was probably due to the experimental error associated with the difficulty in positioning the data collection vehicle in the same location for each test. Small differences in the minimum illumination level points used can also have a marked effect on the uniformity calculations.

It should also be noted that the low values used for the uniformity calculations occur in the paved shoulder areas— usually about midway between lamp posts. If low values were used from the regular roadway pavement only, the uniformity ratios would be much better, as shown in Table 1.

TABLE 1

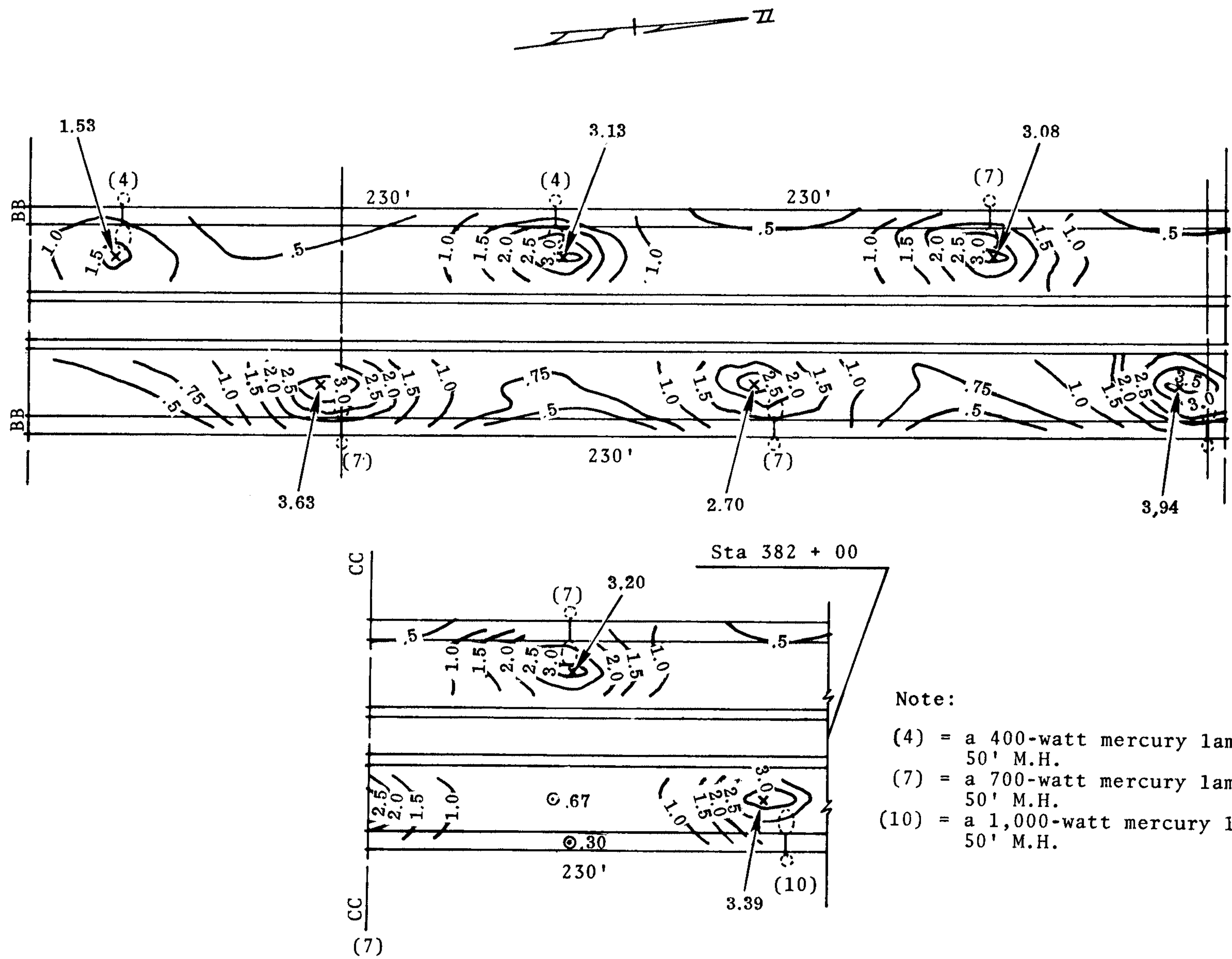
AVERAGE ILLUMINATION AND UNIFORMITY RATIOS IN TWO SECTORS OF THE TRANSITION LIGHTING

Sector	Data	Average fc.(lx)	Uniformity Including Shoulder	Uniformity Excluding Shoulder
1	initial	0.56(6.03)	3.51:1	2.80:1
1	last	0.36(2.80)	3.59:1	3.17:1
2	initial	1.28(13.77)	4.12:1	3.20:1
2	last	0.95(10.22)	4.73:1	3.17:1



Note: (4) = a 400-watt mercury lamp

Figure 6. Isofootcandle diagram showing illumination levels in the transition zone. Areas between the broken lines were tested for uniformity (Test sector 1). (1 fc = 10.76 lx)



Note:

(4) = a 400-watt mercury lamp 50' M.H.

(7) = a 700-watt mercury lamp 50' M.H.

(10) = a 1,000-watt mercury lamp 50' M.H.

Figure 7. Isofootcandle diagrams continued from Figure 6 showing distribution of illumination levels in the transition zone. Areas between the broken lines were tested for uniformity (Test sector 2). (1 fc = 10.76 1x)

Main Line Between Rte. 495 and Edsal Road Interchanges

The illumination data tapes were used to plot the isofootcandle diagrams over a section of the Rte. I-95 roadway lying between the Rte. I-495 and Edsal Road interchanges. This section extends from approximately station 500 to station 530 on the location centerline and is illuminated by 1000-watt mercury luminaires (type IV semi-cutoff) mounted at a 50 ft.(15.24 m) height on a 12 ft.(3.66 m) mast arm. All of these data are shown in Figures 8, 9, 10, and 11.

At the time the data were collected on the roadway shown in Figures 8-11, the lighting had been in service for more than a year. Therefore, the illumination levels shown can be expected to be lower than those that existed when the lighting was first put into service due to depreciation of the lamps and soiling of the luminaires.

An examination of the data reveals that the output of the luminaires varies considerably. The maximum illumination levels near the light sources are usually in the 4 to 4.5 fc.(43.04 to 48.42 lx) range but some have maximums only slightly greater than 2 fc.(21.52 lx). This leads to some variation in the isofootcandle patterns but in general the lighting was uniform. Taking a typical area such as that indicated by the broken lines in Figure 9, the overall average illumination was 1.38 fc. (14.85 lx) with a uniformity ratio of 2.38:1.

The average illumination levels in the reversible lane area was on the order of 0.70 fc.(7.53 lx), and the uniformity was exceptionally good even though the lights had been in service for approximately two years at the time of the measurements. The average illumination levels on the pavement of the reversible lanes would be slightly higher than those shown in Figures 8-11, since the latter are horizontal fc. values from the roof of the car.

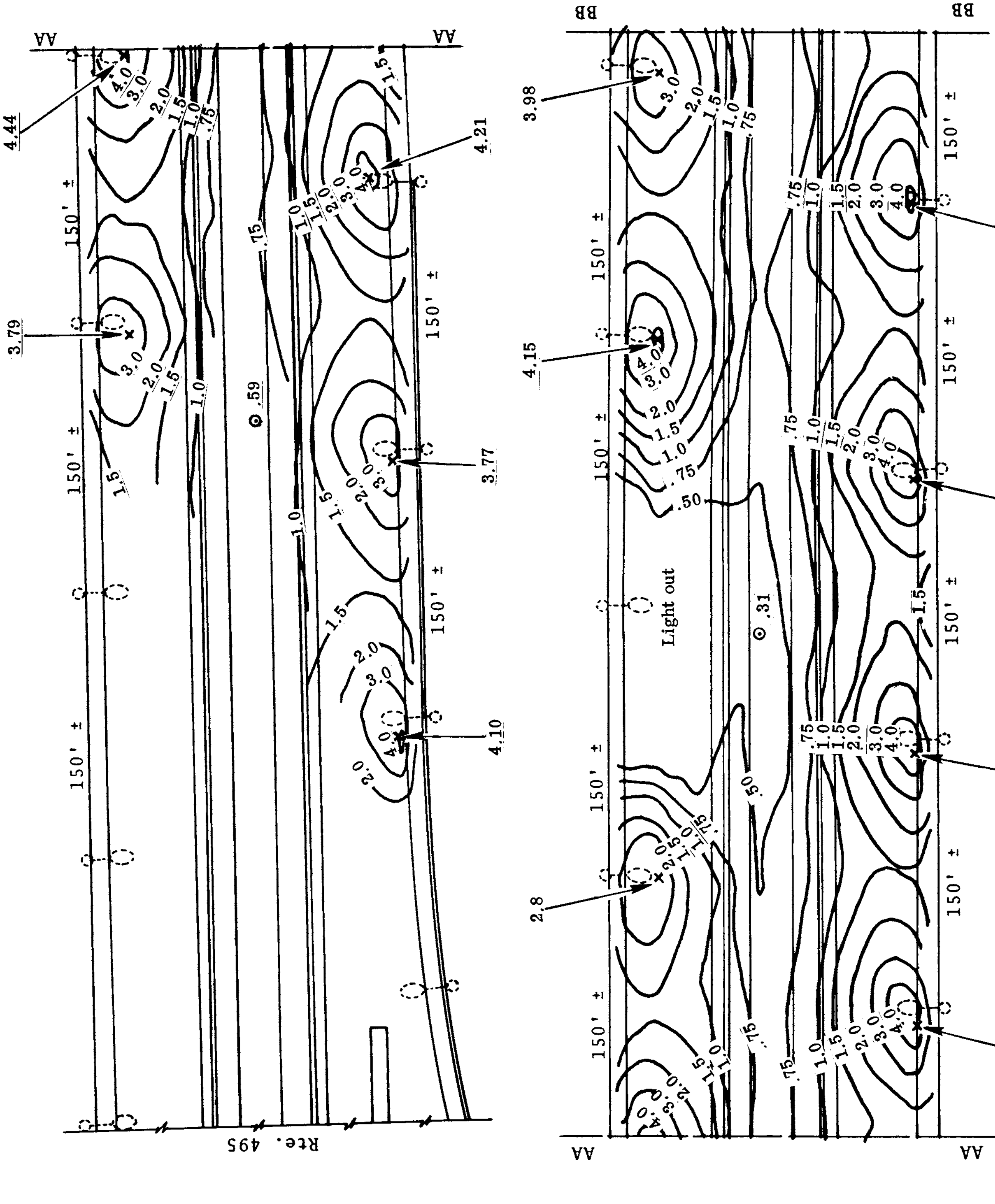


Figure 8. Isofootcandle diagram showing the distribution of illumination on a 10-lane section of Rte. 95 beginning north of the Rte. 495 interchange. 1,000-watt mercury luminaires, 50 ft. M.H., 12 ft. mast arm.(1 fc.= 10.76 lx)

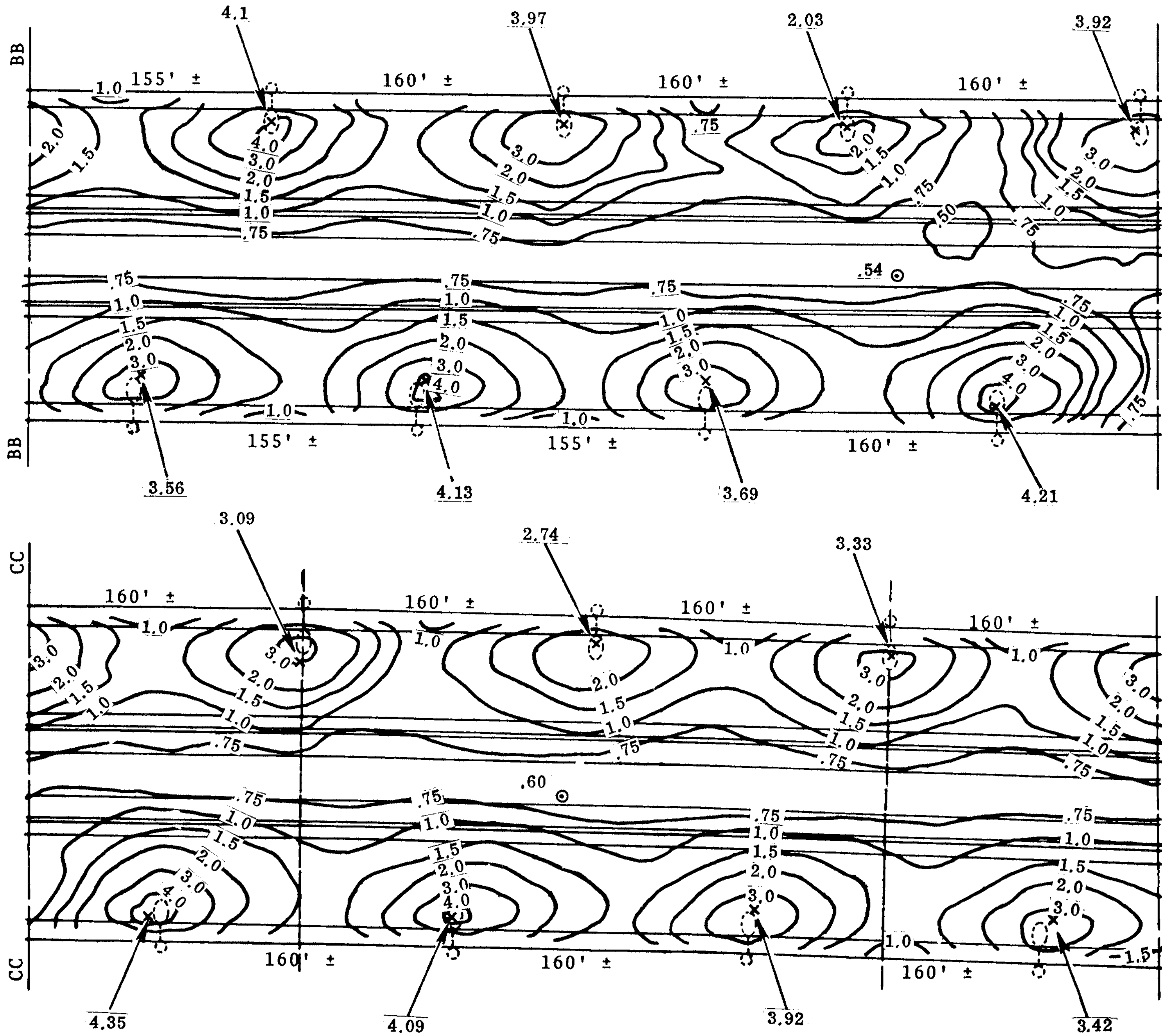


Figure 9. Continued isofootcandle diagram showing the distribution of illumination on a 10-lane section of Rte. 95 between the Rte. 495 and Edsall Road interchanges. Broken lines indicate area used for determining uniformity ratio. (1 fc = 10.76 lx)

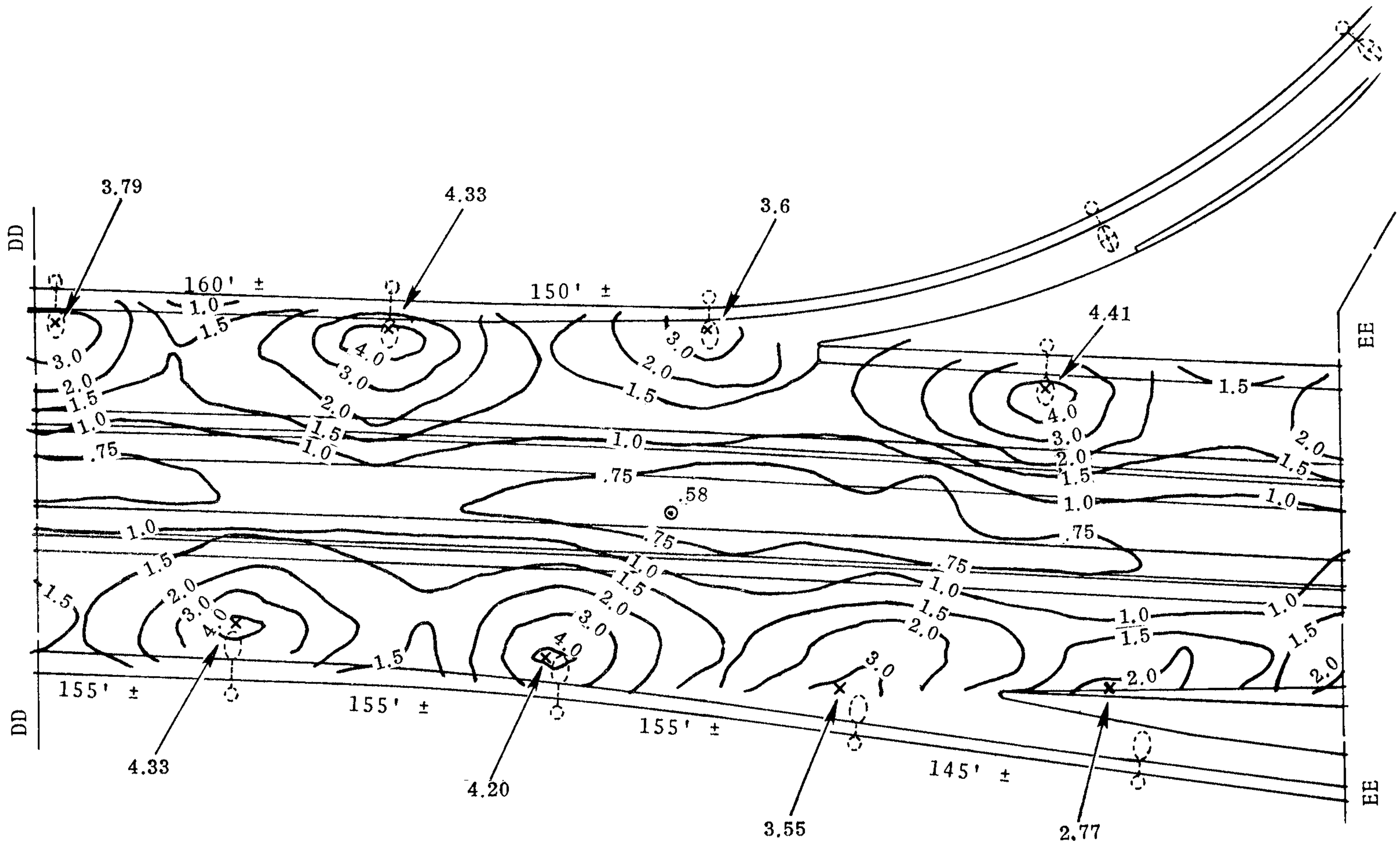


Figure 10. Continued isofootcandle diagram showing the distribution of illumination on a section of Rte. 95 just south of the Edsall Road interchange. (1 fc = 10.76 lx)

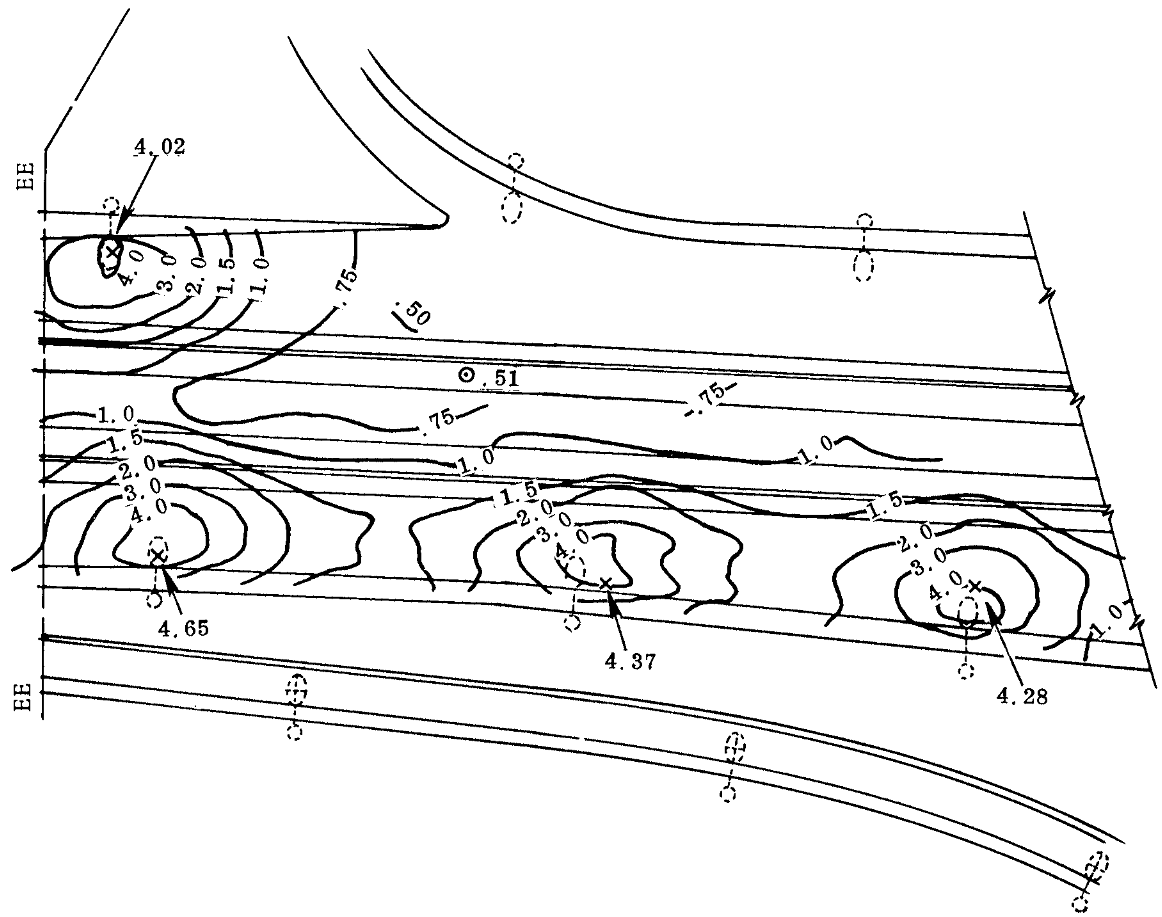


Figure 11. Continued isofootcandle diagram showing the distribution of illumination on Rte. 95 at the Edsall Road interchange. (1 fc = 10.76 lx)

Main Line North of Glebe Road Interchange

Measurements were taken on a portion of the main line of Glebe Road since this section of lighting, as well as that of the Glebe Road interchange itself, was initially turned on when the field study began. A view of this section of roadway looking north toward Washington, D. C. from the bridge over Glebe Road is shown in Figure 12. Luminaires typical of all those used on the main line can be observed in Figure 12, which shows a good view of the 50-ft.(15.24 m) mounting height and 12-ft.(3.66 m) mast arm used with the 1,000-watt mercury luminaires. The sector for which data will be discussed begins beyond the end of the ramp shown to the left in Figure 12 and extends northward. This sector runs from station 849 to station 865 — a distance of approximately 1,600 ft.(488 m).

The initial maximum illumination levels on the sector averaged between 6 and 7 fc.(64.56 and 75.32 lx). After approximately 7 months of operation, considerable lamp lumen depreciation had occurred and the maximum levels had dropped to the 5 to 6 fc.(53.80-64.56 lx) range, although some were slightly higher. Some of the typical strip chart data for the second driving lane (with respect to the right-hand side of the road) of the SBL are shown in Figure 13. The longitudinal distance on the data chart is shown horizontally, with each division representing 35.2 ft.(10.73 m). The level of illumination in footcandles is shown vertically with each major division, in this case, being 1 fc.(10.76 lx). These data are representative of those for the lane shown and for the levels of illumination when the lights were initially turned on and later after approximately 7 month's service. Figure 14 shows the same kind of data for one of the reversible driving lanes. It can be noted from each of these figures that the general configuration of the footcandle trace is virtually identical for each test period. Only the magnitude of the illumination levels has dropped due to lamp and dirt depreciation (soiling of the luminaires). For the particular data shown, for example, the average depreciation in the second SBL was 10% while that on the reversible lane was 17% during the period indicated. This amount of initial depreciation is not unexpected during the early service life of the lamps.

All of the data charts for the full main line roadway, including the shoulders on both the NBL and SBL were used to develop the isofootcandle diagram shown in Figure 15. The initial distribution and levels of illumination for the whole roadway section can be clearly viewed on this diagram. The uniformity of the lighting was excellent — particularly in the reversible lanes. There was some variation in the maximum output of the lamps — some being brighter than others — but this apprears to be a consistent characteristic throughout the project. Therefore, a smaller section of the roadway was extracted from that shown in Figure 15 in such a manner that these typical lamp output variations were included. This section, shown in Figure 16, was used to calculate the average illumination level and the uniformity of the lighting. The uniformity of the total section was found to be 2.57:1. Considering only the reversible lanes, the uniformity was 1.45:1. These uniformity results were very similar to those discussed earlier for the main line lighting north of the Rte. 495 interchange that had been in service for some time when the illumination measurements were made.

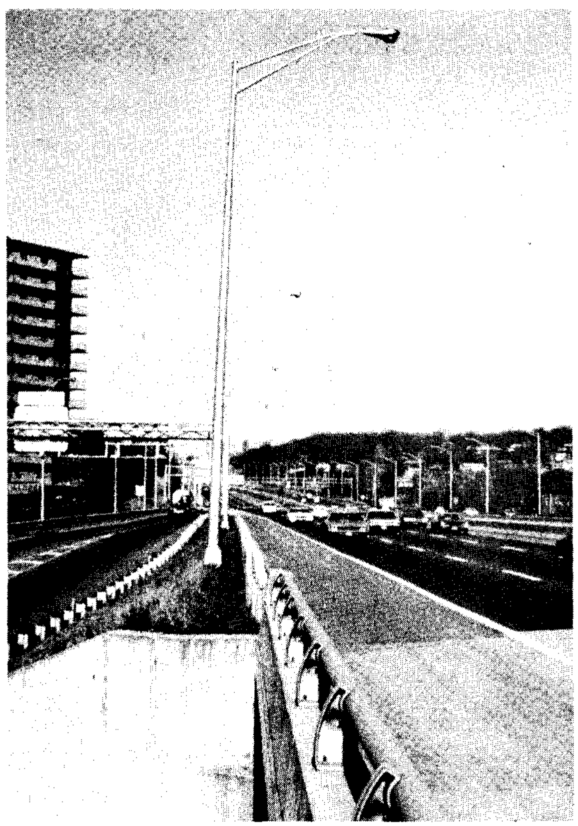


Figure 12. Lighted roadway section of Rte. I-95 north of Glebe Road.

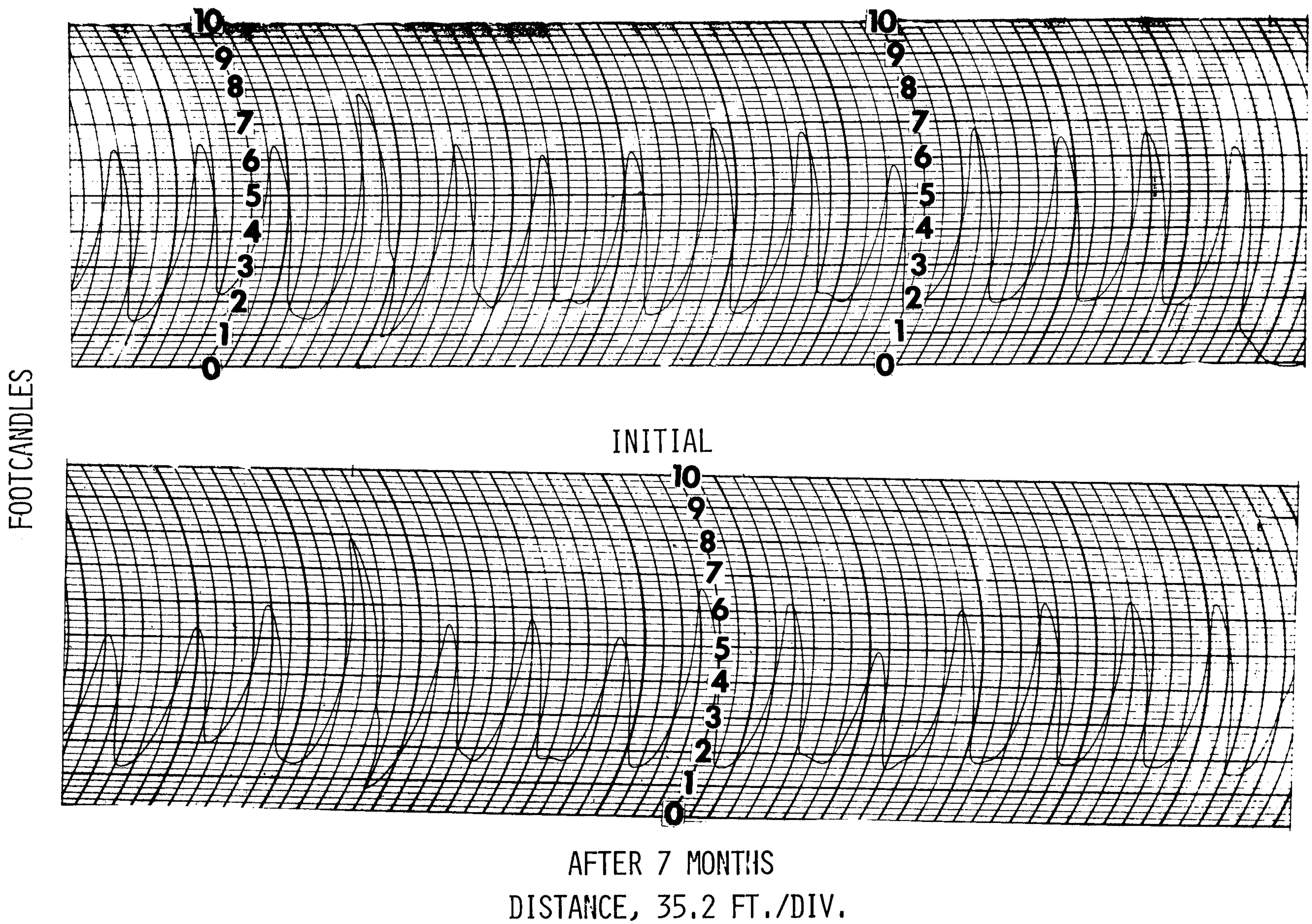


Figure 13. Typical illumination data charts for a main line lane of Rte. 95 north of Glebe Road.(1 fc = 10.76 lx)

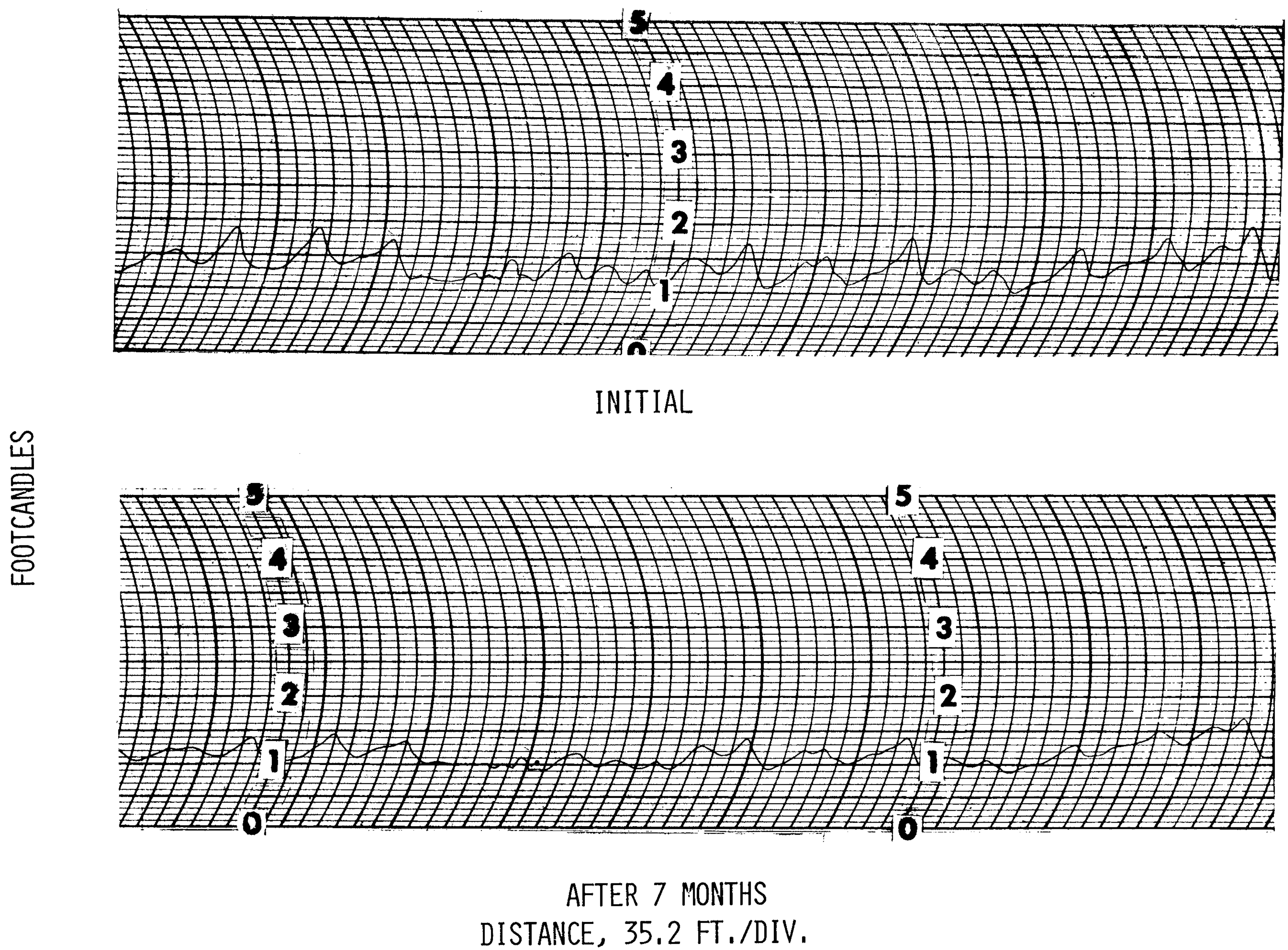


Figure 14. Typical illumination data charts for a driving lane of the reversible lanes of Rte. 95 north of Glebe Road. (1 fc = 10.76 lx)

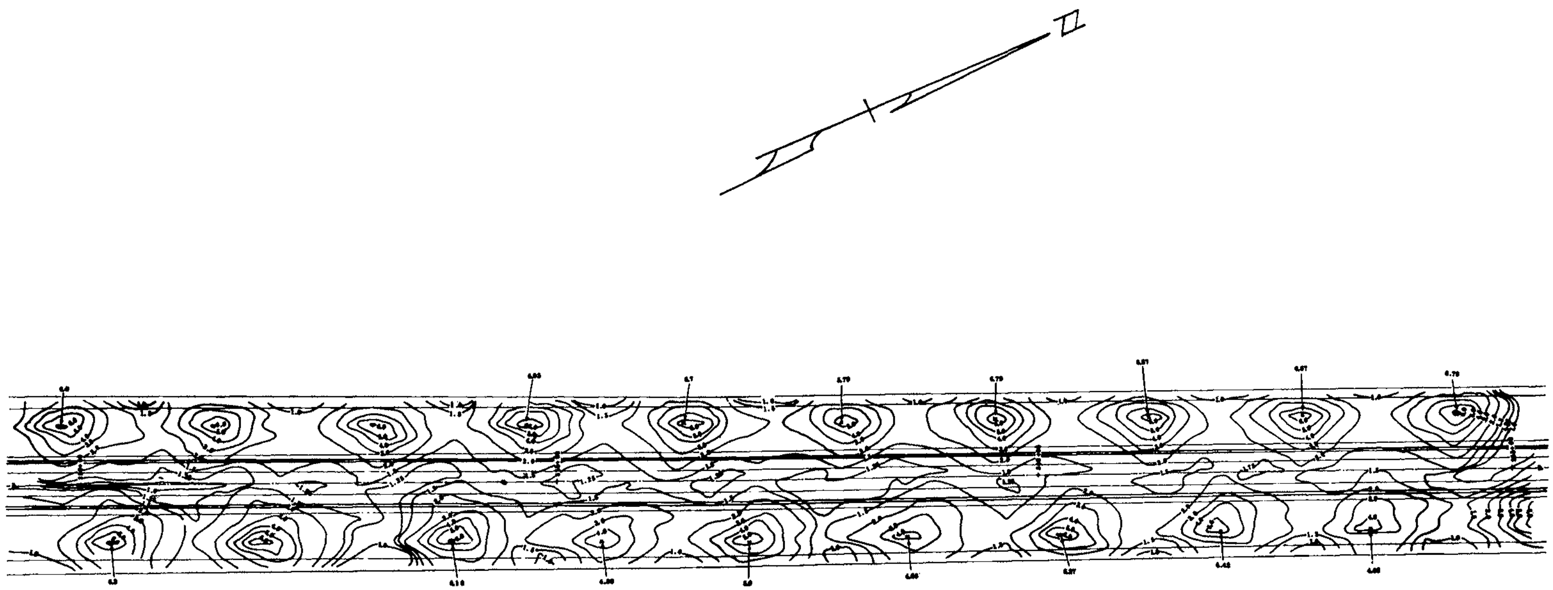


Figure 15. Isofootcandle diagram of the main line roadway area north of Glebe Road. (1 fc = 10.76 lx)

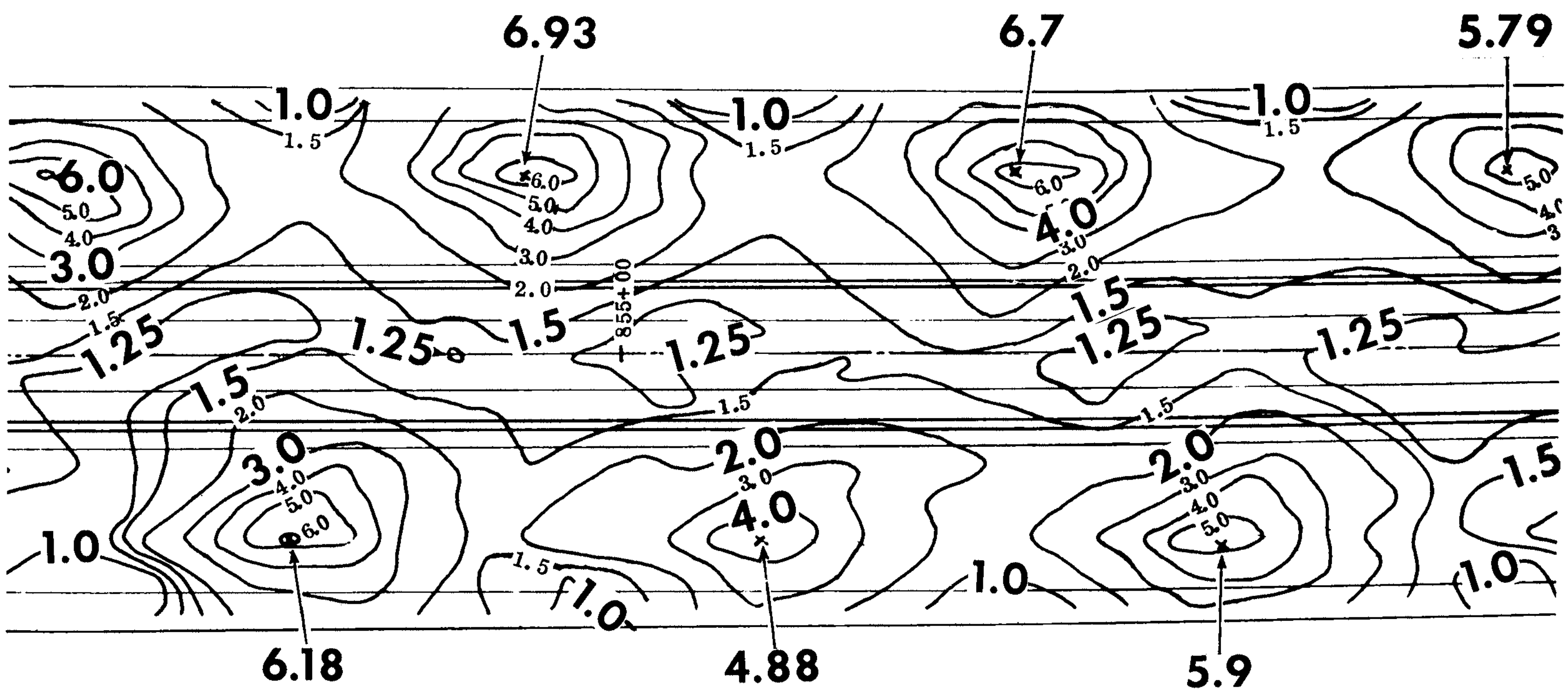


Figure 16. Enlarged section used for uniformity calculations. Variation in lamp output is typical of that found on the main line. (1 fc = 10.76 lx)

Ramp Lighting

Ramp lighting presents a different type of problem from that of the main line, since the geometrics are normally quite different. The sharp degree of curvature and higher rate of grade present on most interchange ramps make it more difficult to obtain the best uniformity and distribution of the lighting. Therefore, measurements were taken on a number of ramps. Two ramps that are representative of the results obtained are ramps B and H of the Glebe Road interchange shown in Figure 17. It can be noted that some of the illumination on these two ramps could be provided by the luminaires on ramps A and F. It can also be noted that the lamp posts are located on the inside of the curvature of the ramps, which normally requires closer spacing of the posts to obtain a desirable distribution of light. The lamps used on these ramps are 700-watt mercury (Type III) mounted at 40 ft.(12.19 m) height.

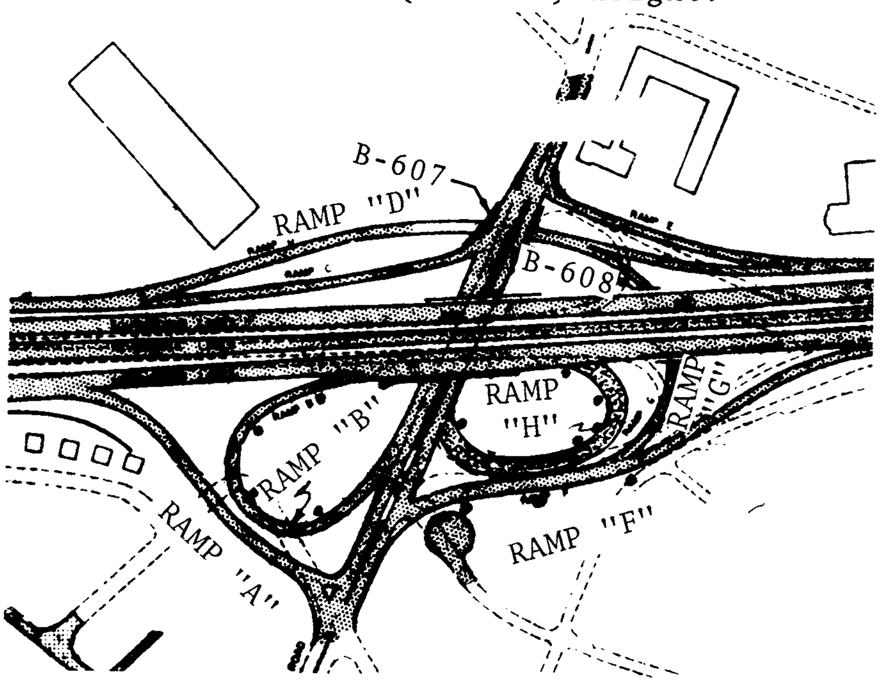


Figure 17. Plan view of the Glebe Road interchange. General luminaire locations on Ramps A, B, H, and F are indicated.

Figure 14 shows the isofootcandle diagram for the lighting on Ramp B. Proceeding clockwise from the lower right (beginning) of ramp B, the distance between the first two lamp posts is approximately 190 ft.(57.91 m). As can be noted from Figure 17, some of the lighting on this area of ramp B was probably designed to be provided by the lamps on the adjacent ramp A. Halfway between the first two luminaires on ramp B, however, the lighting levels were low- some points on the order of 0.01 fc.(0.11 lx) on the shoulder- as indicated in Figure 18. Between the next two lights the illumination levels are nearly zero. The low levels at these points are due partially to the fact that the data were taken from the roof of the vehicle and thereby did not include light that might have been on the pavement. Consequently, hand measurements were taken at the pavement level, and a low value of 0.12 fc.(1.29 lx) was obtained. This value would yield a uniformity ratio of 19.25:1 on the paved area of ramp B, with the average level of illumination being 2.31 fc.(24.86 lx). The distribution of the lighting would probably be better if the lamp posts were spaced closer or if more light were contributed to the ramp from the luminaires on ramp A.

The distribution and maximum levels of illumination at the last two lights on ramp B are unusual in that the isofootcandle patterns are not the same as those normally existing beneath the light source. The maximum level of 6.5 fc.(69.94 lx) near the third luminaire from the beginning of the ramp was not directly under the lamp as would be expected. The same situation exists for the last luminaire shown. This result was probably due to a combination of the grade on the ramp and the influx of additional light on the area from the main line. In general the lighting on the ramp was not particularly good due to the low levels halfway between the luminaires.

The isofootcandle diagram for the lighting on ramp H is shown in Figure 19. The distribution of the illumination on this ramp was better than that on ramp B and could be considered reasonably good by comparison. The uniformity ratio of the lighting based on data taken from the roof of the car was 10.76:1 and the average initial level was 2.69 fc.(28.94 lx). The uniformity of the lighting based on low values taken on the pavement surface was 5.38:1, which is significantly better than that obtained on ramp B but is considerably above the recommended standard of 3:1.

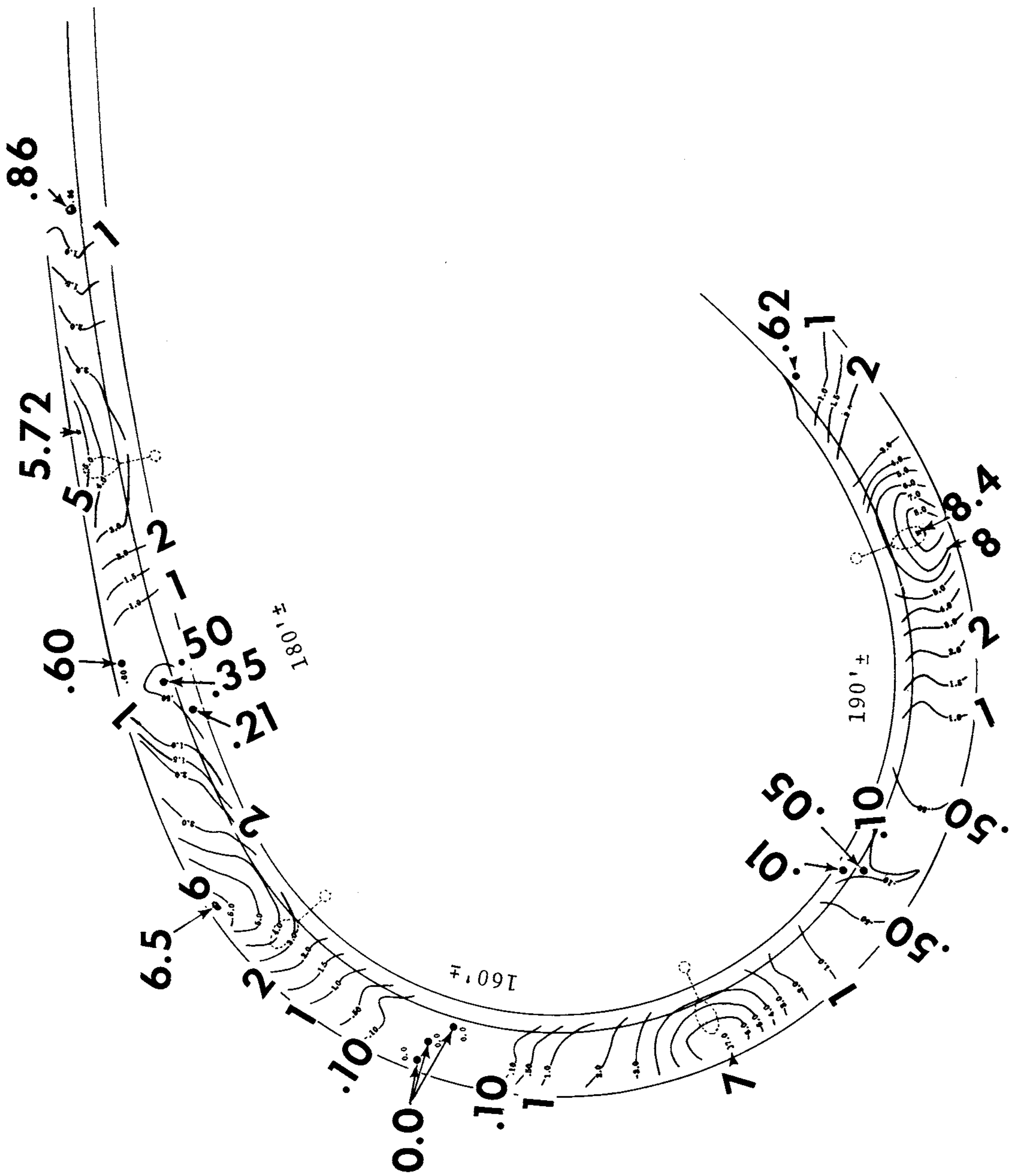


Figure 18. Isofootcandle diagram for ramp "B" of the Glebe Road interchange. (1 fc = 10.76 lx)

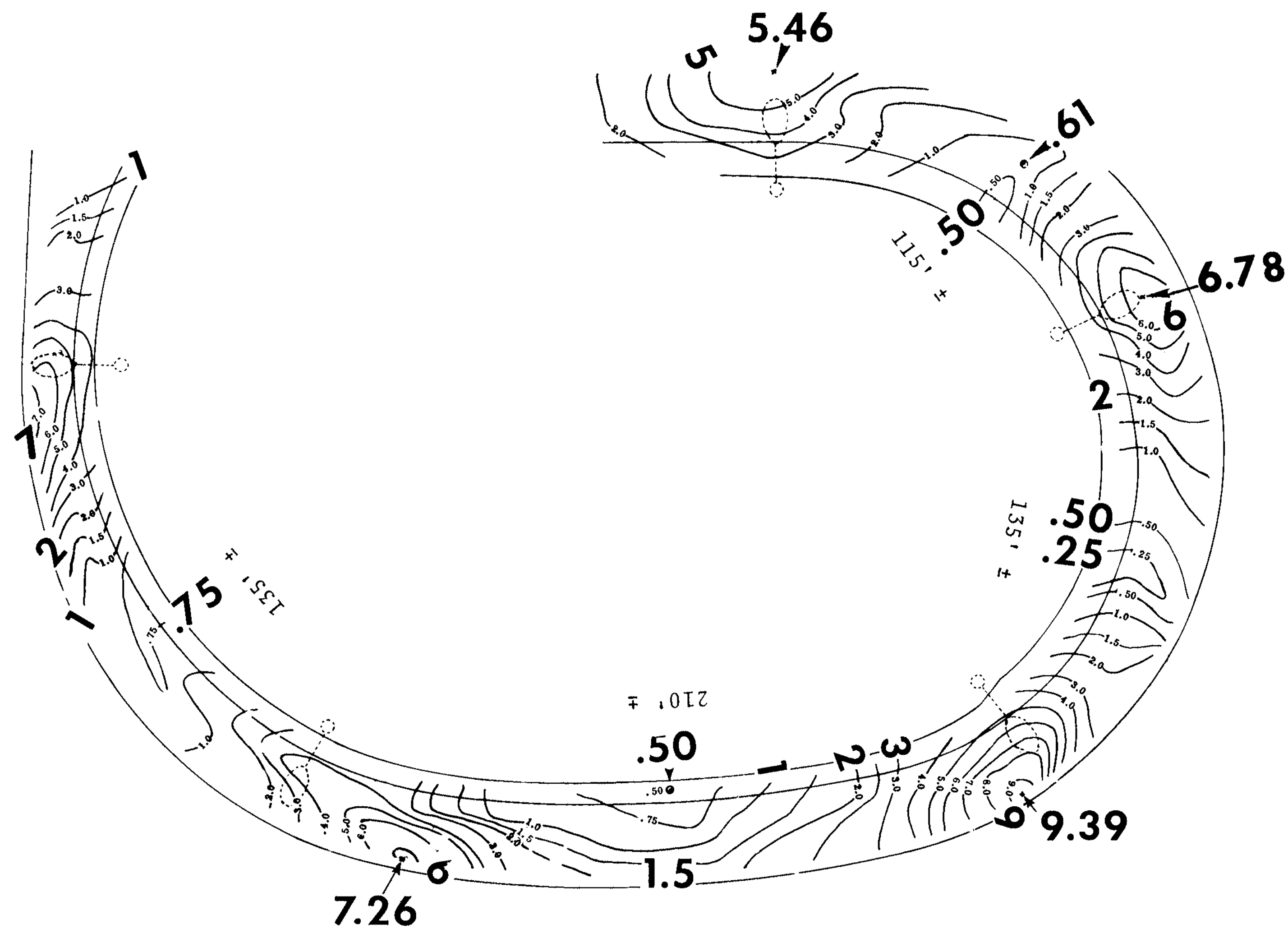


Figure 19. Isofootcandle diagram for ramp "H" of the Glebe Road interchange. (1 fc = 10.76 lx)

Underpass Lighting

Ramp G of the Glebe Road interchange passes beneath the main line of Rte. I-95 and converges with ramp D, which passes under Glebe Road (Figure 17). Each of the underpasses is provided with lighting from 250-watt mercury luminaires mounted on a wall of the structure. In the case of ramp G, six luminaires provide the lighting, while ramp D is lit by three luminaires. The isofootcandle diagrams for ramps G and D are shown, respectively, in Figures 20 and 21.

The average illumination level on the ramp G underpass was 2.87 fc.(30.89 lx) and the uniformity ratio was 4.41:1. On ramp D, the average illumination was 2.76 fc.(29.71 lx) and the uniformity was 3.17:1. There was a difference in the measurements in that only the merging lane of ramp D was included whereas the full ramp width was included for ramp G. The uniformity on ramp D, therefore, would not be as good if the full ramp width were included in the data. While the uniformity of the under bridge lighting on ramp G does not meet the 3:1 desirable ratio, it appears to be good, except in the right corner at the entrance end of the underpass (Figure 20). A slight redirection of the lighting from the end luminaire could probably correct this deficiency.

Ramps to Reversible Lanes (Turkeycock Run)

Some unusual ramp sections that are used to enter and exit the reversible lanes are the Turkeycock Run ramps shown in Figure 22. The illumination on these ramps is provided by 700-watt mercury luminaires (Type III semi-cutoff) mounted at 40 ft.(12.19 m) with a 6-ft.(1.83 m) mast arm. The data for ramp B are presented in this report in the isofootcandle diagrams shown in Figures 23, 24, 25, and 26.

Several things are of interest in the ramp data shown in Figures 23-26. First, the spacing between the lamp posts varies from 150 ft.(45.72 m) on the curved section of the ramp to 195 ft.(59.44 m) near the intersection with the SBL of the main line. Secondly, the maximum level of illumination is much higher under the first three luminaires beyond the end of the bridge (Figures 24 and 25) than it is on the remainder of the ramp.

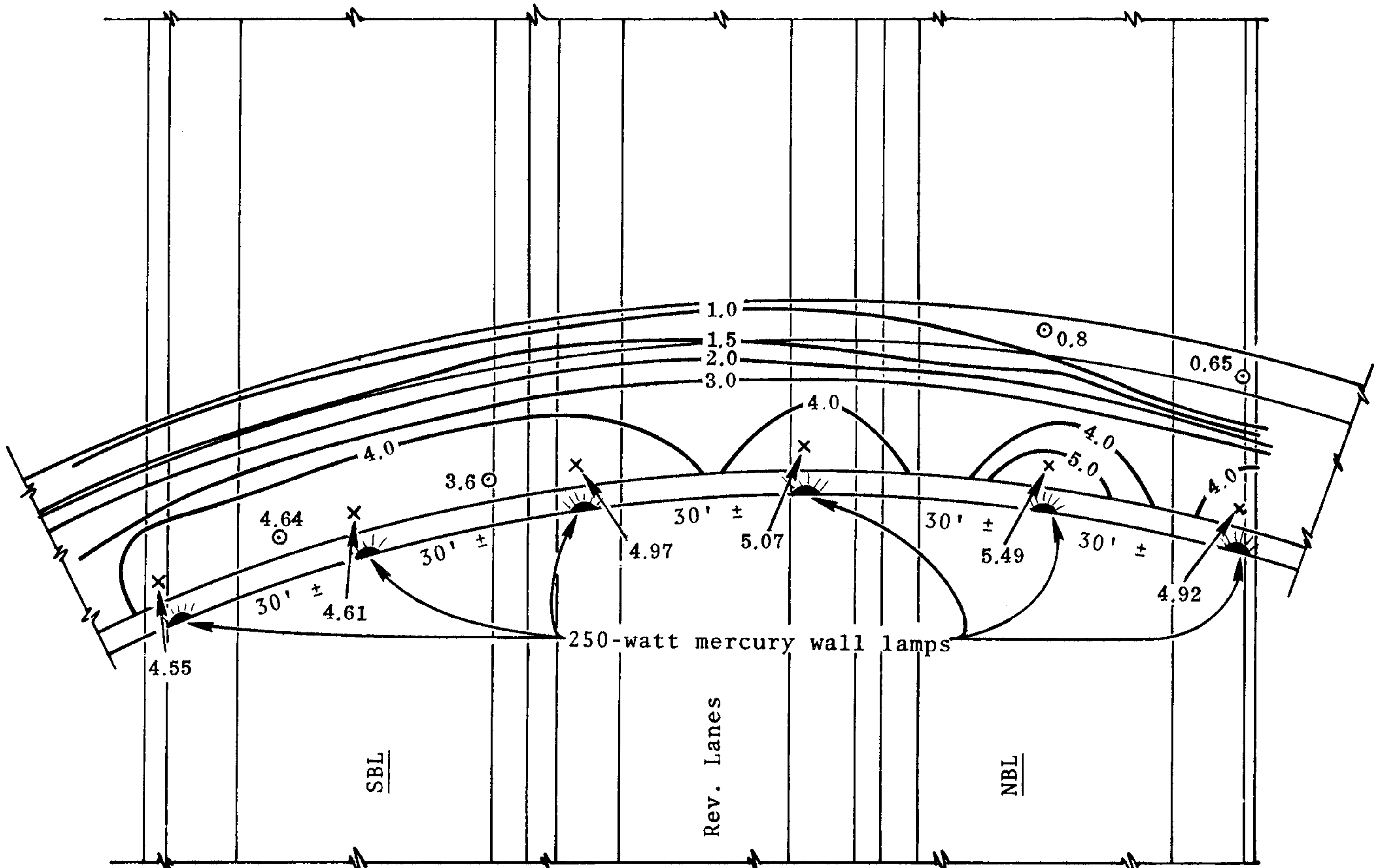


Figure 20. Isofootcandle diagram for ramp "G" underpass lighting. (1 fc = 10.76 lx)

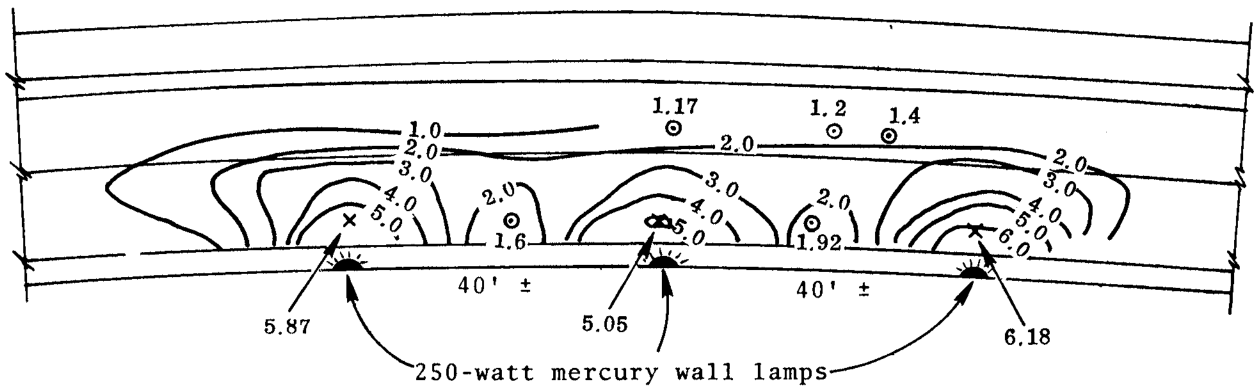


Figure 21. Isofootcandle diagram for ramp "D" underpass lighting.
(1 fc = 10.76 lx)

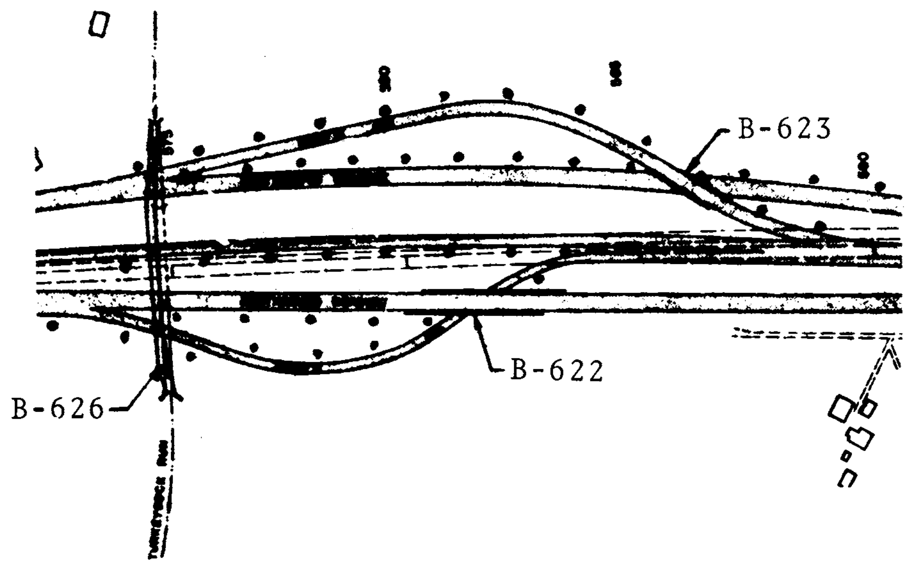


Figure 22. Plan view of the Turkeycock Run ramps.

On the curved section of the ramp the average intensity was 3.75 fc.(40.36 lx), whereas on the straight section it was 2.14 fc.(23.02 lx). Noting that one lamp was out at the time data were taken and excluding this area from the calculations, the average intensity of the lighting over the length of ramp B shown was 2.63 fc.(28.31 lx). This value would yield a uniformity ratio of 11.4:1 for the roadway including the paved shoulders. The low value of the lighting was 0.23 fc.(2.48 lx), which was found on the pavement at several spots located approximately halfway between adjacent luminaires. Due to the higher average intensity in the curved section, the uniformity of the lighting was not as good in this region as it was on the straight section having the lower average intensity. The uniformity thus varied from 9.3:1 on the straight section of the ramp to 16.3:1 on the curved section.

The unusual distribution of the illumination and the maximum level of intensity falling slightly upgrade from the luminaire location indicate that there could be some spillover of light from the main line and that the luminaires may need to be oriented vertically on the support so that the light rays strike the surface equidistance from the luminaire.

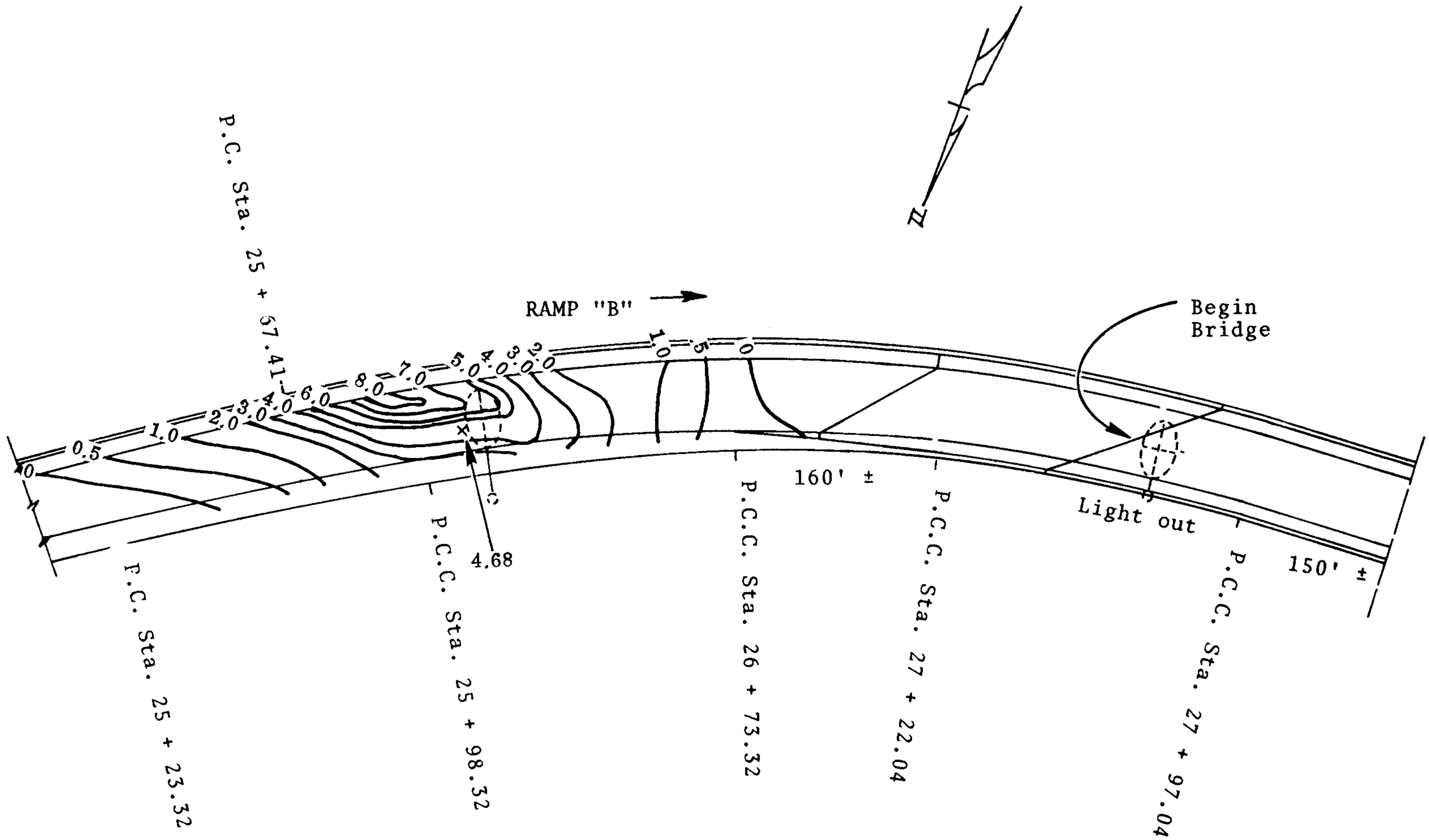


Figure 23. Isofootcandle diagram for the lighting on ramp "B", Turkeycock Run. (1 fc = 10.76 lx)

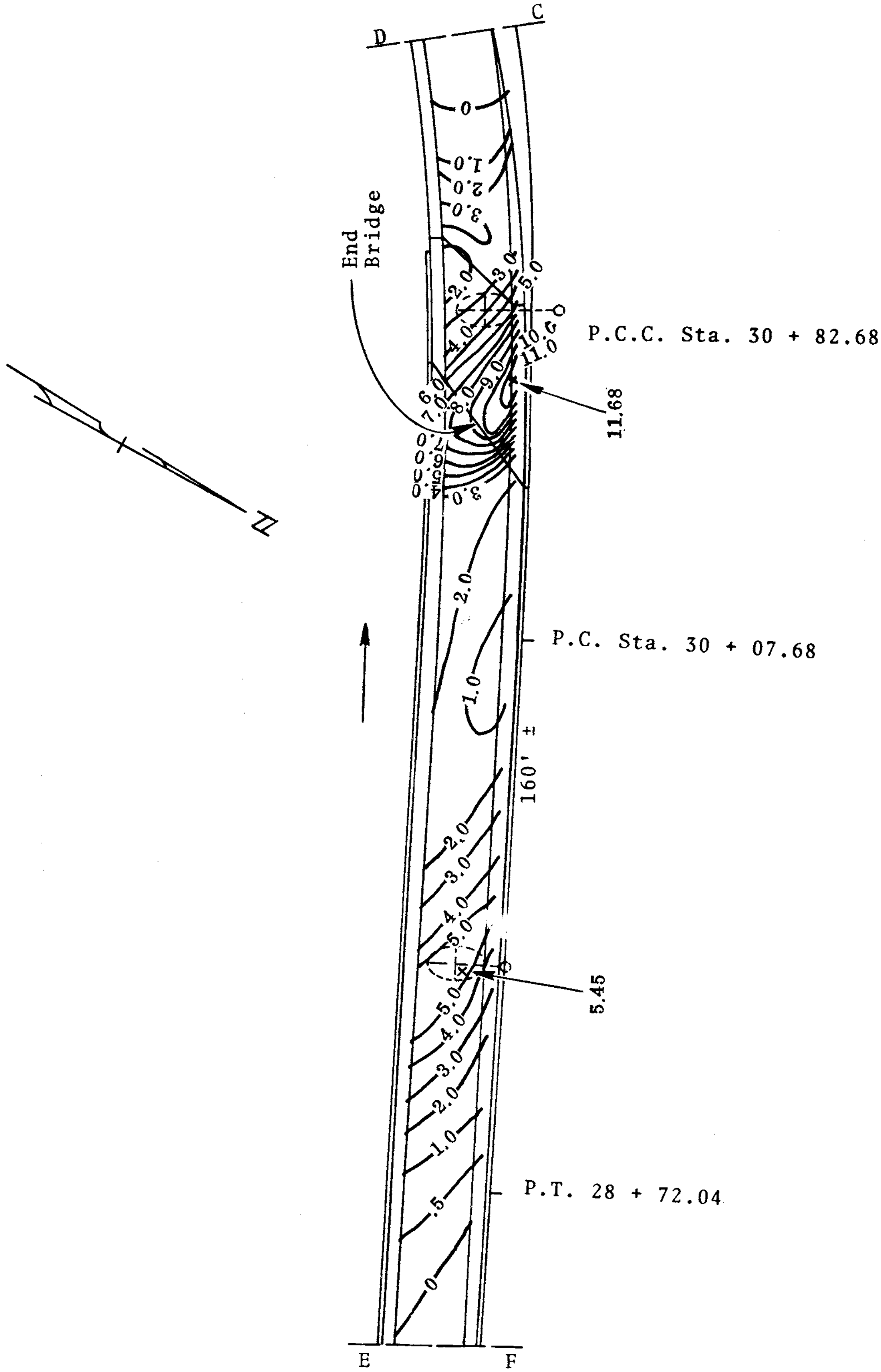


Figure 24. Continued isofootcandle diagram of ramp "B", Turkeycock Run. (1 fc = 10.76 lx)

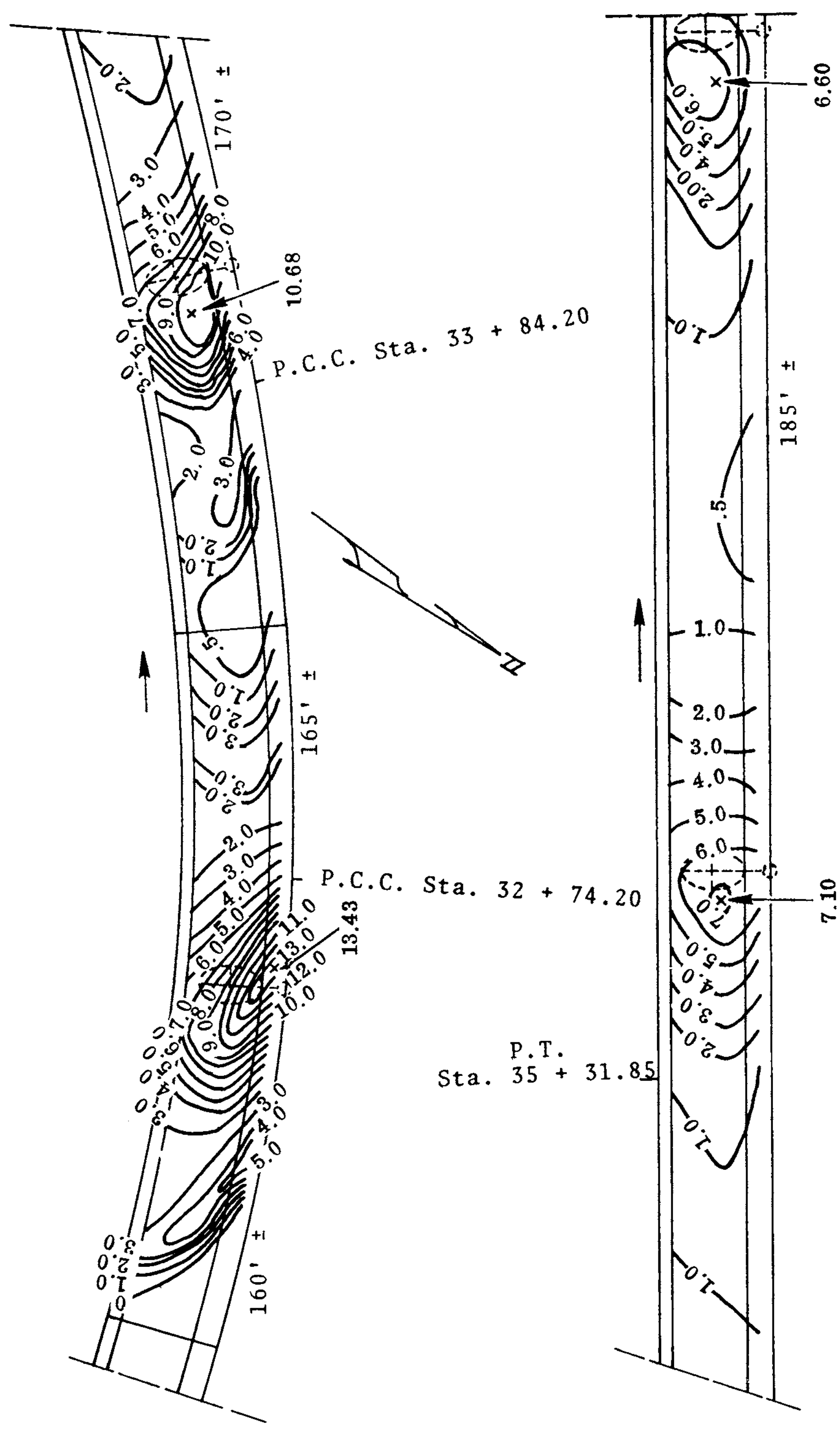


Figure 25. Continued isofootcandle diagram of ramp "B" Turkeycock Run. (1 fc = 10.76 lx)

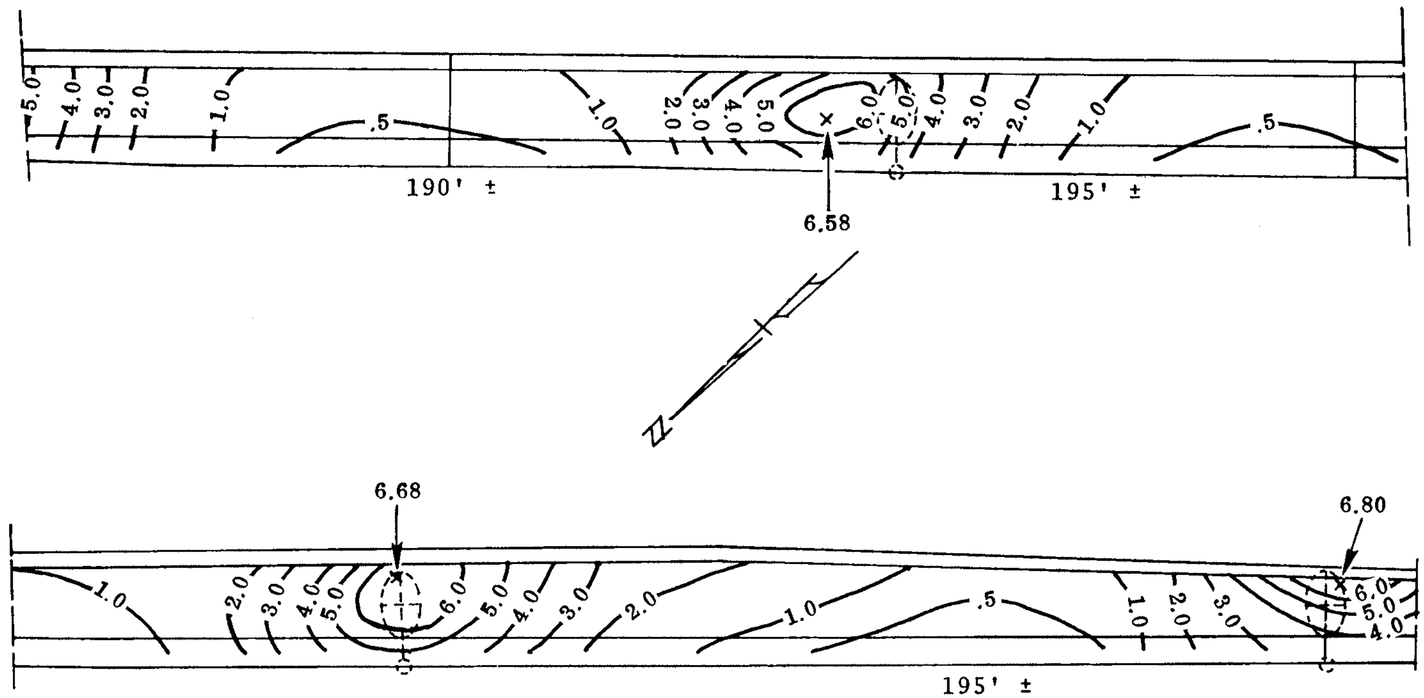


Figure 26. Continued isofootcandle diagram for the lighting on ramp "B", Turkeycock Run. (1 fc. = 10.76 lx)

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Seminary Road over the Main Line

Seminary Road passes over both the main line of Rte. I-95 and the interchange ramps that serve the area. A plan view of the interchange is shown in Figure 27. Seminary Road is one of the few areas on the lighting project that is lit with 400-watt mercury luminaires mounted at a height of 30 ft.(9.14 m) on a 6-ft.(1.83 m) mast arm. A typical distance vs. footcandle data chart for the left-hand EBL is shown in Figure 28. These data were taken after the lighting had been in service for approximately one year. The data traces for the other lanes and shoulder of the roadway have a configuration similar to that shown in Figure 28; only the order of magnitude of the footcandle values differ between the lanes, as would be expected. The lamp posts are located on opposite sides of the roadway in an alternating fashion as can be detected by the alternating high and low peaks on the data trace shown.

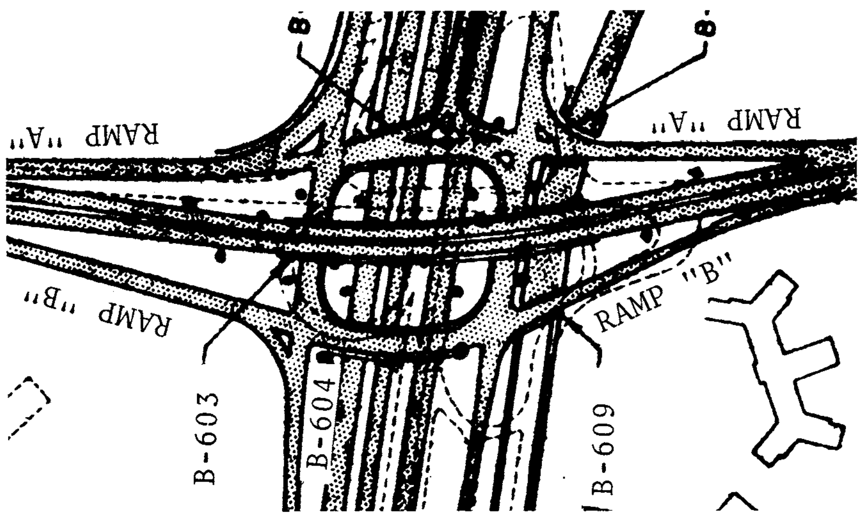

Figure 27. Plan view of the Seminary Rd. interchange.

Data charts like that shown in Figure 28 can be used for each driving lane and shoulder area to develop isofootcandle diagrams, or they can be used individually to calculate the average footcandle value for each lane. An overall average footcandle level can be obtained for the total area surveyed by averaging the individual lanes. The individual lane averages and overall average for a 1,100 ft.(335 m) section of Seminary Road are shown in Table 2 for two test periods taken at 6-month intervals. On an average, the illumination levels depreciated slightly during this time period and the uniformity ratios remained approximately the same at 3.80:1 and 3.73:1, respectively, for the initial and 6-month test periods. While some of the latter data averages appear to be slightly higher than the initial data shown in Table 2, experimental error associated with the positioning of the vehicle between test periods is probably the reason for the unexpected difference. Therefore, from a statistical viewpoint the overall averages would be more representative of the depreciation in the lighting than would be the individual lane averages. In general, however, the lighting was relatively good but the uniformity was slightly above the recommended standards.

TABLE 2

AVERAGE FOOTCANDLE VALUES ON A 1,100-FT. SECTION OF SEMINARY ROAD FOR TWO TIME PERIODS

Lane	Average fc.(lx), initial	Average fc.(lx), After 6 months
Shoulder EBL	1.00(10.76)	0.92(9.90)
RHL, EBL	1.17(12.59)	1.20(12.92)
LHL, EBL	1.23(13.24)	1.22(13.13)
Shoulder, WBL	1.06(11.41)	0.98(10.55)
RHL, WBL	1.15(12.38)	1.06(11.41)
LHL,WBL	1.23(13.24)	1.33(14.32)
Average	1.14(12.27)	1.12(12.06)
Uniformity	3.80:1	3.73:1

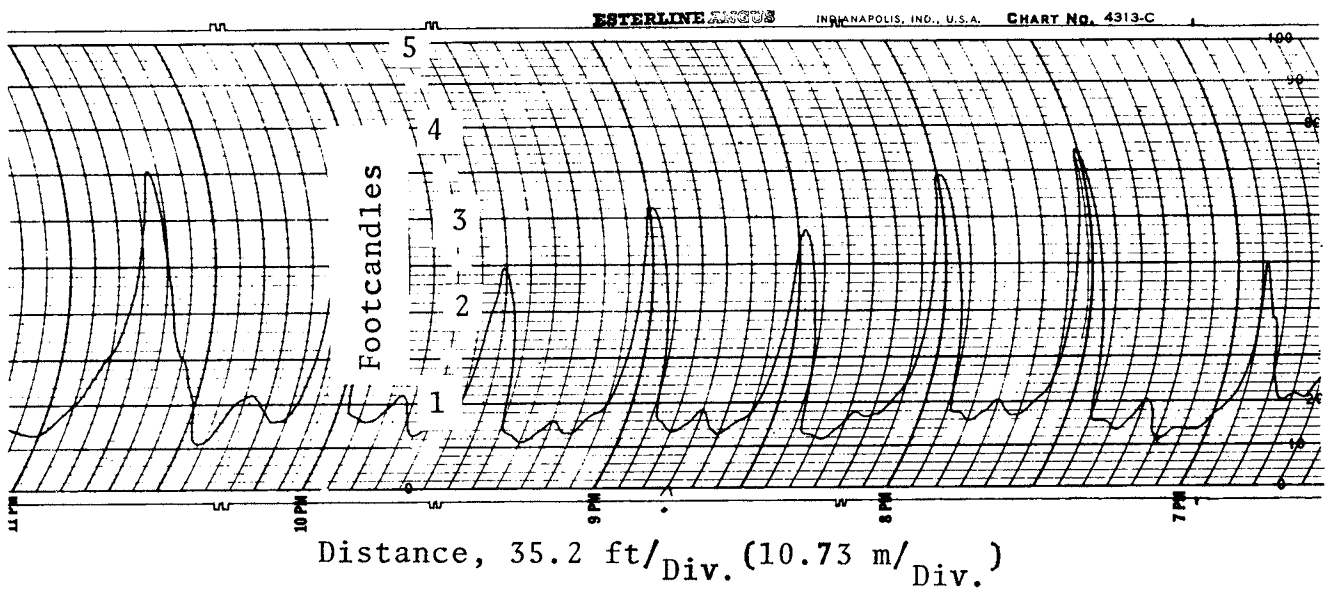

Figure 28. Footcandle– distance data trace for the left-hand driving lane of the EBL of Seminary Road. (1 fc = 10.76 1x)

DISCUSSION

The Shirley Highway lighting study was complicated by several factors during the course of data collection. Initially, measurements were taken on several sections of roadway and ramps in the Springfield interchange area but continued study was hampered by electrical problems in that area. Approximately 9,000 ft.(2,743 m) of electrical cable were eventually replaced in this area according to information supplied to the writer. Similar problems occurred on other ramps, such as Glebe Road, where the lighting was often inoperative during data collection. Additional problems were related to the lighting in some areas being on during daylight. Several sections of the main line lighting in the King St., Shirlington and Seminary Road areas were observed burning during bright daylight hours. The exact reason for this problem during the course of the study is not entirely clear, but reportedly some sections of the lighting were initially set up to be turned on by time clocks which were, at times, not set properly or were malfuntioning. These sections have subsequently been altered to utilize photocell controls.

During the course of the data collection some of the luminaires were apparently relamped due to burnouts. Since this activity was not under the control of the investigators, it would be impossible to evaluate the long-term depreciation of the lighting. It is not known to what degree spot relamping influenced the data presented in the report, but it is not believed to have been a significant factor, except possibly in the Seminary Road results.

Further complicating the study was the energy crisis of 1974. During that period much of the lighting was reduced and at one stage it was turned off between interchanges for approximately 6 months. This situation hampered the long-term study of the illumination levels.

A final problem encountered during the data collection periods involved vandalism, which appears to be a particular problem in the interchange, ramp, and underpass areas. Several wall-mounted luminaires such as the one shown in Figure 29 were found to be broken during data collection. It is likely in this case that rocks were thrown at the lighting. A lesser but similar problem seems to exist on some ramps having the lower mounted luminaires such as the one shown in Figure 30. Vandalism will probably be a reocurring problem with the lighting- particularly on the ramp underpasses such as those at the Glebe Road interchange.

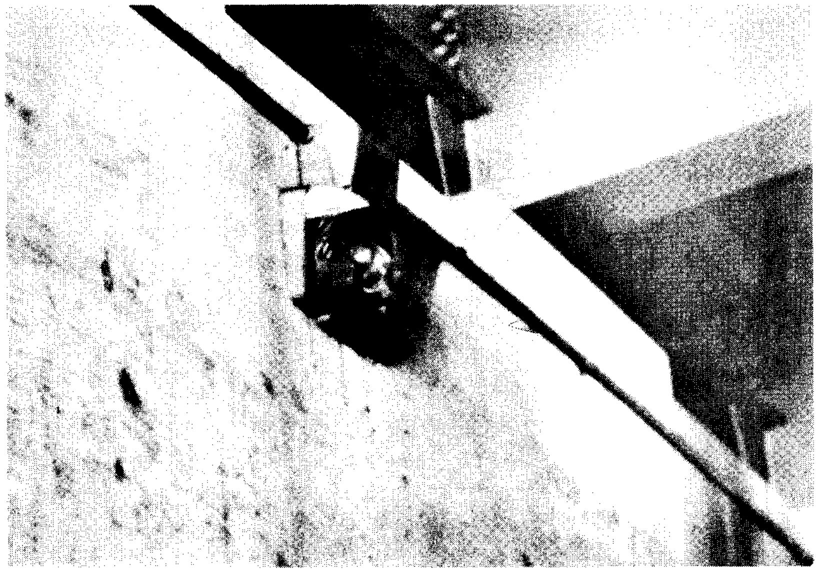

Figure 29. A wall-mounted bridge underpass luminaire that was probably broken by vandals.

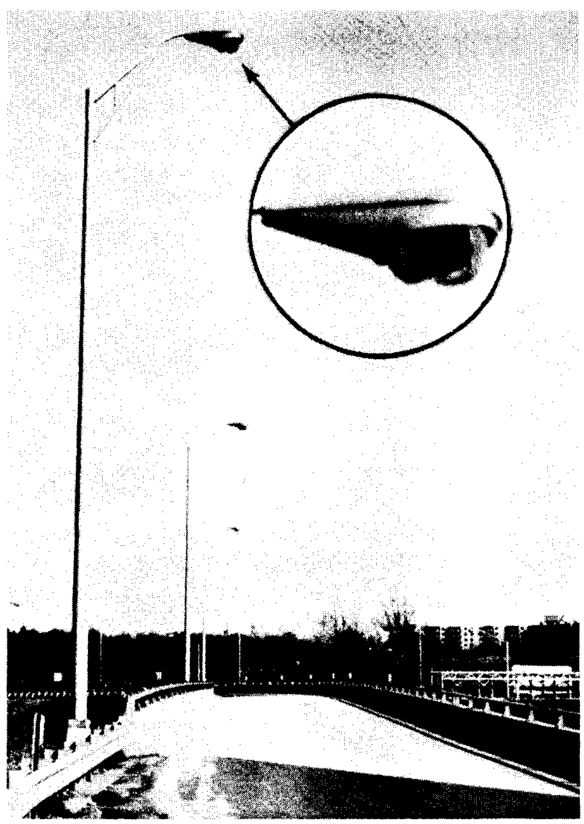

Figure 30. A 40 ft.(12.19m) high interchange ramp luminaire that was broken by vandals.

CONCLUSIONS

It should be restated that the main purpose of the study of the Shirley Highway lighting system was to evaluate and supply information on the levels and uniformity of the illumination on some typical lighted sections of the roadway. Therefore, the following conclusions are based upon the data obtained and pertain only to the levels, distribution, and uniformity of the lighting on the sections of roadway discussed in this report.

1. In general, the lighting on the main line of Rte. I-95 is well within the recommended design standards for which the system was designed. The average fc. levels are considerably higher than the 0.6 fc. (6.46 lx) illumination level recommended by the standards.(6) The uniformity ratios are considerably better than the 3 to 1 minimum recommended.

2. The general distribution of the illumination on the main line roadway areas can be considered excellent. In some instances there is considerable variation in the maximum levels of illumination between adjacent luminaires. Even in sections including this condition, however, the uniformity of the lighting is good.

3. In the reversible lanes on the main line the uniformity of the lighting is excellent.

4. In the transition zone the lighting on the SBL(exiting the lighted area) is low in the area served by luminaires on the opposite side of the road. These levels were approximately half those recommended by the standards. The uniformity of the lighting in several sections of the transition zone was higher than 3 to 1-- ranging from 3.5:1 to 4.73:1, when low values on the roadway shoulder were taken into account. The average illumination levels between adjacent sectors were slightly more than double that of the previous sector-- the Standards suggest that a given section not be more than double the preceding one.

5. The lighting on loop type ramps where the lamp posts are located on the inside of the curvature was generally not good. Examples discussed in the report, however, show that the distribution of the light flux was better on some ramps than on others. Closer spacing of the lamp posts, in some instances, would have improved the distribution characteristics.

6. The bridge underpass lighting was generally good. In one case illustrated in the report, the uniformity of the lighting could probably be improved to meet the standards [6] by the adjustment of one of the wall-mounted luminaires.

7. The uniformity of the lighting on ramp B of Turkeycock Run, which has 40 ft.(12.19m) high luminaires, was below standard. Closer spacing of the lamp posts would probably be required to improved the uniformity of the illumination.

8. Results of the illumination measurements taken on some of the ramps indicate that some of the luminaires may need to be oriented vertically on the support so that the light rays will strike the surface equidistance from the luminaires.

9. Vandalism of the lighting– particularly in the interchange ramp and bridge underpass areas– will probably be a continual maintenance problem.

RECOMMENDATIONS

The lighting on the main line of Rte. I-95 is excellent and fully meets the design standards recommended by the IES as approved by the American National Standards Institute.[6] The lighting on some of the interchange ramps where the luminaires are mounted on the inside of the alignment curvature, some straight ramp sections where the luminaire spacing is high(such as Turkeycock Run), and in the transition zone south of Springfield could be improved by slightly closer spacing of the luminaires or, perhaps, by a wider distribution type luminaire. Since this phase of the study was conducted to provide information on existing light systems which could be used as a guide in future lighting applications, it is recommeded that the inadequacies described above be considered in the design of any future roadway lighting.

ACKNOWLEDGEMENTS

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