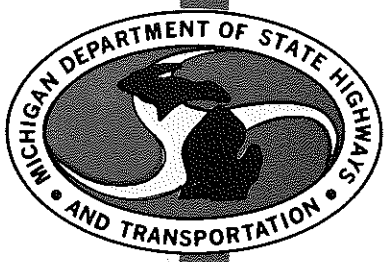
1102

TRAFFIC SIGNAL DIMMING METHODS



TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

TRAFFIC SIGNAL DIMMING METHODS

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Dimming circuits have been in use to reduce nighttime vehicular signal glare. Dimming circuits can also provide an added benefit of reducing energy consumption. However, dimming by reducing the effective voltage to a lamp does affect signal lens color and intensity. Measurements of signal lens color, transmission, and intensity while the lamp was operating on each of three dimming circuits were compared with measurements obtained at a standard 120 v.a.c. and with MDSHT requirements for 12-in. and 8-in. lenses.[1] Lens color and transmission were satisfactory for signal operation on each of the dimming circuits. However, lens intensity measurements did not conform with requirements for either 12-in. or 8-in. signal lenses. Lumen output of a 12-in. signal lamp vs. voltage and efficiency of the dimming circuits have been included for information.

The study was initiated at the request of D. E. Orne, Engineer of Traffic and Safety in a May 25, 1978 memo to K. A. Allemeier. On June 13, 1978, L. A. Tiedeman forwarded the three dimming circuits, a 12-in. traffic signal optical, a 150-watt ASA type P25 clear lamp and three 12-in. diameter lenses (red, yellow, and green). The three dimming circuits as shown in Figure 1 were:

1) a diode circuit which yielded half-wave rectification,
2) a 3M brand proportional automatic intensity control, photocell activated, phase-controlled switch,
3) a 'bucking' transformer.

Color and Intensity Measurements

Color including transmittance of each lens was measured using the 150-watt lamp operating from each of the three dimming circuits and also operating on a standard 120 v.a.c. circuit. Intensity distributions were measured using a standard lamp operating on the various circuits.

Red Lens - The lens color was within specified limits with the signal lamp operating on each of the four circuits. Relative luminous transmittance exceeded the 9.5 percent specified minimum with the signal lamp operating on each of the four circuits. Values are given in Table 1.

The lens failed the intensity (candela) distribution specification minima for 12-in. lenses for each of the three dimming circuits and for the stand-

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[1] MDSHT requirements for 12-in. intensity distribution are the same as the Institute of Traffic Engineers' Standard for Adjustable Face Vehicle Traffic Control Signal Heads, January 1976. MDSHT requirements for 8-in. intensity distribution are 80 percent (due to aluminum reflector) of the Institute of Traffic Engineers' Standard for Adjustable Face Vehicle Traffic Control Signal Heads, January 1976.

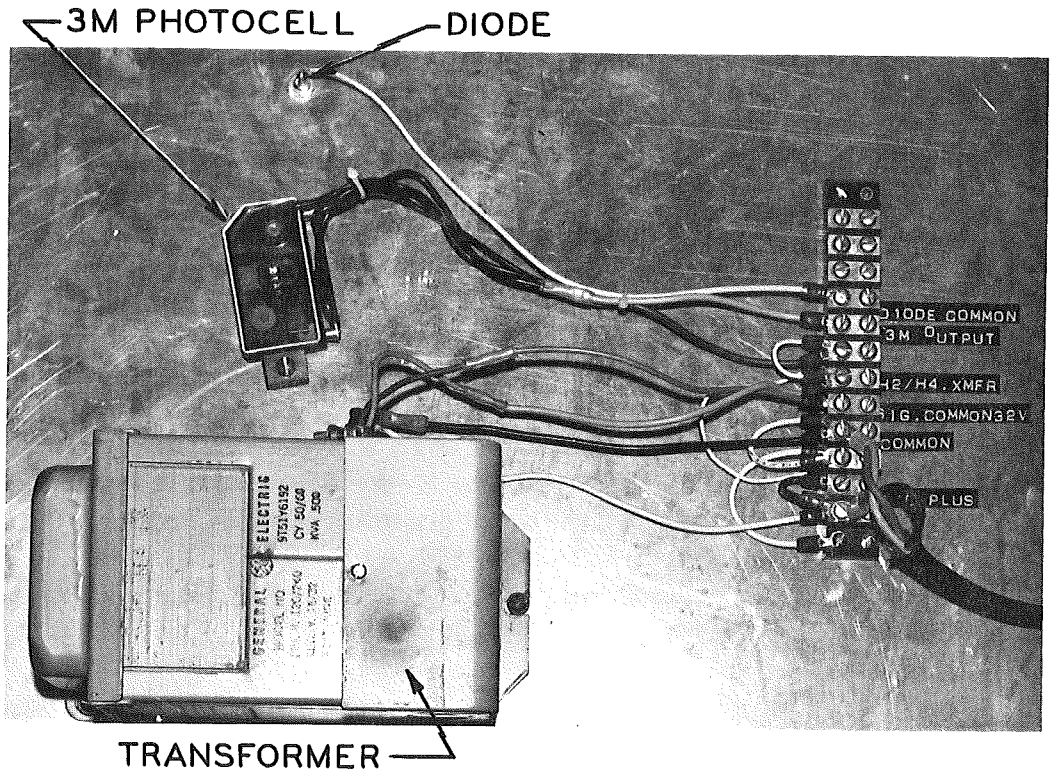

Figure 1. Three traffic signal dimming circuits.

TABLE 1
LENS TRANSMISSION

Circuit	Transmittance, percent		
	Red Lens	Yellow Lens	Green Lens
MDSHT Specified Minimum	9.5	44.0	20.0
Standard 120 v.a.c.	11.4	64.8	17.0
Diode Dimming	13.7	69.0	15.4
3M Dimming	13.1	65.0	14.0
Transformer Dimming	12.0	61.9	13.8

dard 120-v input. The intensity distribution of the red lens, Table 2, exceeded the specification for 35 of 44 test locations using the nominal 120-v circuit, but was below the specified minimum in almost all locations for the three dimming circuits. The red lens intensity distribution with the dimming circuits also failed to meet specifications for 8-in. signals, Table 3.

Yellow Lens - The lens color was within specified limits with the signal lamp operating on each of the four circuits. Relative luminous transmittance exceeded the 44.0 percent specified minimum with the signal lamp operating on each of the four circuits. Values are given in Table 1.

The intensity distribution of the yellow lens was slightly below the specified minimum for 12-in. lenses in two of the 44 total test locations, Table 4, with the signal optical operating at the standard 120-v input. The intensity distribution obtained from each of the dimming circuits failed to meet the 12-in. lens and 8-in. yellow lens specifications; however, the diode and transformer dimming circuits resulted in an intensity distribution only slightly below the 8-in. lens specification minima. The 3M dimming circuit adjusted to operate at its lowest output (with photocell covered) resulted in an intensity distribution well below the minima specified for 8-in. lenses (Table 3).

Green Lens - The lens color was within the specified limits with the signal operating on each of the four circuits. Relative luminous transmittance did not meet the 20 percent specified minimum with the signal lamp operating on any of the four circuits. Values are shown in Table 1.

The intensity distribution of the green lens, Table 5, was below the specified minimum for 12-in. lenses in nine of the locations using the standard 120-v input circuit. The lens intensity values for the dimming circuits all were below specification limits for both 12 and 8-in. lenses (Table 3).

Circuit Characteristics

The dimming circuit characteristics were determined by electrical measurements using rms meters and an oscilloscope (Fig. 2), and also by comparing signal lamp lumen output. Results of the electrical measurements are shown in Table 6. For comparison purposes the 3M circuit photocell was only partially covered to produce 86.5 v at the signal lamp comparable to the voltage output of the other two circuits.

The diode, transformer, and 3M circuit (photocell completely covered) and the 3M circuit (photocell partially covered) each showed an approximate 2, 9, 16, and 14-watt loss, respectively, within the circuit.

Manufacturers standard rated lumen value for the 12-in. signal lamp is 1,950 lumens. We measured 1,632 lumens on the lamp supplied, which is typical for off-the-shelf lamps. While varying the input voltage to the lamp from 70 to 120 v.a.c., the lumen output was obtained and the values are shown in Table 7 and Figure 3. The lamp lumen output was also measured with the lamp operating on each of the three dimming circuits. These values are also shown in Table 7 and Figure 3. An equivalent lamp voltage based on lumen output was calculated for each of the dimming circuits and is shown in Table 7.

Since intensities obtained with the 12-in. signals operating on the dimming circuits were compared with intensity requirements for 8-in. signals it can be noted from Figure 3 that a 12-in. (1,950 lumens) signal lamp would have to operate at not less than 90 v in order to equate to the standard 8-in. signal. The standard 8-in. signal lamp produces 655 lumens, 34 percent of the 12-in. signal lamp at the nominal 120-v input.

In an FHWA report on traffic signals the author referred to dimmed signal circuits operating at 70 v.[2] References are not given, but it does indicate that 12-in. signals, for example, could be operating at 70 v. If this were the case the 12-in. signal at 70 v would be operating at approximately 1/3 the intensity of an 8-in. signal at 120-v input. The FHWA report also shows that the color temperature of a 15-watt lamp operating at 70 v approaches 2,150 K and at 90 v, 2,350 K. Current limits for signal colors are based on a lamp color temperature range of 2,350 to 2,850 K.

Lamp color temperature is affected by lamp voltage changes, the lower the voltage the more red emitted by the lamp. The effect on a red lens is minimal, the yellow lens appears more amber and the green lens appears darker. The net effect is that the intensity ratio of the red to green lens changes and that change could affect those drivers having color deficient vision.

The circuits have been evaluated in the laboratory and the evaluation results warrant further study by traffic signal engineers. If it can be assumed that, in general, the operation of an 8-in. signal is satisfactory then equivalent performance could be obtained from a 12-in. signal operating at not less than 90 v.

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[2] King, D. F., "Development of Standards and Tests for Acceptance of Traffic Signal Lenses," U. S. Department of Transportation, Report No. FHWA-RD-77-93, November 1977.

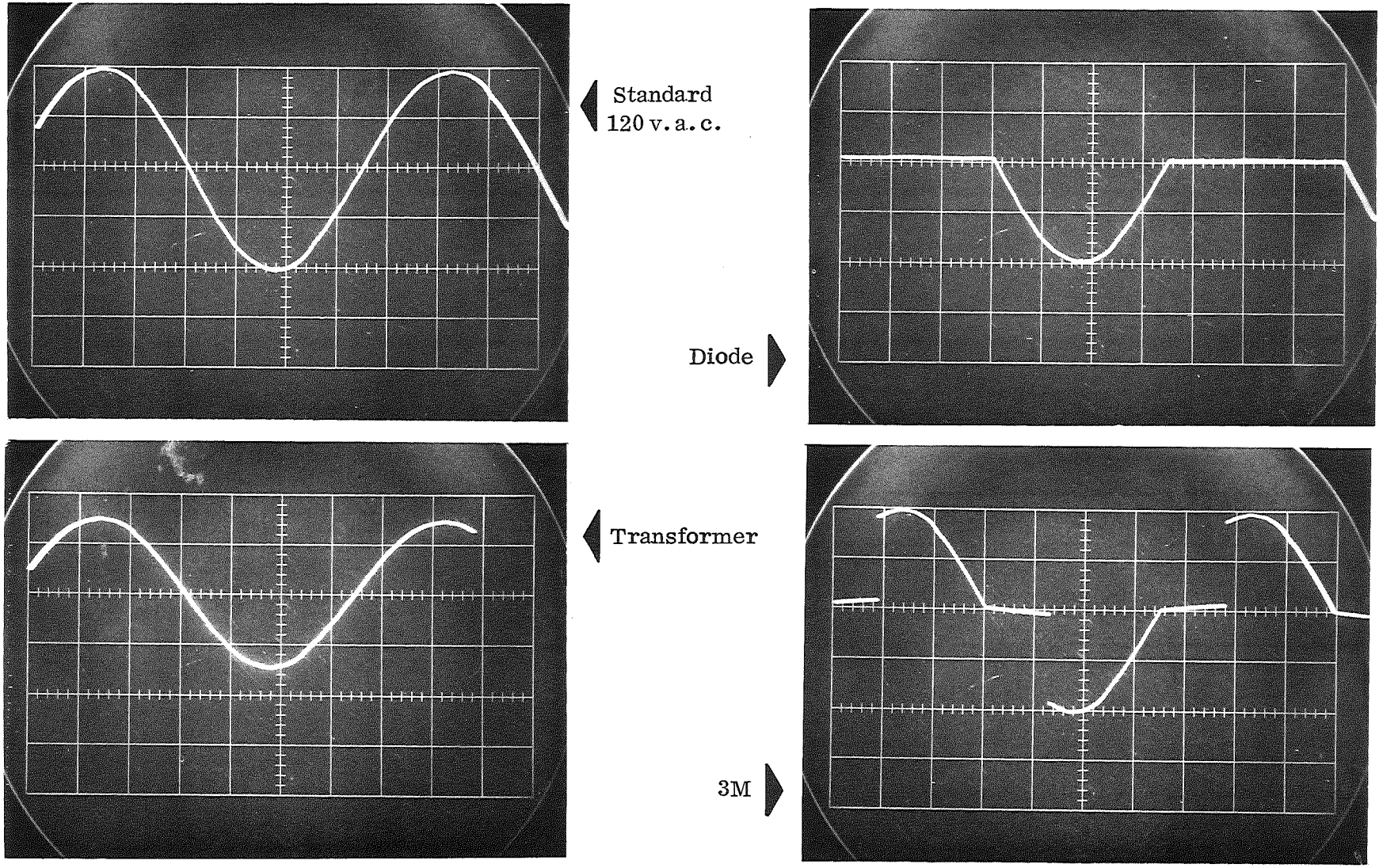

Figure 2. Voltage output of standard 120 volt circuit and of the three dimming circuits.

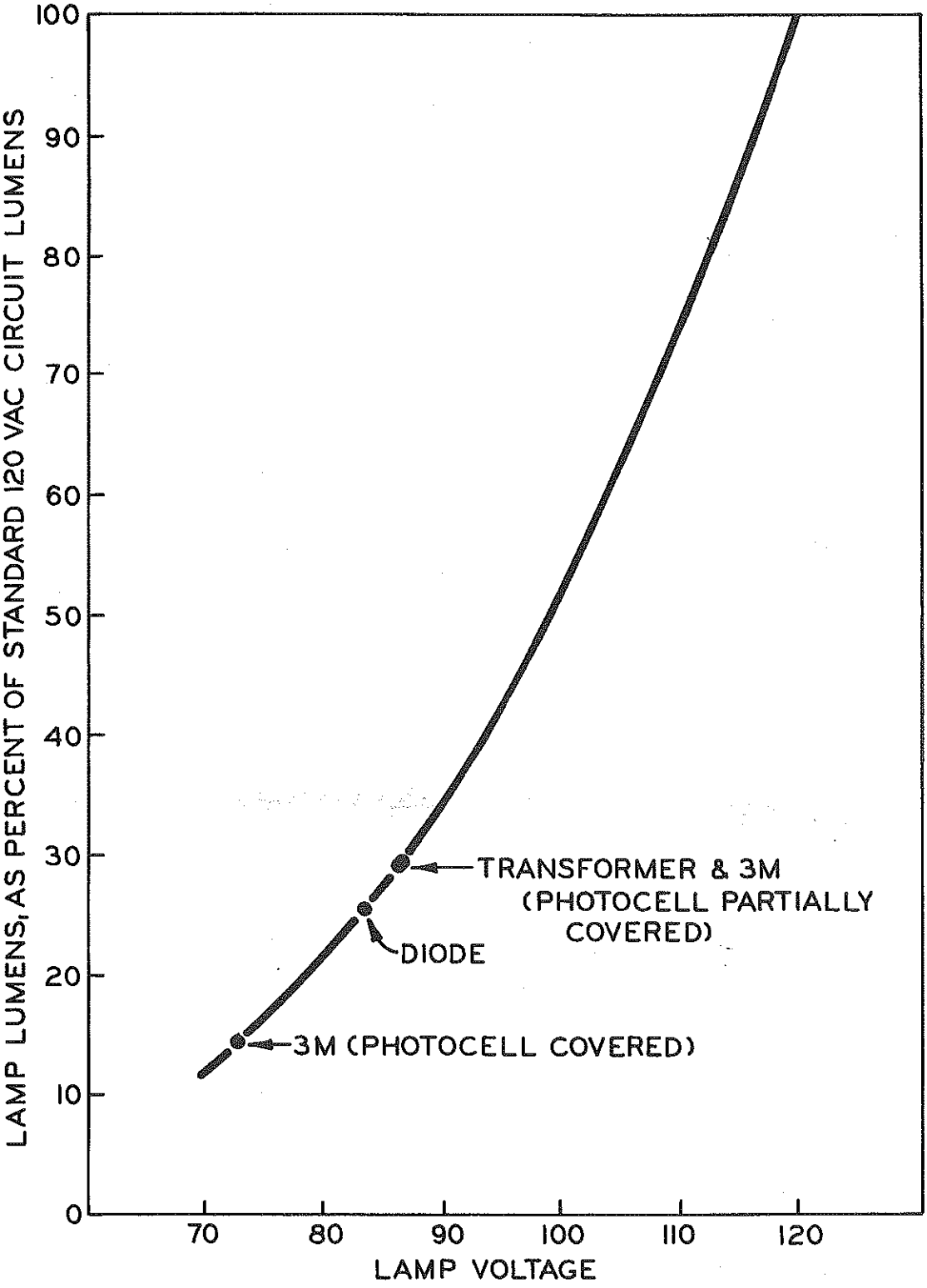

Figure 3. Effect of lamp voltage on lamp lumens.

TABLE 2
TWELVE-INCH RED LENS INTENSITY DISTRIBUTION IN CANDELA
(Values in parentheses are below specified minimum)

Circuit	Vertical Angle, degrees down	Horizontal Angle, degrees											
		Left						Right					
		27-1/2	22-1/2	17-1/2	12-1/2	7-1/2	2-1/2	2-1/2	7-1/2	12-1/2	17-1/2	22-1/2	27-1/2
Specification Minima	2-1/2			90.2	166.0	295.0	399.0	399.0	295.0	166.0	90.2		
	7-1/2	19.0	45.1	104.0	171.0	238.0	266.0	266.0	238.0	171.0	104.0	45.1	19.0
	12-1/2	19.0	26.1	40.4	52.3	57.0	59.4	59.4	57.0	52.3	40.4	26.1	19.0
	17-1/2	19.0	23.8	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	23.8	19.0
Standard 120 v.a.c. Circuit	2-1/2			179.0	220.0	317.0	(288.0)	(289.0)	(282.0)	210.0	168.0		
	7-1/2	69.2	106.0	137.0	(166.0)	(200.0)	(216.0)	(214.0)	(196.0)	(168.0)	136.0	105.0	63.4
	12-1/2	42.5	54.4	72.4	87.5	100.0	110.0	110.0	103.0	91.1	76.4	59.8	45.7
	17-1/2	28.8	34.9	40.5	45.2	54.0	54.4	55.5	51.9	46.3	42.0	35.1	30.1
Diode Dimming Circuit	2-1/2			(52.4)	(64.4)	(92.7)	(84.3)	(84.6)	(82.5)	(61.4)	(49.2)		
	7-1/2	20.2	(31.0)	(40.1)	(48.6)	(58.5)	(63.2)	(62.6)	(57.3)	(49.2)	(39.8)	(30.7)	(18.5)
	12-1/2	(12.4)	(15.9)	(21.2)	(25.6)	(29.2)	(32.2)	(32.2)	(30.1)	(26.6)	(22.4)	(17.5)	(13.4)
	17-1/2	(8.4)	(10.2)	(11.8)	(13.2)	(15.8)	(15.9)	(16.2)	(15.2)	(13.5)	(12.3)	(10.3)	(8.8)
3M Dimming Circuit	2-1/2			(30.4)	(37.4)	(53.8)	(48.9)	(49.1)	(47.9)	(35.7)	(28.5)		
	7-1/2	(11.8)	(18.0)	(23.3)	(28.2)	(34.0)	(36.7)	(36.4)	(33.3)	(28.5)	(23.1)	(17.8)	(10.8)
	12-1/2	(7.2)	(9.2)	(12.3)	(14.9)	(17.0)	(18.7)	(18.7)	(17.5)	(15.5)	(13.0)	(10.2)	(7.8)
	17-1/2	(4.9)	(5.9)	(6.9)	(7.7)	(9.2)	(9.2)	(9.4)	(8.8)	(7.9)	(7.1)	(6.0)	(5.1)
Transformer Dimming Circuit	2-1/2			(60.3)	(74.1)	(107.0)	(97.0)	(97.4)	(95.0)	(70.8)	(56.6)		
	7-1/2	23.3	(35.7)	(46.2)	(55.9)	(67.4)	(72.8)	(72.1)	(66.0)	(56.6)	(45.8)	(35.4)	21.4
	12-1/2	(14.3)	(18.3)	(24.4)	(29.5)	(33.7)	(37.1)	(37.1)	(34.7)	(30.7)	(25.7)	(20.2)	(15.4)
	17-1/2	(9.7)	(11.8)	(13.6)	(15.2)	(18.2)	(18.3)	(18.7)	(17.5)	(15.6)	(14.2)	(11.8)	(10.1)

TABLE 3
SPECIFICATION INTENSITY DISTRIBUTION IN CANDELA
FOR 8-in. TRAFFIC SIGNAL LENSES

Lens	Vertical Angle, degrees down	Horizontal Angle, degrees											
		Left						Right					
		27-1/2	22-1/2	17-1/2	12-1/2	7-1/2	2-1/2	2-1/2	7-1/2	12-1/2	17-1/2	22-1/2	27-1/2
Red	2-1/2			22.7	54.0	94.4	125.6	125.6	94.4	54.0	22.7		
	7-1/2	9.5	17.1	38.0	60.8	83.2	95.2	95.2	83.2	60.8	38.0	17.1	9.5
	12-1/2	7.6	11.4	19.0	26.4	31.2	34.2	34.2	31.2	26.4	19.0	11.4	7.6
	17-1/2	3.8	5.7	7.6	9.5	13.2	15.2	15.2	13.2	9.5	7.6	5.7	3.8
Yellow	2-1/2			105.0	246.0	422.0	581.0	581.0	422.0	246.0	105.0		
	7-1/2	44.0	79.2	176.0	282.0	387.0	440.0	440.0	387.0	282.0	176.0	79.2	44.0
	12-1/2	35.2	52.8	88.0	123.0	141.0	158.0	158.0	141.0	123.0	88.0	52.8	35.2
	17-1/2	17.6	26.4	35.2	44.0	61.6	70.4	70.4	61.6	49.0	35.2	26.4	17.6
Green	2-1/2			48.0	112.0	192.0	264.0	264.0	192.0	112.0	48.0		
	7-1/2	20.0	36.0	80.0	128.0	176.0	200.0	200.0	176.0	128.0	80.0	36.0	20.0
	12-1/2	16.0	24.0	40.0	56.0	64.0	72.0	72.0	64.0	56.0	40.0	24.0	16.0
	17-1/2	8.0	12.0	16.0	20.0	28.0	36.0	36.0	28.0	20.0	16.0	12.0	8.0

TABLE 4
TWELVE-INCH YELLOW LENS INTENSITY DISTRIBUTION IN CANDELA
(Values in parentheses are below specified minimum)

Circuit	Vertical Angle, degrees down	Horizontal Angle, degrees											
		Left						Right					
		27-1/2	22-1/2	17-1/2	12-1/2	7-1/2	2-1/2	2-1/2	7-1/2	12-1/2	17-1/2	22-1/2	27-1/2
Specification Minima	2-1/2			418.0	770.0	1,364.0	1,848.0	1,848.0	1,364.0	770.0	418.0		
	7-1/2	88.0	209.0	484.0	792.0	1,100.0	1,231.0	1,231.0	1,100.0	792.0	484.0	209.0	88.0
	12-1/2	88.0	121.0	188.0	242.0	264.0	275.0	275.0	264.0	242.0	188.0	121.0	88.0
	17-1/2	88.0	110.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	121.0	110.0	88.0
Standard 120 v.a.c. Circuit	2-1/2			1,296.0	1,578.0	2,061.0	(1,847.0)	(1,837.0)	1,606.0	1,224.0	939.0		
	7-1/2	565.0	857.0	1,056.0	1,209.0	1,531.0	1,466.0	1,373.0	1,168.0	958.0	704.0	335.0	322.0
	12-1/2	350.0	458.0	582.0	652.0	726.0	777.0	720.0	648.0	566.0	434.0	335.0	267.0
	17-1/2	213.0	257.0	294.0	339.0	396.0	388.0	366.0	363.0	298.0	266.0	236.0	181.0
Diode Dimming Circuit	2-1/2			345.0	420.0	549.0	492.0	489.0	424.0	326.0	250.0		
	7-1/2	150.0	228.0	281.0	322.0	407.0	390.0	365.0	311.0	255.0	187.0	89.1	85.6
	12-1/2	93.1	122.0	155.0	173.0	193.0	207.0	192.0	172.0	150.0	115.0	89.1	71.0
	17-1/2	56.6	68.4	78.2	90.2	105.0	103.0	97.4	96.6	79.3	70.8	62.8	48.1
3M Dimming Circuit	2-1/2			(185.0)	(225.0)	(294.0)	(264.0)	(262.0)	(230.0)	(175.0)	(134.0)		
	7-1/2	(80.8)	(122.0)	(151.0)	(173.0)	(219.0)	(210.0)	(196.0)	(167.0)	(137.0)	(101.0)	(47.9)	(46.0)
	12-1/2	(50.0)	(65.5)	(83.2)	(93.2)	(104.0)	(111.0)	(103.0)	(92.7)	(80.9)	(62.1)	(47.9)	(38.2)
	17-1/2	(30.4)	(36.8)	(42.0)	(48.5)	(56.6)	(55.5)	(52.3)	(51.9)	(42.6)	(38.0)	(33.7)	(25.9)
Transformer Dimming Circuit	2-1/2			(394.0)	(480.0)	(630.0)	(568.0)	(556.0)	(482.0)	(372.0)	(286.0)		
	7-1/2	172.0	261.0	(321.0)	(368.0)	(466.0)	(446.0)	(418.0)	(355.0)	(292.0)	(214.0)	(102.0)	98.0
	12-1/2	106.0	139.0	(177.0)	(198.0)	(221.0)	(236.0)	(219.0)	(197.0)	(172.0)	(132.0)	(102.0)	(81.2)
	17-1/2	(64.8)	(78.2)	(89.4)	(103.0)	(120.0)	(118.0)	(111.0)	(110.0)	(90.7)	(80.9)	(71.8)	(55.1)

TABLE 5

TWELVE-INCH GREEN LENS INTENSITY DISTRIBUTION IN CANDELA

(Values in parentheses are below specified minimum)

Circuit	Vertical Angle, degrees down	Horizontal Angle, degrees											
		Left						Right					
		27-1/2	22-1/2	17-1/2	12-1/2	7-1/2	2-1/2	2-1/2	7-1/2	12-1/2	17-1/2	22-1/2	27-1/2
Specification Minima	2-1/2			190.0	350.0	620.0	840.0	840.0	620.0	350.0	190.0		
	7-1/2	40.0	95.0	220.0	360.0	500.0	560.0	560.0	500.0	360.0	220.0	95.0	40.0
	12-1/2	40.0	55.0	85.0	110.0	120.0	125.0	125.0	120.0	110.0	85.0	55.0	40.0
	17-1/2	40.0	50.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	50.0	40.0
Standard 120 v.a.c. Circuit	2-1/2			387.0	467.0	(600.0)	(605.0)	(606.0)	(604.0)	415.0	376.0		
	7-1/2	146.0	227.0	285.0	(347.0)	(402.0)	(445.0)	(452.0)	(422.0)	360.0	300.0	232.0	154.0
	12-1/2	98.8	124.0	158.0	190.0	213.0	232.0	232.0	212.0	191.0	168.0	131.0	114.0
	17-1/2	66.4	77.2	84.4	100.0	117.0	121.0	124.0	118.0	104.0	97.9	84.7	74.3
Diode Dimming Circuit	2-1/2			(87.9)	(106.0)	(136.0)	(137.0)	(138.0)	(137.0)	(94.3)	(85.4)		
	7-1/2	(33.2)	(51.6)	(64.7)	(78.8)	(91.3)	(101.0)	(103.0)	(95.9)	(81.8)	(68.1)	(52.7)	(35.0)
	12-1/2	(22.4)	(28.2)	(35.9)	(43.2)	(48.4)	(52.7)	(52.7)	(48.2)	(43.4)	(38.2)	(29.8)	(25.9)
	17-1/2	(15.1)	(17.5)	(19.2)	(22.7)	(26.6)	(27.5)	(28.2)	(26.8)	(23.6)	(22.2)	(19.2)	(16.9)
3M Dimming Circuit	2-1/2			(45.3)	(54.7)	(70.3)	(70.8)	(71.0)	(70.7)	(48.6)	(44.0)		
	7-1/2	(17.1)	(26.6)	(33.4)	(40.6)	(47.1)	(52.1)	(52.9)	(49.4)	(42.2)	(35.1)	(27.2)	(18.0)
	12-1/2	(11.6)	(14.5)	(18.5)	(22.2)	(24.9)	(27.2)	(27.2)	(24.8)	(22.4)	(19.7)	(15.3)	(13.3)
	17-1/2	(7.8)	(9.0)	(9.9)	(11.7)	(13.7)	(14.2)	(14.5)	(13.8)	(12.2)	(11.5)	(9.9)	(8.7)
Transformer Dimming Circuit	2-1/2			(108.0)	(130.0)	(167.0)	(169.0)	(169.0)	(168.0)	(116.0)	(105.0)		
	7-1/2	40.7	(63.3)	(79.4)	(96.7)	(112.0)	(124.0)	(126.0)	(118.0)	(100.0)	(83.6)	(64.6)	42.9
	12-1/2	(27.5)	(34.6)	(44.0)	(53.0)	(59.4)	(64.6)	(64.6)	(59.1)	(53.2)	(46.8)	(36.5)	(31.8)
	17-1/2	(18.5)	(21.5)	(23.5)	(27.9)	(32.6)	(33.7)	(34.6)	(32.9)	(29.0)	(27.3)	(23.6)	(20.7)

TABLE 6
ELECTRICAL PARAMETERS

	Circuit	Voltage rms, volts	Current rms, amps	Volt-Amps, watts	Power, rms, watts	Power Factor, percent
Input	Standard 120 v.a.c.	120.0	1.269	152.3	152.5	100.0
	Diode	86.5 *	1.090	94.3	94.3	---
	3M (photocell covered)	120.0	1.282	153.9	87.8	63.9
	3M (photocell partially covered)	120.3	1.304	156.9	102.9	65.6
	Transformer	120.0	1.006	120.7	101.9	84.4
Output	Standard 120 v.a.c.	120.0	1.269	152.3	152.5	100.0
	Diode	84.8	1.090	92.3	92.3	100.0
	3M (photocell covered)	73.2	0.982	72.0	72.1	100.0
	3M (photocell partially covered)	86.5	1.023	88.5	88.6	100.0
	Transformer	86.7	1.066	92.4	92.6	100.0

* $\cong 120/\sqrt{2}$ v.a.c.

TABLE 7
LAMP LUMEN OUTPUT

Circuit	Input Voltage	Equivalent Lamp Voltage From Lumen Output	Lamp Lumens	Standard Rated Lumens
Standard 120 v.a.c.	120	120.0	1632	1950
Diode	120	83.4	423	505
3M (photocell covered)	120	72.7	233	279
3M (photocell partially covered)	120	86.2	472	571
Transformer	120	86.3	484	577
Standard	120	120	1632	1950
	115	115	1410	1685
	110	110	1203	1437
	105	105	1018	1217
	100	100	848	1014
	95	95	700	836
	90	90	564	675
	85	85	454	542
	80	80	357	427
	75	75	266	318
Standard	70	70	193	230