INTERIM REPORT NO. 1

EVALUATION OF PAVEMENT EDGE INSET AND LOW LEVEL ILLUMINATION LIGHTS IN FOG

by

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(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways and the University of Virginia)

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SUMMARY

The Virginia Highway Research Council was asked to search for ways of making travel safer on fogbound highways. All literature obtainable on fog research was reviewed, and after an indepth review of fog abatement techniques it became apparent that neither technology nor hardware had advanced to the degree that it was feasible for highway usage. The literature did, however, suggest that two types of lights had potential for usage in fog. The types were:

(1) Pavement inset lights for delineation of roadway(referred to as a lineal guidance system and unidirectional airport runway lights), and

(2) lights mounted at low elevations for forward visibility.

This finding was reported to Highway Department officials, who then requested that the Research Council obtain several of each type of light and set up an experiment to test the effectiveness of each. The pavement inset lights obtained were unidirectional airport runway lights 12 inches in diameter and weighing approximately 50 pounds. Each light carries a 200-watt bulb and the intensity is variable. The low elevation lights are 500-watt, high intensity, quartz floodlights.

The pavement inset lights were tested by placing them on the pavement surface in line with the edge line marking on each side of the road. They were tested by varying (1) the spacings between them and (2) their intensities. The testing, which was performed by a test crew and by professional members of the Research Council's staff, was cut short by the opening of the section of I-64 on which the lights were installed. After a review of the limited number of test results and consultations, a recommendation for spacing and intensities was made.

It was recommended that a $\frac{1}{2}$-half mile section of lights be installed in the eastbound lane of I-64 in Augusta County on Afton Mountain from milepost 27.90 to milepost 28.40.

Daylight intensity of the lights will be 30% maximum and night intensity will be 10% maximum. At these intensities good delineation is afforded without undue glare.

It has been adjudged that this $\frac{1}{2}$-mile section is necessary to provide information for deciding whether the lights should be installed on the entire 6-mile section of I-64 spanning Afton Mountain. In the event that the 6-mile section is recommended at a later date the design of this half-mile section will be compatible and this shorter installation can be connected directly to it.

No results or recommendation are included for the low level illumination lights since not enough testing has been performed to allow any valid judgment on their effectiveness.

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GENESIS OF STUDY

This study came about as a result of a request from the Maintenance Division to J. H. Dillard, Head of the Research Council, that an investigation be made to determine if any practical fog abatement or lighting methods had been developed. A short study entitled "Fog — A Review of the Literature Pertaining to Highway Problems and Possible Solutions" was undertaken, and it was found that:

"1. Fogs are significant contributors to multiple car accidents that often result in fatalities.

2. Neither systems that adequately abate fogs nor lighting systems that provide minimum visibility requirements have evolved.

3. Most abatement techniques stem directly from methods used at airports.

4. It is very improbable that a lighting system can be designed that will produce a visibility level equal to the before fog condition.

5. Fog abatement techniques have not progressed to the point that they are feasible for highway use.

6. Of the several lighting systems cited in the literature, the two that appear to hold the most promise are:

   a. A lineal guidance system employing lights inset into the pavement, and

   b. A low level lighting system."[1]

The report on this short study was presented to the Maintenance Research Advisory Committee, and it was decided that further study would be initiated to test the two aforementioned lighting systems. It was further decided that the funding of the study would be a joint venture with the Maintenance Division providing the equipment and the Research Council providing the personnel.

PURPOSE

The purpose of the study is to evaluate the two lighting systems discussed in the literature review. In the case of the lineal lighting system, it will be determined if lights inset into the pavement edge will produce sufficient guidance to keep motorists from getting lost in heavy fog and provide enough light to outline the pavement edge so as to allow them to maintain control of their vehicles and keep them on the road. Also to be determined is whether snowplowing will remove the lights from the pavement surface or severely damage them. For the preliminary investigation of damage only, two lights have been installed in the pavement and will be observed this winter.

In the case of the low level lighting system, luminares mounted at low elevations (12 feet or less) will be evaluated to determine if driver sight distance can be significantly increased.

EQUIPMENT AND INSTALLATION

Lineal Guidance System

The following paragraphs describe the equipment used in the lineal guidance system. Because of the uniqueness of the equipment for highway usage, description as well as photographs of each part are given.

Unidirectional Airport Runway Lights

Lighting in the test system is supplied by 10 unidirectional airport runway light assemblies. The assemblies are weatherproof units containing a 200 watt, 6.6 ampere, long life, quartz filament lamp, a reflector, prism and electrical contacts. The entire assembly is contained in a ductile iron casting which is fastened to the base receptacle by 6 bolts and is sealed with a rubber O ring. The light assembly is 12 inches in diameter, 3.5 inches deep, and weighs approximately 50 pounds. Figure 1 is a close-up of the light assembly. Note the 2-pole electrical connection that plugs into a L 834 transformer. The light assembly, when installed, is essentially flush with the pavement, but the sloped dome juts approximately $\frac{1}{4}$-inch above the surface. The manufacturer has given assurance that the lights will withstand snowplowing; two lights have been installed in I-64 on Afton Mountain to determine if this assurance is warranted (see Figure 2).

Transformers

The electrical system is wired in series, so when one light burns out the whole system ceases to function. This problem is solved by using an L 834 transformer with each light. Upon activation, the current flows through the transformer and bypasses the open circuit caused by the bulb being burned out, thus allowing the system to continue functioning. Figure 3 shows the transformer and its electrical connections. In the center is a receptacle that connects to the runway light plug shown in Figure 1. The single connectors (one male and one female) tie in with the balance of the system. Figure 4 shows the light assembly and transformer hooked up.

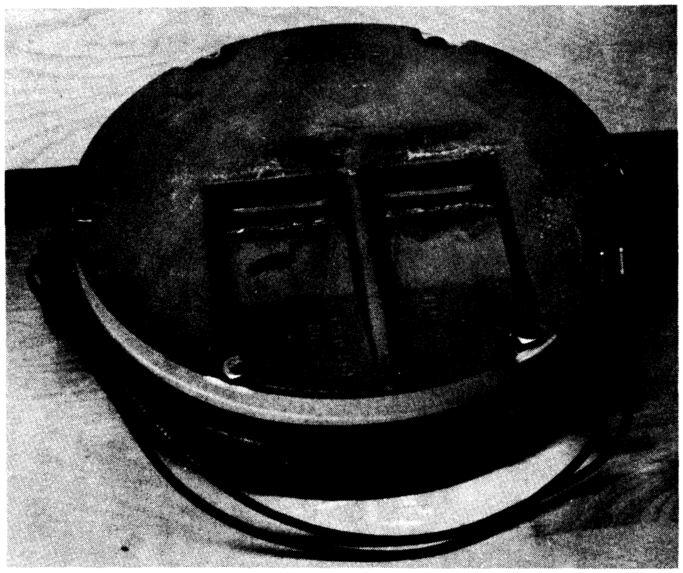

Figure 1. Close-up of unidirectional light.

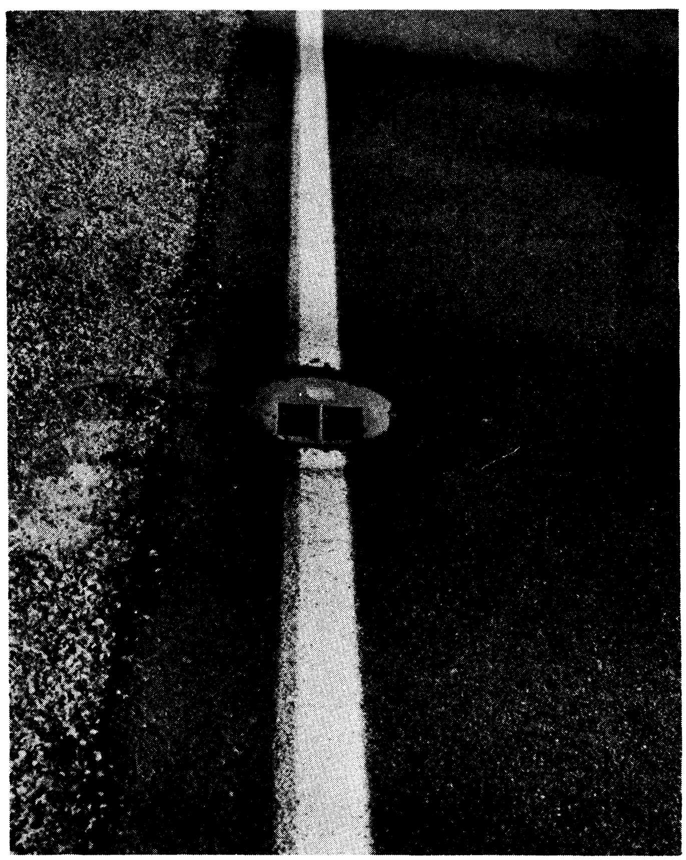

Figure 2. Unidirectional light mounted in pavement.

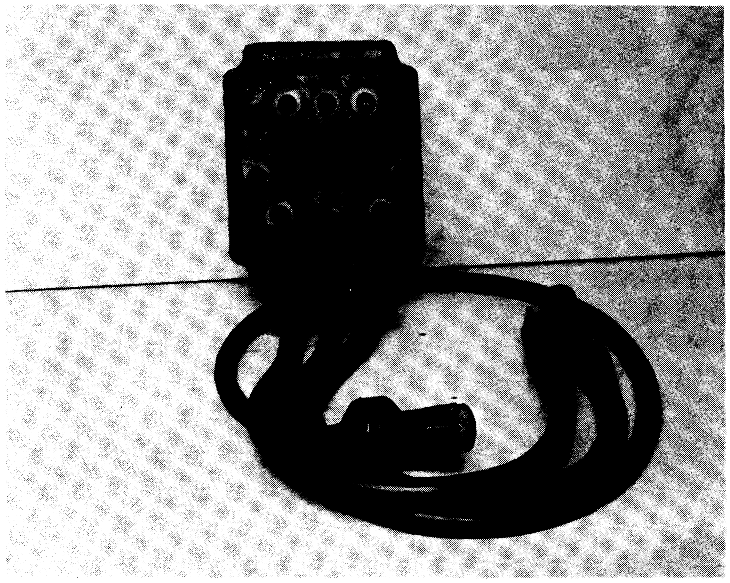

Figure 3. L 834 transformer used with runway light.

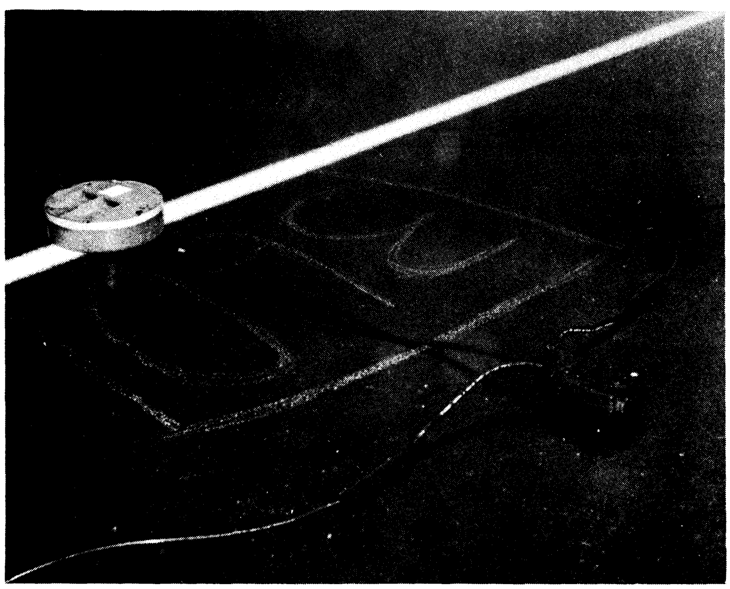

Figure 4. Pavement light transformer.

Constant Current Regulator

An integral part of the system is a constant current regulator. The regulator is designed to control the intensity of the lights within the range of brightness required for operation under various conditions of visibility. Illumination intensity is adjusted by a "brightness selector" switch. The regulator is a static type, constant current device for direct control of a 6.6 ampere series load. It is designed to supply output currents of 6.6, 5.5, and 4.8 amperes. A change in output current is accomplished by setting the "brightness control" switch at 100%, 30%, or 10%. Figure 5 displays the control panel of the regulator. The runway control power switch is the master switch that activates the output system. The only other switch used for the experiment was the aforementioned brightness selector switch. Figure 6 shows the entire regulator.

Figure 5. Control panel for constant current regulator.

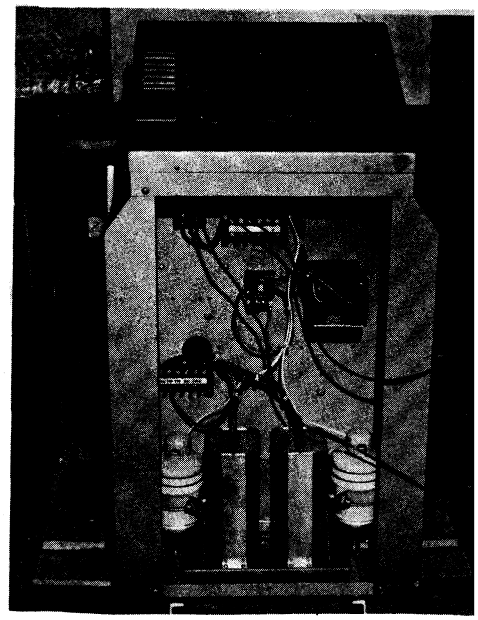

Figure 6. Constant current regulator with front panel removed.

Power Source

In the experiment, the pavement lights are powered by a 208-240 volt alternating current portable generator rated at 10 kilowatts. (The Virginia Department of Highways had purchased 30 such power units for other purposes and one was made available for this experiment.) The maximum power requirements for the pavement lights are 240 volts and 10 amperes, which may be varied by the constant current regulator.

Luminares Mounted at Low Elevations

In a study done in 1960 by Dr. D. E. Spencer,(2) it was determined that visibility (sight distance) could be increased by the use of specially designed luminares mounted with their bases $2\frac{1}{2}$ feet in height and the cutoff plane rotated 4.15° below horizontal to keep the blanket of illuminated fog as thin as possible, and by rotating the cone of illumination 110° to the center line of the road in the direction of travel. From that study it was determined that a lighting system for use in fog should have the following attributes:

1. The volume of illuminated fog between the driver and the road should be small.
2. the light that must traverse this volume of fog should do it at angles to the driver's vision that produce the minimum light scattering, and
3. direct glare sources should be minimized.

For this present study, 500-watt, lightweight, weatherproof, quartz floodlights featuring wide horizontal and narrow vertical beam spread are being employed. Figure 7 is a close-up photograph of the light fixture, including a special mount designed by the Research Council.

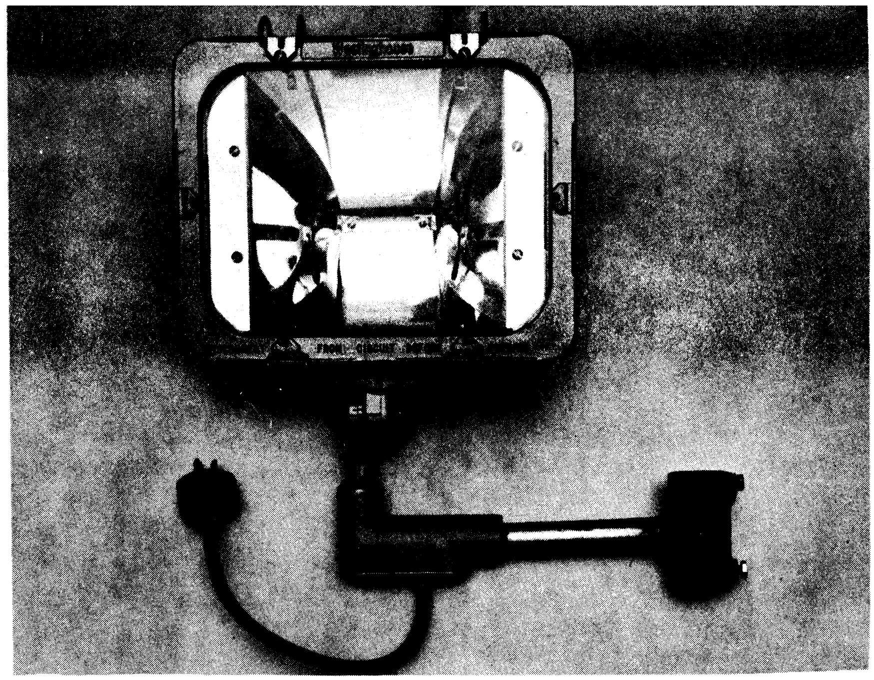

Figure 7. 500-watt quartz floodlight.

The horizontal length (width) is $10\frac{1}{4}$ inches, the height 8-1/8 inches, and the thickness $5\frac{1}{2}$ inches. The 500-watt quartz iodine lamp is powered by a 120-volt system. The horizontal beam spread is 80.4° and the vertical spread is 19.0°, however the vertical spread is limited by the cutoff. The floodlight produces 5,184 lumens and an average maximum candlepower of 42,250.

A special mounting standard consisting of a 1-inch diameter galvanized pipe 12 feet in length, welded to an automobile wheel, and graduated in $\frac{1}{2}$-foot lengths was fabricated at the Research Council. The mounting arm on the light (Figure 7) slips over the top of the standard and may be adjusted to any height. Figure 8 shows the mounting assembly. The guy wires seen on the assembly were added when it was found that strong gusts of wind tipped the standard over.

Power for the lights is furnished by the generator used with the inset lights and the electrical hookup consists of wires run along the ground with receptacles similar to wall sockets spaced 30 feet apart. From each light, a drop cord 15 feet in length is attached to make the connection.

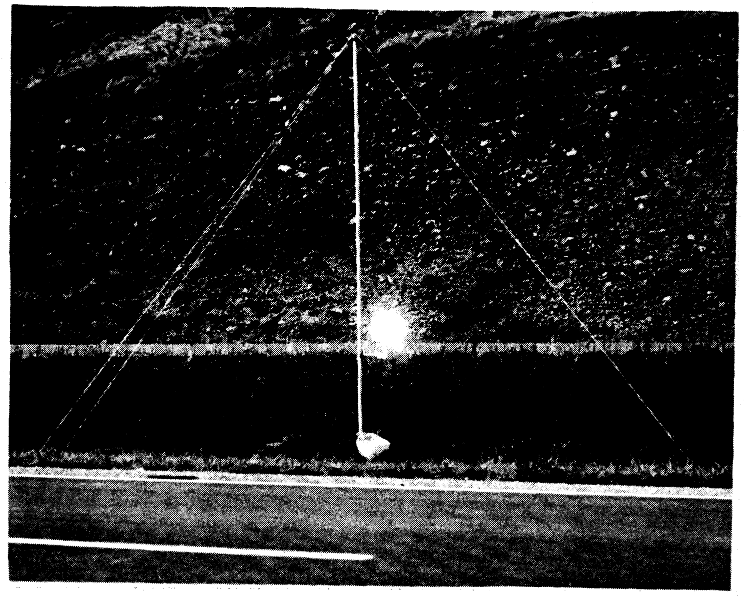

Figure 8. Mounting assembly for floodlights consists of 12-foot pipe welded to automobile wheel, guy wires, sand bags, and specially designed arm on light. The luminare is lighted.

PROBLEMS ENCOUNTERED IN STUDY

The major problem associated with the study so far was that the equipment was not received until November. By the middle of November, when the final troubleshooting and adjustments to equipment had been accomplished, the heavy fog season was over. The foggy conditions in the winter are often caused by low-lying clouds which tend to move before equipment can be set up and testing begun. A further problem was that equipment had to be removed from the test site after each test period for fear of theft and vandalism. The final problem was brought about by the opening of the Afton Mountain section of I-64, where the test site was located, in the latter part of December. The author believed it inadvisable to continue testing after the road was opened to traffic due to the danger to the traveling public and test personnel. Adequate test sites are very difficult to locate.

METHODOLOGY

In keeping with the purpose of the study and the working plan, the experiment was designed to determine the optimum intensity and spacing* for the lineal guidance

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*Refer to Glossary for definition of terms.

lights and the optimum spacing and height for the low level illumination lights. Figure 9 shows the test layout for both types of lighting. The wiring is so designed to allow various spacings and the constant current regulator, located in the mobile home, allows the intensity of the runway lights to be varied. The intensity of the quartz floodlights cannot be varied. Figure 10 is a schematic diagram of the test course and the lighting arrangement for the lineal guidance system.

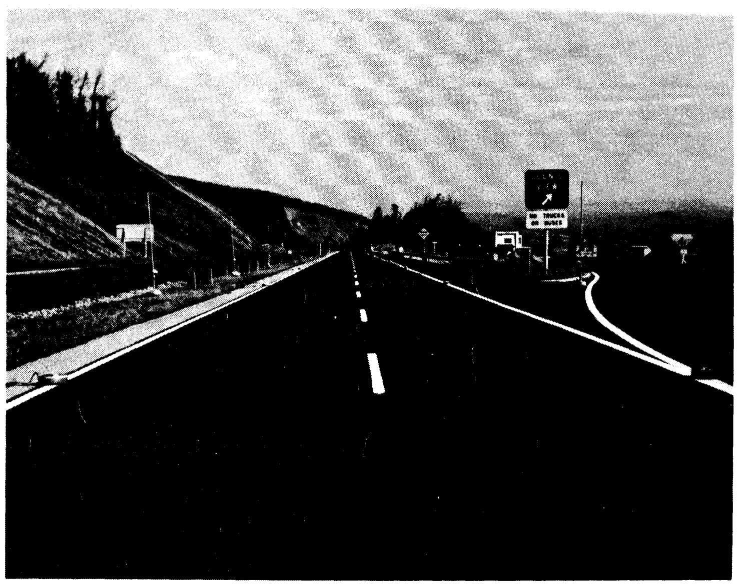

Figure 9. Test site with lights in place.

To test the pavement inset lights the spacings between light centers were varied from 50 feet to 300 feet and the intensities were varied from 10% brightness to 100% brightness. From these two variables, an optimum combination was determined.

To determine the optimum spacing and intensity for the lights, it was planned that test subjects would be driven through the experimental installation. However, after some very basic experimentation, cut short by the opening of the road to the public, it became clear to the author and other persons involved that the lights were definitely a driving aid and that they were subject to negligible damage from snowplows. On the basis of these opinions, and because of the urgency of the work and the near impossibility of finding another suitable test site in the area this phase of testing was concluded. Consequently, photographic evidence of the performance of the lights was gathered as a basis for consultations with Highway Department officials as to the next step in the study.

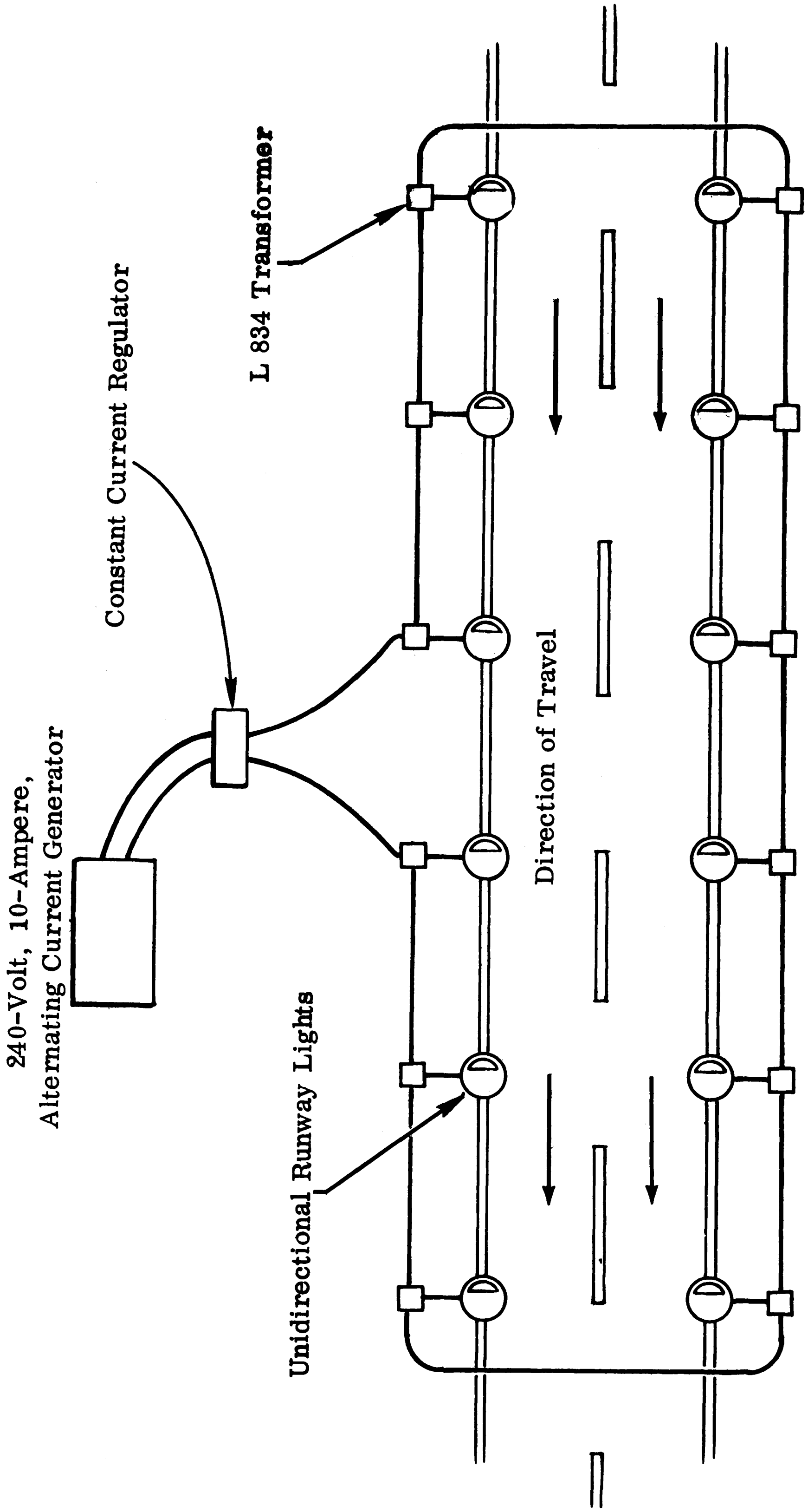

Figure 10. Diagram of lineal guidance system.

For the low level lights optimum mounting heights, proper aiming of the luminaires, and the best cutoff angle will be determined.

RESULTS

Pavement Inset Lights

After a limited amount of testing, cut short due to the opening of the road to the public, the pavement inset lights were adjudged by the author and others active in the experiment to be an excellent means for delineating the edges of a highway. The tests, as previously mentioned under Methodology, consisted of varying the spacings between the lights and the intensity of the lights. The optimum spacing was determined to be 200 feet and the optimum intensity for daylight to be 30% of the maximum, or 123 watts, and the optimum night intensity to be 10%, or 84 watts. (Since less testing was performed than was desirable, three different spacing patterns are recommended in a later section of the report.)

Figure 11 shows the lights in heavy fog during daylight, and although 3 lights on each side (a distance of at least 300 ft.) can be seen, the photo does not actually reproduce the helpful effect that occurs when comparing the situations with the lights on and off.

In the snowplowing portion of the experiment, approximately 12 runs were made across the light in plowing for one snow and an additional 10 runs were made over it on bare pavement. The appearance of the light after these two experiments can be seen in Figures 12 and 13. It may be observed from the photographs that a slight shaving of the dome metal occurred during the snowplowing. More shaving of metal occurred, as was to be expected, while plowing on bare pavement than occurred when plowing with snow on the road. Figure 14 shows the snowplow traveling at 30 mph with the blade in contact with the light.

Figure 11. Runway lights spaced 120 feet apart in heavy fog.

Figure 12. Unidirectional light after plowing for one snow with carbide blade equipped snowplow.

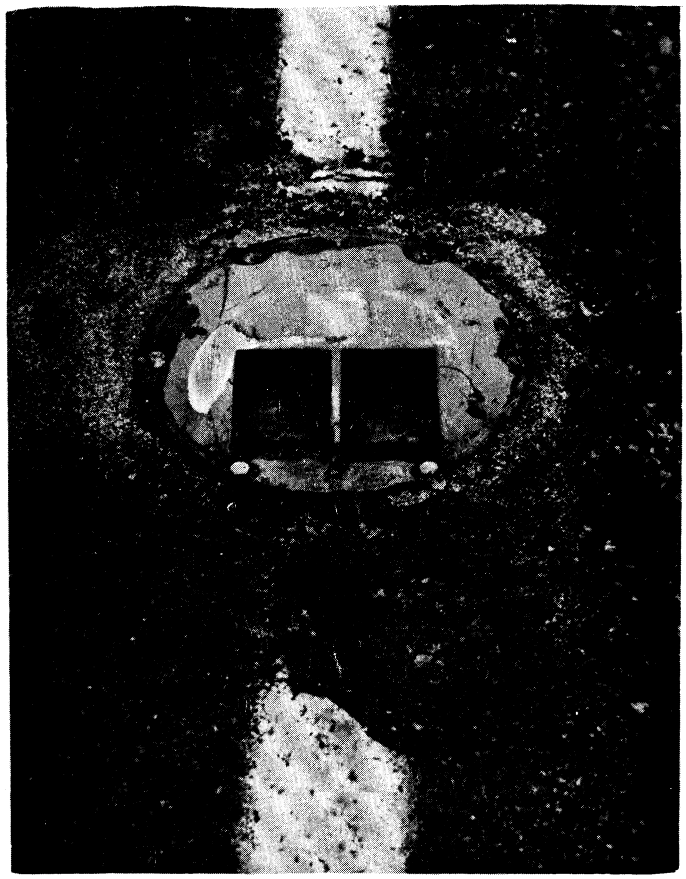

Figure 13. Light after being snowplowed during one snow and repeated snowplow tests on bare pavement — slight shaving may be noted.

Figure 14. Moving snowplow blade in contact with light on bare pavement.

RECOMMENDATION

The author met with personnel of the Maintenance Division, Equipment Division, and the Research Council to discuss in detail the results of the tests. Discussed were costs, installation problems, maintenance, etc. This group recommended that a permanant installation of the pavement inset lights using fixed commercial electrical power be installed on the traveled portion of roadway in the eastbound lane of I-64, approximately from milepost 27.90 to milepost 28.40. The group recommended that the lights be installed on both edges of the road in line with the edge line markings and at spacings as in Table 1.

Table 1

Light Configuration for $\frac{1}{2}$-Mile Experimental Test Section in the Eastbound Lane of I-64 in Augusta County

Milepost		Spacing in Feet	Total Distance at this Spacing in Feet	Number of Lights Required at this Spacing
From	To			
27.90	28.04	250	750	6
28.04	28.31	200	1,400	14
28.31	*28.40	100	500	10

*Beginning of deceleration lane to Rt. 250.

The equipment for the installation has been ordered and will be installed by state forces. It is expected that the work can be accomplished by June 1, 1973.

Triggering of the light system will be by the fog-sensing device that actuates the fog warning sign now in place on the roadway section selected. The daylight intensity of the lighting will be 30% of the maximum of the unit with an output of 2,250 candelas and a hot spot of 3,600 candelas. For night lighting, where contrast is greater between light and darkness, the intensity setting will be 10% of maximum, which produces an output of 750 candelas with a hot spot of 1,200 candelas. At the 30% setting, the light burns at 123 watts of power, and at the 10% setting, at 84 watts. The average life of the bulb at the 30% setting is 7,500 hours, with a range from 5,000-10,000 hours. These settings can be accomplished automatically by a photoelectric cell and the constant current regulator, the latter of which is an integral part of the system.

The $\frac{1}{2}$-mile section is necessary to provide information for a recommendation on whether to install the lights on the entire 6 miles of I-64 spanning the mountain. It may be desirable to partially redesign the light assembly to make it even more immune to snowplowing, although the only effect observed on the lights after repeated passes with a snowplow on bare pavement was a slight shaving of metal from the dome. The light itself was not damaged. In tuning this small system the intensities may need to be adjusted slightly. The design of this $\frac{1}{2}$-mile section will be compatible with a larger system and should the larger installation be recommended later this system will plug directly into it.

No results or recommendations are included for the low level illumination lights since not enough testing has been performed to allow any valid judgment on their effectiveness. In keeping with the desire of the Maintenance Division, these lights will be tested. The Metropolitan Transportation Division is going to install continuous lighting in the guardrail on a long bridge in Norfolk, and consideration should be given to using this as a fixed test site for the low elevation lights.

COST DATA

For $\frac{1}{2}$-Mile Section in One Direction

The equipment necessary for the $\frac{1}{2}$-mile and 6-mile installations is listed in Tables 2 and 3. Under items 1, 3, and 9 of Table 2 what appears to be a shortage of equipment is compensated for by usage of equipment purchased for prior testing. Under item 1 the requirement is for 2 regulators and the Research Council has 1; for item 3 the requirement is for 30 lights and the Council has 10 usable ones; and for item 9 the requirement is for 30 transformers and the Council has 12.

Table 2

Equipment for ½-Mile Section

Item No.	Description	Quantity	Price Each	Total
1	L-811 Regulator - 4 KW 240 VAC input	1	$775.00	$ 775.00
2	L-824 C #8 Standard Wire	6,000 ft.	690.00	690.00
3	Lights — L-850 BS-M	20	100.00	2,000.00
4	1000 B Cover Plate	30	7.20	216.00
5	4420-M Transformer Housing	30	16.65	499.50
6	2052 Gaskets	30	1.00	30.00
7	54-B6-B6 Connector Kit (Primary)	30	4.10	123.00
8	90PS6 Connector Kit	30	3.50	105.00
9	200 Watt Transformer	18	28.80	518.40
10	Shipping Charges for above material			150.00
11	Installation Fixtures for L-850AS-M	5	N/C	
	Conduit and Installation (installation by state forces)			7,500.00
	Overhead and Miscellaneous			2,000.00
			Total Cost	$14,606.90

Table 3

Equipment for 6-Mile Section in Both Directions

Item No.	Description	Price	Total
1	624 Lights	$63,000	
2	Regulators	24,000	
3	Transformers	25,000	
4	No. 8 Standard Wire	24,000	
5	Conduit	24,000	
6	Handholds	16,000	
			$176,000
	Miscellaneous Items and Overrun		24,000
	Installation Costs (labor)		130,000
	Overhead		30,000
		Total	$360,000

Note: Installation cost data for the above section were taken from airport installation records.

GLOSSARY

CANDELA.	The unit of luminous intensity; one lumen per unit solid angle (steradian). 1 candela per square inch = 452 footlamberts.
CANDLEPOWER.	Luminous intensity in a specified direction expressed in candelas. It is no indication of the total light output.
FOOTCANDLE.	The unit of illumination when the foot is the unit of length; the illumination on a surface one square foot in area on which is uniformly distributed a flux of one lumen. It equals one lumen per square foot.
FOOTLAMBERTS.	The unit of photometric brightness (luminance) equal to 1 candela per square foot. A theoretical perfectly diffusing surface emitting or reflecting flux at the rate of one lumen per square foot would have a photometric brightness of one footlambert in all directions. No actual surface completely fulfills this condition.
LUMEN.	The unit quantity of light output. It is defined as the amount of light which falls on an area of one square foot, every point of which is one foot distant from a source of one candela. A uniform source of light of one candela emits a total of 12.57 lumens but for practical purposes is taken as a 1-to-10 ratio.
SPACING.	The distance in feet between successive lighting units measured along the center line of a street.

ACKNOWLEDGEMENTS

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G. N. Garrison, furnishing personnel.

John Stulting, fabrication of equipment.

P. D. Hughes, photography.

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