

SECTION 16718

VEHICLE TRAFFIC CONTROL SIGNAL HEADS –  
Light Emitting Diode (LED) Circular Signal Supplement

PART 1 GENERAL

1.01 SECTION INCLUDES

The purpose of this specification is to provide the minimum performance requirements for a 300 mm (12 in) Light Emitting Diode (LED) vehicle traffic signal module while in service. This specification is not intended to impose restrictions upon specific designs and materials that conform to the purpose and the intent of this specification. This specification is not restricted to any specific LED technology.

1.02 DEFINITIONS

- A. Catastrophic Failure: The total loss of visible illumination from an LED light source.
- B. Chromaticity: The color of the light emitted by a module, specified by the  $x, y$  chromaticity coordinates on the 1931 Commission Internationale d'Eclairage (CIE) chromaticity diagram.
- C. Conditioning: Energizing a LED signal module at a specified ambient temperature for a specified period of time, to cause any early electronic component mortality failures to occur and to detect any component reliability problems.
- D. Duty Cycle: The amount of time during a specified time period that a module is energized, expressed as a percent of the specified time period.
- E. Hard Coat: A surface coating or film to provide front surface abrasion resistance.
- F. LED Light Source: A single light emitting diode (LED) or an array of LEDs.
- G. LED Signal Module (module): A signaling unit comprised of an array of LEDs and related power supply, and any required lenses, which, when connected to appropriate power, provides a circular signal indication.
- H. Luminance: The luminous flux emitted or reflected from a surface, in a given direction, per unit solid angle, divided by the area of the surface, expressed as  $\text{cd/m}^2$ .
- I. Luminous Intensity: The luminous flux emitted in a given direction from a source, per unit solid angle, expressed in candelas (cd).

- J. Minimum Maintained Luminous Intensity: The minimum luminous intensity a module is required to provide throughout service as a traffic control signal.
- K. Nominal Operating Voltage: The AC RMS voltage, 120 VAC, at which photometric performance and power consumption are specified.
- L. Power Consumption: The electrical power in Watts consumed by a module when operated at nominal operating voltage and ambient operating temperature range.
- M. Power Factor: The power factor equals Watts divided by Volt-Ampere or the ratio of power consumption in Watts to Volt-Amperes.
- N. Total Harmonic Distortion (THD): THD is the ratio of the root-mean-square (RMS) value of the harmonics to the amplitude of the fundamental component of the AC waveform.
- O. Translate: To move an object along a linear vector, such that the orientation of the object does not rotate relative to the original frame of reference.
- P. Turn OFF Time: The amount of time required after removal of the nominal operating voltage for the LED signal module to show no visible illumination.
- Q. Turn OFF Voltage: The voltage below which the LED signal module emits no visible illumination.
- R. Turn ON Time: The amount of time required for the LED signal module to reach 90% of full illumination.
- S. Volt-Amperes: The product of the root-mean-square (RMS) line voltage and RMS line current, measured with true RMS meters.
- T. Diffused: Lens must be designed to diffuse the light form the LED array over the surface of the lens.

### 1.03 ENVIRONMENTAL REQUIREMENTS

- A. All exposed components of a module shall be suitable for prolonged exposure to the environment, without appreciable degradation that would interfere with function or appearance. As a minimum, selected materials shall be rated for service for a period of a minimum of 72 months in a south-facing Arizona Desert installation.
- B. A module shall be rated for use throughout an ambient operating temperature range, measured at the exposed rear of the module, of  $-40^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$ ) to  $+74^{\circ}\text{C}$  ( $+165^{\circ}\text{F}$ ).

- C. A module shall be protected against dust and moisture intrusion, including rain and blowing rain.
- D. The module lens shall not crack, craze or yellow due to solar UV irradiation typical for a south-facing Arizona Desert installation after a minimum of 72 months in service.

## PART 2 PRODUCTS

### 2.01 MATERIALS

#### A. LED SIGNAL MODULE

1. A module shall be capable of replacing the existing optical components or signal module in a signal housing, or shall provide a complete replacement of the signal head.
2. The module lens shall be hard coated or otherwise made to comply with the material exposure and weathering effects requirements of the Society of Automotive Engineers (SAE) J576.
3. The module lens supplied shall be covered by transparent film or materials with similar color and transmissive characteristics.
4. The module lens may be a replaceable part, without the need to replace the complete LED signal module. Removal of lense will be with simple hand tools and such that no inclusion of additional adhesive, sealants, etc will be required to provide replacement of lense.
5. Materials used for the lens and module construction shall conform to ASTM specifications for the materials, where applicable.
6. Lens must diffuse the LED array over the entire surface of the lens.
7. LED Modules used for arrows must meet same photometric and chromaticity requirements as circular modules. (optional)
8. Enclosures containing either the power supply or electronic components of the signal module shall be made of UL94 flame retardant materials. The module lens is excluded from this requirement.

### 2.02 MODULE IDENTIFICATION

- A. Each module shall be identified on the backside with the manufacturer's name, model, operating characteristics and serial number. The operating characteristics identified shall

include the nominal operating voltage and stabilized power consumption, in watts and Volt-Amperes.

- B. Modules and removable lenses shall have a prominent and permanent vertical indexing indicator, i.e., UP Arrow, or the word UP or TOP, for correct indexing and orientation in the signal housing.
- C. Modules conforming to all non-optional requirements of this specification may have the following statement on an attached label: “Manufactured in Conformance with the COH LED Circular Signal Supplement.”

2.03 PHOTOMETRIC REQUIREMENTS

A. Luminous Intensity, Uniformity & Distribution.

- 1. Minimum maintained luminous intensity: When operated under the conditions defined in Sections 1.03-B and 2.04-A-1, the luminous intensity values for modules shall not be less than the values calculated using the method described below for a minimum period of 72 months.
- 2. Calculate the vertical intensity factor ( $f(I_{Vert})$ ) for the range from 12.5 degrees up (+12.5) to 27.5 degrees down (-27.5), using the appropriate equation:

For  $\theta_{Vert} > -2.5$  degrees:

$$f(I_{Vert}) = 0.05 + 0.9434 * e^{-\left(\frac{\theta_{Vert} + 2.5}{5.3}\right)}$$

For  $\theta_{Vert} \leq -2.5$  degrees:

$$f(I_{Vert}) = 0.26 + \left(\frac{\theta_{Vert}}{143}\right) + 0.76 * \left[ e^{-0.02(\theta_{Vert} + 2.5)^2} \right]^{(-0.07 * \theta_{Vert})}$$

where:  $\theta_{Vert}$  is the angle measured above or below a horizontal plane perpendicular to the face of the module lens. (Note: angles above the horizontal plane are positive, while angles below the horizontal plane are negative.)

3. Calculate the horizontal intensity factor ( $f(I_{Horiz})$ ) for the range from 27.5 degrees left to 27.5 degrees right:

$$f(I_{Horiz}) = 0.05 + \left( 0.95 * e^{\left( \frac{-1}{2} * \left( \frac{\theta_{Horiz}}{11} \right)^2 \right)} \right)$$

where:  $\theta_{Horiz}$  is the angle measured from a vertical plane to the left or right, perpendicular to the face of the module lens.

4. Select the appropriate peak minimum maintained luminous intensity value for the specified module size and color:

Peak minimum maintained luminous intensity values, at  $\theta_{Vert} = -2.5$  deg and  $\theta_{Horiz} = 0$  deg [ $I_{(-2.5, 0)}$ ], by size and color of the module are:

Color	$I_{(-2.5, 0)}$	
	200m	300m
Red	165 cd	365 cd
Yello	410 cd	910 cd
Green	215 cd	475 cd

5. Multiply the vertical intensity factor times the horizontal intensity factor (for the selected pair of angles). Round the result to two significant figures, and multiply the combined angular intensity factor times the peak minimum maintained luminous intensity value for the appropriate signal size and color:

$$I_{(\theta_{vert}, \theta_{horiz}, size, color)} = [f(I_{Vert}) * f(I_{Horiz})] * I_{(-2.5, 0)}$$

The resultant value of the luminous intensity shall be rounded to the nearest whole number.

Example: What is the minimum maintained luminous intensity value for a green, 300 mm LED signal light at 5 degrees down and 10 degrees left?

$$I_{(-5, 10, 300, \text{Green})} = [f(I_{\text{vert} = -5}) * f(I_{\text{horiz} = 10})] * 475 \text{ cd}$$

$$I_{(-5, 10, 300, \text{Green})} = [0.953 * 0.678] * 475 \text{ cd}$$

$$I_{(-5, 10, 300, \text{Green})} = 0.65 * 475 = 309 \text{ cd}$$

6. Table 1 located at end of spec., provides the minimum maintained luminous intensity values, over the required angular range, at 5-degree increments. Note that the horizontal limitations vary for various vertical angles (e.g.: at  $\theta_{\text{Vert}} = +12.5$  degrees, requirements are only specified from 7.5 degrees right to 7.5 degrees left, while at  $\theta_{\text{Vert}} = -12.5$  degrees, the horizontal limitations are from 27.5 degrees right to 27.5 degrees left). Table 2 located at end of spec, provides the minimum maintained luminous intensity values, over the required angular range, at 2.5-degree increments. Tables 1 and 2 are provided to illustrate the minimum required values at certain specific angles within the required angular range of performance (i.e. while testing for light output compliance of a module in a laboratory, an agency may use Table 1, and/or other specific pairs of vertical and horizontal angles of its choosing within the required angular range.) One must use the procedure outlined above for determining the minimum maintained luminous intensity values at any specific pairs of vertical and horizontal angles within the required angular range.
7. Maximum permissible luminous intensity: When operated within the temperature range specified in Section 1.03-B, the actual luminous intensity for a module shall not exceed three times the required peak value of the minimum maintained luminous intensity for the selected signal size, and color.
8. Luminance uniformity: The uniformity of the signal output across the entire module lens shall not exceed a ratio of 10 to 1 between the maximum and minimum luminance values ( $\text{cd/m}^2$ ).

**B. CHROMATICITY**

1. Color regions: The measured chromaticity coordinates of modules shall conform to the following color regions, based on the 1931 CIE chromaticity diagram (see Figure 1):

Red:  $y = 0.308$ ;  $y = 0.953 - 0.947x$ ;  $y = 0.290$ :

Point	Red	
	X	y
1	0.692	0.308
2	0.681	0.308
3	0.700	0.290
4	0.710	0.290

Yellow:  $y = 0.151 + 0.556x$ ;  $y = 0.972 - 0.976x$ ;  $y = 0.235 + 0.300x$ :

Point	Yellow	
	X	Y
1	0.545	0.454
2	0.536	0.449
3	0.578	0.408
4	0.588	0.411

Green:  $y = 0.655 - 0.831x$   $x = 0.150$ ;  $y = 0.422 - 0.278x$ :

Point	Green	
	X	Y
1	0.005	0.651
2	0.150	0.531
3	0.150	0.380
4	0.022	0.416

2. Color uniformity: The dominant wavelength for any individual color measurement of a portion of the emitting surface of a module shall be within  $\pm 3\text{nm}$  of the dominant wavelength for the average color measurement of the emitting surface as a whole.

2.04 ELECTRIC

All wiring and terminal blocks shall meet the requirements. Two secured, color coded, 600V, jacketed wires, a minimum of 20 AWG and at least 1 meter (39 in) in length, conforming to the NFPA 70, National Electrical Code, and rated for service at +105°C, shall be provided.

**A. VOLTAGE RANGE**

1. LED signal modules shall operate from a  $60\pm 3$  Hz AC line power over a voltage range from 80 to 135 VAC RMS.
2. Fluctuations in line voltage over the range of 80 to 135 VAC shall not affect luminous intensity by more than  $\pm 10$  percent.
3. The module circuitry shall prevent flicker of the LED output at frequencies less than 100 Hz over the voltage range specified in Section 2.04-A-1.
4. Low Voltage Turn OFF: There shall be no visible illumination from the LED signal module when the applied voltage is less than 35 VAC.
5. Turn-ON and Turn-OFF Time: A module shall reach 90% of full illumination (turn-ON) within 75 msec of the application of the nominal operating voltage. The signal shall cease emitting visible illumination (turn-OFF) within 75 msec of the removal of the nominal operating voltage.

**B. TRANSIENT VOLTAGE PROTECTION**

1. The on-board circuitry of a module shall include voltage surge protection, to withstand high-repetition noise transients and low-repetition high-energy transients.

**C. INPUT PROTECTION (optional)**

1. At the point of entry to the module for each input provide two 0.5-Ohm, 10-watt wire-wound power resistors with 0.2 micro Henries inductance (one on the AC+ Line & on the AC- Line). Provide one 20 Joule surge arrestor between AC+ to AC-. A 0.68 microfarad capacitor must be placed between AC+ & AC - (between the resistor & arrestor).

**D. ELECTRONIC NOISE**

1. The LED signal and associated on-board circuitry shall meet the requirements of the Federal Communication Commission (FCC) Title 47, Subpart B, Section 15 regulations concerning the emission of electronic noise by Class A digital devices.

**E. POWER FACTOR AND AC HARMONIES**

1. Modules shall provide a power factor of 0.90 or greater when operated at nominal operating voltage, and 25°C (77°F).



2. Total harmonic distortion induced into an AC power line by a module at nominal operating voltage, and at 25°C (77°F), shall not exceed 20%.

F. CONTROLLER ASSEMBLY COMPATIBILITY

1. The current draw shall be sufficient to ensure compatibility and proper triggering and operation of load current switches and conflict monitors in signal controller units.
2. Off State Voltage Decay: When the module is switched from the On state to the Off state the terminal voltage shall decay to a value less than 10 VAC RMS in less than 100 milliseconds when driven by a maximum allowed load switch leakage current of 10 milliamps peak (7.1 milliamps AC).

G. FAILED STATE IMPEDANCE

1. The module shall be designed to detect catastrophic loss of the LED load. Upon sensing the loss of the LED load, the module shall present a resistance of at least 250 kΩ across the input power leads within 300 msec. The LED light source will be said to have failed catastrophically if it fails to show any visible illumination when energized according to Section 2.04-A-1 after 75 msec.

PART 3 EXECUTION

3.01 PHYSICAL & MECHANICAL REQUIREMENTS

A. GENERAL

1. Modules shall fit into existing traffic signal housings built to the VTCSH Standard without modification to the housing, or shall be stand-alone units that incorporate a housing meeting the performance and design requirements of the VTCSH Standard.
2. Installation of a module into an existing signal housing shall not require the use of special tools. The module shall connect directly to existing electrical wiring system.

3.02 CONSTRUCTION

- A. A module shall be a self-contained device, not requiring on-site assembly for installation into an existing traffic signal housing. The power supply for the module may be either integral or packaged as a separate component. The power supply may be designed to fit and mount inside the traffic signal housing adjacent to the LED signal module.
- B. Assembly and manufacturing processes for a module shall be designed to assure all internal LED and electronic components are adequately supported to withstand mechanical shock and vibration due to high winds and other sources.

END OF SECTION

**Table 1**

Table 1 provides the minimum maintained luminous intensity values for the Section 16718 COH SPEC. LED Circular Signal, for the range from 12.5 degrees above to 22.5 degrees below the horizontal plane, and from 27.5 degrees left to 27.5 degrees right of the vertical plane, at 5 degree increments. Minimum Maintained Luminous Intensity Values—Section 16718 COH SPEC LED Circular Signal

Vertical Angle	Horizontal Angle	Luminous Intensity (candela)					
		200m (8-inch)			300 mm (12-inch)		
		Red	Yellow	Green	Red	Yellow	Green
+12.5	2.5	17	41	22	37	91	48
	7.5	13	33	17	29	73	38
+7.5	2.5	31	78	41	69	173	90
	7.5	25	62	32	55	137	71
	12.5	18	45	24	40	100	52
+2.5	2.5	68	168	88	150	373	195
	7.5	56	139	73	124	309	162
	12.5	38	94	49	84	209	109
	17.5	21	53	28	47	118	62
-2.5	22.5	12	29	15	26	64	33
	2.5	162	402	211	358	892	466
	7.5	132	328	172	292	728	380
	12.5	91	226	118	201	501	261
	17.5	53	131	69	117	291	152
-7.5	22.5	28	70	37	62	155	81
	27.5	15	37	19	33	82	43
	2.5	127	316	166	281	701	366
	7.5	106	262	138	234	582	304
	12.5	71	176	92	157	391	204
	17.5	41	103	54	91	228	119
-12.5	22.5	21	53	28	47	118	62
	27.5	12	29	15	26	64	33
	2.5	50	123	65	110	273	143
	7.5	40	98	52	88	218	114
	12.5	28	70	37	62	155	81
-17.5	17.5	17	41	22	37	91	48
	22.5	8	21	11	18	46	24
	27.5	5	12	6	11	27	14
	2.5	23	57	30	51	127	67
	7.5	18	45	24	40	100	52
-17.5	12.5	13	33	17	29	73	38
	17.5	7	16	9	15	36	19

	22.5	3	8	4	7	18	10
-22.5	2.5	17	41	22	37	91	48
	7.5	13	33	17	29	73	38
	12.5	10	25	13	22	55	29
	17.5	5	12	6	11	27	14
-27.5	2.5	12	29	15	26	64	33
	7.5	8	21	11	18	46	24

Note 1: Luminous intensity values for equivalent left and right horizontal angles are the same.

Note 2: Tabulated values of luminous intensity are rounded to the nearest whole value.

**Table 2**

Table 2 provides the minimum maintained luminous intensity values for the Section 16718 COH SPEC LED Circular Signal, for the range from 12.5 degrees above to 22.5 degrees below the horizontal plane, and from 27.5 degrees left to 27.5 degrees right of the vertical plane, at 2.5 degree increments.

Minimum Maintained Luminous Intensity Values—Section 16718 COH SPEC LED Circular Signal

Vertical Angle	Horizontal Angle	Luminous Intensity (candela)					
		200m (8-inch)			300 mm (12-inch)		
		Red	Yellow	Green	Red	Yellow	Green
+12.5	0	18	45	24	40	100	52
	2.5	17	41	22	37	91	48
	5	17	41	22	37	91	48
	7.5	13	33	17	29	73	38
+10.0	0	23	57	30	51	127	67
	2.5	23	57	30	51	127	67
	5	21	53	28	47	118	62
	7.5	18	45	24	40	100	52
+7.5	0	31	78	41	69	173	90
	2.5	31	78	41	69	173	90
	5	28	70	37	62	155	81
	7.5	25	62	32	55	137	71
	10	21	53	28	47	118	62
	12.5	18	45	24	40	100	52
+5.0	0	46	115	60	102	255	133
	2.5	45	111	58	99	246	128
	5	41	103	54	91	228	119
	7.5	36	90	47	80	200	105
	10	31	78	41	69	173	90
	12.5	25	62	32	55	137	71
+2.5	0	69	172	90	153	382	200
	2.5	68	168	88	150	373	195
	5	63	156	82	139	346	181
	7.5	56	139	73	124	309	162
	10	46	115	60	102	255	133
	12.5	38	94	49	84	209	109
	15	30	74	39	66	164	86
	17.5	21	53	28	47	118	62
	20	17	41	22	37	91	48
	22.5	12	29	15	26	64	33

0.0	0	106	262	138	234	582	304
	2.5	102	254	133	226	564	295
	5	96	238	125	212	528	276
	7.5	84	209	110	186	464	242
	10	71	176	92	157	391	204
	12.5	58	144	75	128	319	166
	15	45	111	58	99	246	128
	17.5	33	82	43	73	182	95
	20	25	62	32	55	137	71
	22.5	18	45	24	40	100	52

**Table 2 (cont'd)**

Vertical Angle	Horizontal Angle	Luminous Intensity (candela)					
		200m (8-inch)			300 mm (12-inch)		
		Red	Yellow	Green	Red	Yellow	Green
-2.5	0	165	410	215	365	910	475
	2.5	162	402	211	358	892	466
	5	150	373	196	332	828	432
	7.5	132	328	172	292	728	380
	10	112	279	146	248	619	323
	12.5	91	226	118	201	501	261
	15	71	176	92	157	391	204
	17.5	53	131	69	117	291	152
	20	38	94	49	84	209	109
	22.5	28	70	37	62	155	81
	25	20	49	26	44	109	57
27.5	15	37	19	33	82	43	
-5.0	0	157	390	204	347	865	451
	2.5	153	381	200	339	846	442
	5	142	353	185	314	783	409
	7.5	125	312	163	277	692	361
	10	107	267	140	237	592	309
	12.5	86	213	112	190	473	247
	15	66	164	86	146	364	190
	17.5	50	123	65	110	273	143
	20	36	90	47	80	200	105
	22.5	26	66	34	58	146	76
	25	20	49	26	44	109	57
27.5	15	37	19	33	82	43	
-7.5	0	130	324	170	288	719	375
	2.5	127	316	166	281	701	366
	5	119	295	155	263	655	342
	7.5	106	262	138	234	582	304
	10	89	221	116	197	491	257
	12.5	71	176	92	157	391	204
	15	56	139	73	124	309	162
	17.5	41	103	54	91	228	119
	20	30	74	39	66	164	86
	22.5	21	53	28	47	118	62
	25	17	41	22	37	91	48

	27.5	12	29	15	26	64	33
-10.0	0	89	221	116	197	491	257
	2.5	86	213	112	190	473	247
	5	81	201	105	179	446	233
	7.5	71	176	92	157	391	204
	10	59	148	77	131	328	171
	12.5	48	119	62	106	264	138
	15	38	94	49	84	209	109
	17.5	28	70	37	62	155	81
	20	20	49	26	44	109	57
	22.5	15	37	19	33	82	43
	25	12	29	15	26	64	33
	27.5	8	21	11	18	46	24

**Table 2 (cont'd)**

Vertical Angle	Horizontal Angle	Luminous Intensity (candela)					
		200m (8-inch)			300 mm (12-inch)		
		Red	Yellow	Green	Red	Yellow	Green
-12.5	0	50	123	65	110	273	143
	2.5	50	123	65	110	273	143
	5	46	115	60	102	255	133
	7.5	40	98	52	88	218	114
	10	35	86	45	77	191	100
	12.5	28	70	37	62	155	81
	15	21	53	28	47	118	62
	17.5	17	41	22	37	91	48
	20	12	29	15	26	64	33
	22.5	8	21	11	18	46	24
	25	7	16	9	15	36	19
	27.5	5	12	6	11	27	14
-15.0	0	30	74	39	66	164	86
	2.5	30	74	39	66	164	86
	5	28	70	37	62	155	81
	7.5	25	62	32	55	137	71
	10	20	49	26	44	109	57
	12.5	17	41	22	37	91	48
	15	13	33	17	29	73	38
	17.5	10	25	13	22	55	29
	20	7	16	9	15	36	19
	22.5	5	12	6	11	27	14
-17.5	0	23	57	30	51	127	67
	2.5	23	57	30	51	127	67
	5	21	53	28	47	118	62
	7.5	18	45	24	40	100	52
	10	17	41	22	37	91	48
	12.5	13	33	17	29	73	38
	15	10	25	13	22	55	29
	17.5	7	16	9	15	36	19
	20	5	12	6	11	27	14
	22.5	3	8	4	7	18	10
-20.0	0	20	49	26	44	109	57
	2.5	20	49	26	44	109	57
	5	18	45	24	40	100	52

	7.5	17	41	22	37	91	48
	10	13	33	17	29	73	38
	12.5	12	29	15	26	64	33
	15	8	21	11	18	46	24
	17.5	7	16	9	15	36	19
-22.5	0	17	41	22	37	91	48
	2.5	17	41	22	37	91	48
	5	15	37	19	33	82	43
	7.5	13	33	17	29	73	38
	10	12	29	15	26	64	33
	12.5	10	25	13	22	55	29
	15	7	16	9	15	36	19
	17.5	5	12	6	11	27	14

**Table 2 (cont'd)**

Vertical Angle	Horizontal Angle	Luminous Intensity (candela)					
		200m (8-inch)			300 mm (12-inch)		
		Red	Yellow	Green	Red	Yellow	Green
-25.0	0	15	37	19	33	82	43
	2.5	13	33	17	29	73	38
	5	13	33	17	29	73	38
	7.5	12	29	15	26	64	33
-27.5	0	12	29	15	26	64	33
	2.5	12	29	15	26	64	33
	5	10	25	13	22	55	29
	7.5	8	21	11	18	46	24

Note 1: Luminous intensity values for equivalent left and right horizontal angles are the same.

Note 2: Tabulated values of luminous intensity are rounded to the nearest whole value.

Figure 1

Color Regions for LED Traffic Control Signal Lights:

Figure 1 illustrates the acceptable color regions for traffic control signal lights using LED emitters as the light source.

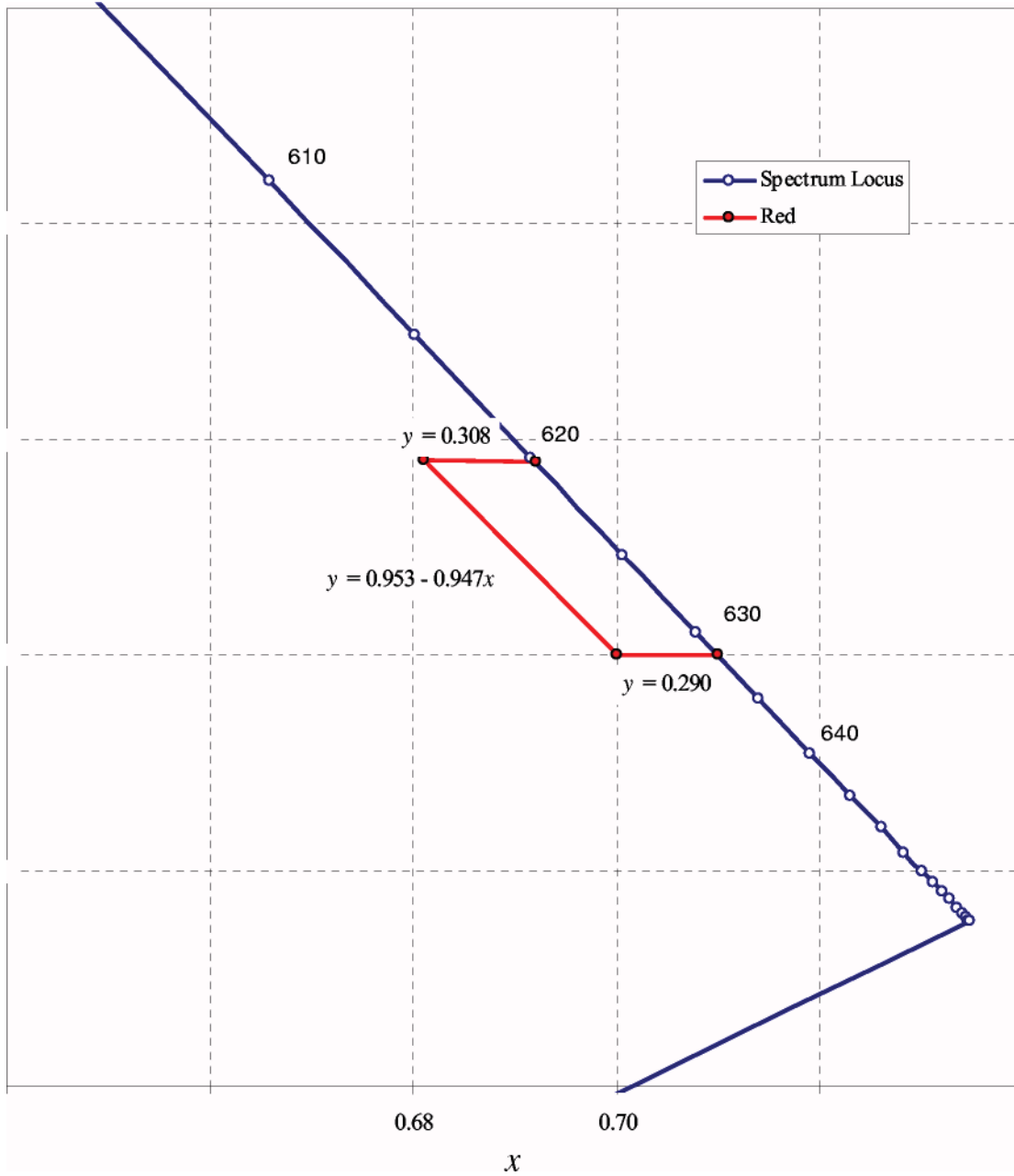


Figure 1a: Color Region for Red Traffic Control Signal Lights

Figure 1 (cont'd)

Color Regions for LED Traffic Control Signal Lights:

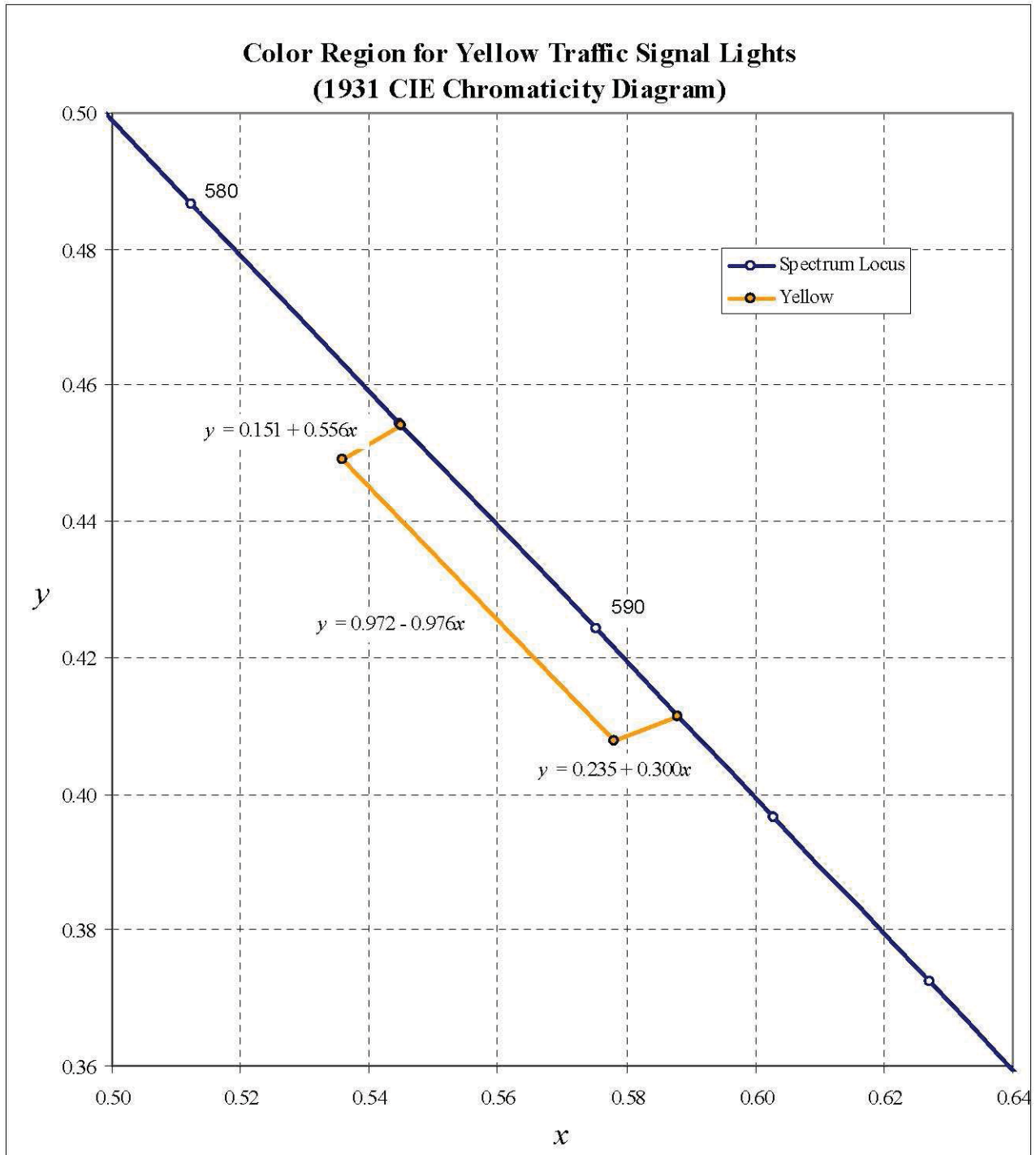


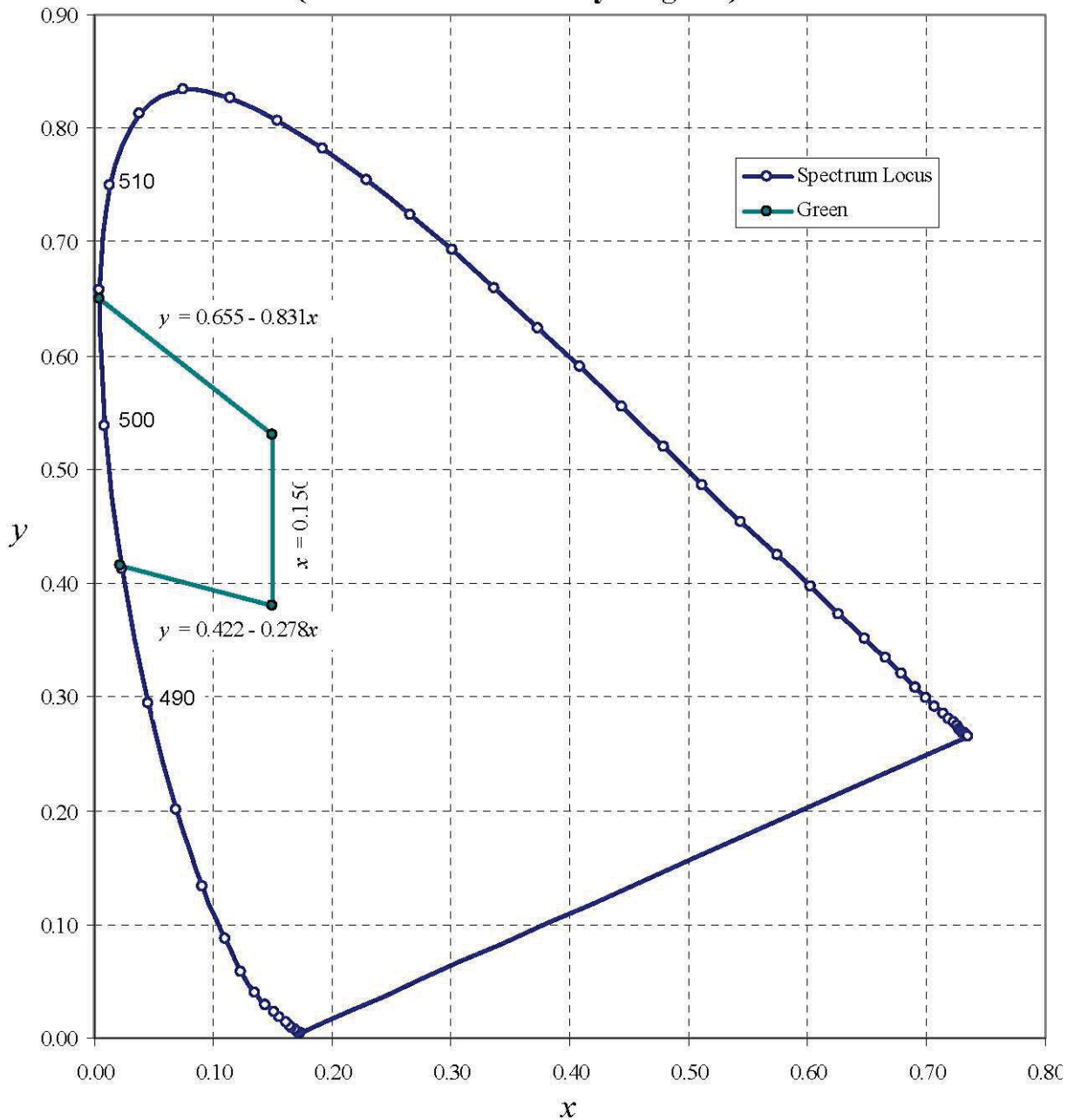


Figure 1b: Color Region for Yellow Traffic Control Signal Lights

Figure 1 (cont'd)

Color Regions for LED Traffic Control Signal Lights:

Color Region for Green Traffic Signal Lights  
(1931 CIE Chromaticity Diagram)



**TECHNICAL SPECIFICATION**

**LIGHT EMITTING DIODE (LED)  
VEHICLE TRAFFIC SIGNAL MODULE**

Table 1 a. – Minimum Maintained Luminous Intensity

Vertical Angle	Horizontal Angle	Red 8"		Yellow 8"		Green 8"		RED 12"		Yellow 12"		Green 12"	
		Min.	160%	Min.	110%	Min.	135%	Min.	160%	Min.	110%	Min.	135%
12.5	2.5	17	27	41	45	22	30	37	59	91	100	48	65
	7.5	13	21	33	36	17	23	29	46	73	80	38	51
7.5	2.5	31	50	78	86	41	55	69	110	173	190	90	122
	7.5	25	40	62	68	32	43	55	88	137	151	71	96
	12.5	18	29	45	50	24	32	40	64	100	110	52	70
2.5	2.5	68	109	168	185	88	119	150	240	373	410	195	263
	7.5	56	90	139	153	73	99	124	198	309	340	162	219
	12.5	38	61	94	103	49	66	84	134	209	230	109	147
	17.5	21	34	53	58	28	38	47	75	118	130	62	84
-2.5	22.5	12	19	29	32	15	20	26	42	64	70	33	45
	2.5	162	259	402	442	211	285	358	573	892	981	466	629
	7.5	132	211	328	361	172	232	292	467	728	801	380	513
	12.5	91	146	226	249	118	159	201	322	501	551	261	352
	17.5	53	85	131	144	69	93	117	187	291	320	152	205
-7.5	22.5	28	45	70	77	37	50	62	99	155	171	81	109
	27.5	15	24	37	41	19	26	33	53	82	90	43	58
	2.5	127	203	316	348	166	224	281	450	701	771	366	494
	7.5	106	170	262	288	138	186	234	374	582	640	304	410
	12.5	71	114	176	194	92	124	157	251	391	430	204	275
	17.5	41	66	103	113	54	73	91	146	228	251	119	161
-12.5	22.5	21	34	53	58	28	38	47	75	118	130	62	84
	27.5	12	19	29	32	15	20	26	42	64	70	33	45
	2.5	50	80	123	135	65	88	110	176	273	300	143	193
	7.5	40	64	98	108	52	70	88	141	218	240	114	154
	12.5	28	45	70	77	37	50	62	99	155	171	81	109
	17.5	17	27	41	45	22	30	37	59	91	100	48	65
-17.5	22.5	8	13	21	23	11	15	18	29	46	51	24	32
	27.5	5	8	12	13	6	8	11	18	27	30	14	19
	2.5	23	37	57	63	30	41	51	82	127	140	67	90
	7.5	18	29	45	50	24	32	40	64	100	110	52	70
	12.5	13	21	33	36	17	23	29	46	73	80	38	51
-22.5	17.5	7	11	16	18	9	12	15	24	36	40	19	26
	22.5	3	5	8	9	4	5	7	11	18	20	10	14
	2.5	17	27	41	45	22	30	37	59	91	100	48	65
	7.5	13	21	33	36	17	23	29	46	73	80	38	51
-27.5	12.5	10	16	25	28	13	18	22	35	55	61	29	39
	17.5	5	8	12	13	6	8	11	18	27	30	14	19
	2.5	12	19	29	32	15	20	26	42	64	70	33	45
-27.5	7.5	8	13	21	23	11	15	18	29	46	51	24	32