Equipment and Material Standards of the Institute of Transportation Engineers

November 1998
The Institute of Transportation Engineers (ITE) is an international educational and scientific association of transportation and traffic engineers and other professionals who are responsible for meeting mobility and safety needs. ITE facilitates the application of technology and scientific principles to research, planning, functional design, implementation, operation, policy development and management for any mode of transportation by promoting professional development of members, supporting and encouraging education, stimulating research, developing public awareness, and exchanging professional information; and by maintaining a central point of reference and action.

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* These ITE standards are specifically referenced in the U.S. Department of Transportation’s Manual on Uniform Traffic Control Devices for Streets and Highways, 1988 Edition. Please refer to the Institute’s Web site for up-to-date information on these and other standards: http://www.ite.org/itesstandardupdate/.
signals

chapters 1-9
Traffic Signal Lamps

This report was approved as a Revised Standard of the Institute of Transportation Engineers by the ITE Board of Direction on December 11, 1980 in concurrence with the Institute's Technical Council. It supersedes the Tentative Revised Standard on Traffic Signal Lamps approved by the ITE Board of Direction on January 30, 1978.

The Standard was developed by Technical Council Committee 4R-S.

Members of the Committee were J. A. Buck; Robert Holsinger; Ronald L. Hurbat; Conrad Lapinski; R. A. Lind; J. M. Lynch; Craig Leiser; A. C. Rousseau; Charles T. Murray; J. Patrick Short; James A. Thompson; J. G. Wares; J. Gordon White; Ronald S. Fiorczykowski; Thomas Urbanik, II; and Peter A. Fausch, Chairman.

THE TRAFFIC SIGNAL LAMP STANDARD

1.0 Purpose. The purpose of this Standard is to provide a guide for the minimum design specification for traffic signal lamps. The standard represents the minimum requirements for traffic signal lamps and is not intended to impose restrictions upon designs or materials which conform to the purpose and intent of this Standard. Reference should be made to the ITE Technical Standard, Adjustable Face Vehicle Signal, for additional information on application of traffic signal lamps. Signal manufacturers' performance specifications may also be referred to in order to determine the suitability of a lamp for its intended use.

2.0 General

2.1 Definitions

2.1.1 Traffic Signal Lamp — A lamp designed for use in traffic signal heads.

2.1.2 Rated Voltage — The nominal or design operating voltage of the lamp; the voltage at which rated watts, lumens, and life are determined.

2.1.3 Rated Watts — The average initial power (watts) consumed, when the lamp is operated at rated voltage.

2.1.4 Rated Life — The (arithmetic) average of burning hours for a sample number of lamps operated at rated voltage and defined operating conditions.

2.1.5 Duty Cycle — The amount of time during a given unit of time that the lamp is actually energized, expressed as a percentage (i.e., 30 minutes per hour would be a 50-percent duty cycle).

2.1.6 Lumen — Unit of luminous flux indicating light output. (Traffic signal lamp output is rated in lumens.)

2.1.7 Rated "Initial" Lumens — The average amount of luminous flux (light) produced by a statistically acceptable sample of lamps on operation at rated voltage after having been seasoned to one-half to one percent of rated life.

2.1.8 Minimum "Initial" Lumens — A minimum value of initial light output below which no more than a specified percentage of individual lamps will be permitted, as measured in 2.1.7 above.

2.1.9 Burning Position — Physical positioning of the lamp in the traffic signal. Normally, traffic signal lamps are used in the horizontal burning positions with the opening between filament ends up.

2.1.10 Overall Length (O.L.) — The total distance from the tip of the bulb to the tip of the base, including solder on the base eyelet (does not apply to PAR (Parabolic Annular Reflector) type lamps).

2.1.11 Light Center Length (L.C.L.) — The dimension, in inches (cm), from the center of the filament to the tip of the base (including solder on the base eyelet).

2.1.12 Glass Envelope (bulb) — Bulb is designated by prefix letter(s) and suffix numbers(s). The prefix letter indicates the shape, while the suffix number indicates the maximum diameter of the bulb, expressed in eighths of an inch (does not apply to PAR (Parabolic Annular Reflector) type lamps).

2.1.13 Filament — The electrical resistance element heated to incandescence by electric current.

2.1.14 Filament Shape — The filament configuration identified by
prefix letter(s) and suffix number (for example, C-9. The prefix letter "C" means the filament wire is coiled; the suffix number "9" means a horseshoe shape).

2.1.15 Candela (cd) — Unit of luminous intensity.

2.1.16 Candlepower (l) — Luminous intensity expressed in candelas and specified as candlepower in a specific direction.

2.1.17 Beam Candlepower — The intensity of a beam forming light source, expressed in candelas measured in a given direction.

2.1.18 Beam Spread — The angle between the two directions in the plane in which the candlepower is equal to a stated percent (usually 10 percent) of the maximum candlepower in the beam.

2.1.19 Candlepower Distribution Curve — An isocandela curve representing the variation of luminous intensity with respect to angular deviations from reference axis. Generally, this value is only measured as a function of total system performance.

2.1.20 Color Temperature — The apparent initial color temperature of the filament, measured in degrees Kelvin (°K).

2.2 System Requirements

Traffic signal lamps, in order to provide uniformity of application, shall be compatible with the design requirements of the optical systems of standard traffic signal sections. Because traffic control devices impose a greater service requirement than most applications of electrical incandescent lamps, the construction features of traffic signal lamps require that the filament shall be adequately supported to withstand the vibration that may be induced in the lamp by signal system design, suspension, vehicular traffic and high winds.

All traffic signal lamps shall have a base made of brass and shall be either a standard, medium screw-type or a 3-prong for optically programmed signals. The glass envelope shall be clear or diffused, depending upon the desired optical characteristics of the end system operation. The light center length (L.C.L.) shall be in conformance with the system design requirements, as specified in Section 3.1 of this Standard.

3.0 Specific Design Requirements

3.1 Traffic signal lamps for use in 8-inch nominal (200 mm) traffic signal sections shall have a light center length of 2.7/16-inch (62 mm). All traffic signal lamps for use in 12-inch nominal (300 mm) traffic signal sections shall have a light center length of 3-inches (76 mm). All traffic signal lamps should be designed to provide a minimum 6,000 hour life.

3.2 Traffic signal lamps for use in 8-inch (200 mm) traffic signal sections shall provide 595 initial lumens (550 minimum initial lumens).

3.3 Traffic signal lamps for use in 12-inch (300 mm) traffic signal sections shall provide 1750 rated initial lumens (1650 minimum initial lumens).

3.4 Traffic signal lamps for use in 12-inch (300 mm) optically programmed signal sections shall provide 950 beam candlepower (150-watt) or 500 beam candlepower (75-watt) in a PAR 46 envelope.

3.5 Marking — The glass envelope of the lamps of the individual lamp packaging shall be indelibly marked to show: (1) the manufacturer’s identification, (2) the rated voltage, (3) the rated lumens, (4) rated average life and orientation of lamp for proper burning position. In addition, the lamp manufacturer shall, by date code or other means, identify the lot from which an individual lamp was obtained.

3.6 Traffic signal lamps shall operate over the temperature range from minus 40 °F to plus 165 °F, and from zero to 100 percent humidity.

4.0 Quality Assurance and Testing

4.1 Test Procedure — Unless otherwise specified, all tests shall be made in a competent and expert engineering manner by the manufacturer. The manufacturing quality system and testing facilities shall be certified as meeting standards of General Service Administration’s "Quality Approved Manufacturer Program." The manufacturer will be required to supply the necessary equipment, assistance, power, and facilities for making such initial tests and examinations, and be required to keep proper records of examinations and tests. The procuring agency shall have the privilege of having access to the records of such tests at all reasonable times.

4.2 Submission for Inspection — Lamps shall not be submitted for inspection until they have been held 48 hours from the time that they are manufactured.

4.3 Lot Definition — A lot shall be all of the lamps of any type and size offered for acceptance at any one time.

4.4 Acceptance Inspection — Traffic signal lamps shall be subjected to physical inspection tests in accordance with the sampling procedures of Military Standard MIL-STD-105. Acceptance quality levels for physical inspections (AQL’s) shall be 1.0 percent for major defects and 4.0 percent for minor defects. Major defects are those likely to result in failure or provide unsatisfactory service. Minor defects are primarily cosmetic or appearance.

4.4.1 Rating Test Conditions — Before measuring lamps in the initial rating test, they shall be sufficiently seasoned (one-half to one percent of rated life) to have reached stable values of watts and lumens. Lamps shall be operated for seasoning at rated voltage, plus or minus 0.5 percent, and for rating tests at rated volts ±0.25 percent. The measurements of total lumens shall be made with an accurate photometric device capable of accepting and integrating the entire luminous output of the lamp under test, such as a 4-foot diameter integrating sphere (see IES Guide for Electric/Photometric Measurements of General Service Incandescent Lamps (LM-45)).

4.4.2 Rejection for Low Initial Lumens — Any lot of lamps shall
be rejected, if 20 percent plus 2 or more of the rating test lamps fall below the value listed in 3.2, 3.3, and 3.4.

4.5 Life Performance Test Lamp Selection and Test Quantities — The lamps of the life performance test shall be selected from the rating test lamps in the ratio of not less than 5 from the first 500 lamps (or part thereof) and 5 from each succeeding 1,000 lamps. The life-test lamps selected shall be representative of the rating-test lamps.

4.5.1 Life-Tested Voltage — Life-test lamps shall be operated at rated voltage, plus or minus 1.0 percent. Force-testing shall not be used to establish life rating values.

Force testing in accordance with IES Standards at elevated voltage may be used to verify lot performance once the basic design configuration has acceptably passed a rated voltage life test.

4.5.2 Position of Burning — Lamps shall be operated in the horizontal position.

4.5.3 Rejection for Failure to Meet Life Requirement — Any lot of lamps, provided that such lot is represented on test by the minimum required number of lamps (not less than 5) selected in accordance with 4.5, shall be rejected if the average life of the life-test or force-test lamps falls below the life value given in the applicable figure by more than the life tolerance specified in Table 1 for the number of life-test lamps averaged.

4.6 Life-Test Conditions — Lamps shall be burned continuously to end-of-life, allowing one "off" period per 24 hours (IES Approved Method for Life Testing of General Lighting Incandescent Lamps (LM-49)).

<table>
<thead>
<tr>
<th>Number of Lamps Averaged</th>
<th>Allowable Percent Variation From Rated Life</th>
<th>Number of Lamps Averaged</th>
<th>Allowable Percent Variation From Rated Life</th>
<th>Number of Lamps Averaged</th>
<th>Allowable Percent Variation From Rated Life</th>
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<tr>
<td>250 and above</td>
<td>5</td>
<td>20-24</td>
<td>17</td>
<td>9</td>
<td>25</td>
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<tr>
<td>100-249</td>
<td>8</td>
<td>18-19</td>
<td>18</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td>55-59</td>
<td>10</td>
<td>16-17</td>
<td>19</td>
<td>7</td>
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<td>45-54</td>
<td>11</td>
<td>14-15</td>
<td>20</td>
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<td>35-44</td>
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<td>5</td>
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<td>24</td>
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</table>

On account of the natural and inherent variations in individual lamp performance, the average test results of a small number of test samples cannot be depended upon to indicate exactly the average from the larger quantity from which the test samples were taken. The tables of allowable variations are devised in accordance with the observed accuracy of lamp testing methods and the observed variations in lamp performance.

![Diagram](image)

**Figure 1. Effect of voltage applied to a lamp on light output and lamp life.**
Vehicle Traffic Control
Signal Heads

1.00 Purpose

The purpose of this standard is to provide a guide for the preparation of specifications for vehicle traffic control signal heads. The standard represents the requirements for equipment described herein and is not intended to impose restrictions upon (1) design and materials that conform to the purpose and the intent of this standard or (2) installation of traffic signal heads. Further, this standard is not intended to describe fiberoptic or optically programmable signal heads or components.

2.00 General

2.01 Definitions

1. Traffic Control Signal—A device by which traffic is alternately assigned the right-of-way to the various movements at an intersection or other roadway location.

2. Signal Head—An arrangement of one or more signal lenses in signal faces that may be designated accordingly as one-way, two-way, etc.

3. Signal Face—That part of a signal head provided for controlling traffic in a single direction. Turning indications may be included in a signal face.

4. Signal Section—That part of a signal face containing an optical unit.

5. Optical Unit—An assembly of lens, reflector, lamp, and lamp socket with the necessary supporting parts to be used for providing a single signal indication.

6. Signal Indication—The illumination of a traffic signal lens or equivalent device or a combination of several lenses or equivalent devices at the same time.

2.02 Position of Signal Indications

Signal indications shall be assembled in accordance with the latest revision of the Manual on Uniform Traffic Control Devices for Streets and Highways.1

3.00 Physical and Mechanical Requirements

3.01 General

Each vehicle traffic signal head shall consist of an assembly of one or more signal faces.

Each signal face shall consist of an assembly of signal sections to provide the required number of indications. The sections shall be joined together in a manner that provides both mechanical integrity and maximum protection against intrusion of dust and weather.

Each signal section shall consist of a housing, a door, and an optical assembly together with the necessary gaskets.

Each signal section shall be provided with a visor.

Each signal section and its associated optical system shall be capable of operating satisfactorily with the section's axis either vertical or horizontal.

Each signal section shall be provided with openings in the top and bottom (at either end in the case of a horizontally oriented signal section as needed) for mounting purposes. Each opening shall be round to accommodate 1½ inch nominal diameter pipe. Each unused opening shall be closed with a plug or cap.

3.02 Strength Requirements

It is recognized that each purchaser can require signals to be made up of different materials and also that signal sections may be arranged in various configurations and that certain physical tests may be required by the purchaser. For this purpose an optional strength requirement is included.

A three-section face made up of all 8-inch or all 12-inch sections, complete with optical units with backplates, shall have backplates extending beyond the side by 8 inches for an 8-inch lens and 5 inches for a 12-inch lens. The entire assembly shall, when supported solely from the top or bottom section, be capable of withstanding the laboratory equivalent of a sustained wind load of 25 pounds per square foot applied perpendicular to the front and rear of the sign face and backplate.2

The applied wind loading will be equally distributed among the three sections. "Withstanding" means that the specified load, when applied for a period of 24 hours, shall not cause any damage to the signal face or backplate or any permanent deformation sufficient to result in adverse performance of the signal face. "Adverse performance" means a permanent deflection of more than 10 degrees in either the vertical or horizontal plane after the test load has been removed from the rear of the signal face and more than 5 degrees in either the vertical or horizontal plane after the test load has been removed from the front of the signal face.

With an external bracket assembly may be used for supporting or reinforcing signal faces that are to be posttop or mast-arm mounted. Such bracket assemblies shall be capable of withstanding the tests specified above.

1 U.S. Department of Transportation, Federal Highway Administration.

2 An external bracket assembly may be used for supporting or reinforcing signal faces that are to be posttop or mast-arm mounted. Such bracket assemblies shall be capable of withstanding the tests specified above.
4.00 Housing, Door, and Visor

4.01 General

The door of each signal section shall be hinged to the housing to permit access to the section for relamping. The door shall be secured with simple devices or design features that will hold the door closed when the section is subjected to the loading specified in Section 3.02. Use of tools to open and close doors shall not be required.

4.02 Dimensions

Each 8-inch and 12-inch signal section shall be constructed to accommodate the 8-inch and 12-inch nominal dimension optical units.

4.03 Visors

Each signal section shall be provided with a visor. Visors will be classified on the basis of lens encirclement as full circle, tunnel (bottom open), or cap (bottom and lower sides open).

The visor shall be a minimum of 9½ inches in length for nominal 12-inch round lenses and 7 inches in length for nominal 8-inch round lenses, with a downward tilt of 3½ degrees.

Each visor shall be mounted on its door in a manner that eliminates the escape of light from the lens between the visor and the door.

Each visor shall be secured to its door in a manner that will prevent its removal by wind. Each visor shall be capable of being oriented for either vertical or horizontal mounting of the signal section.

4.04 Materials and Fabrication

1. Each housing shall be made using one of the following methods and materials.

A. Cast from aluminum alloy. Material for cast housings shall be aluminum alloy S-12A, S-12B, SC-84A, SC-84B, or SG-100B, conforming to the specifications in ASTM Designation B-85-71, or the latest revision thereof. Material for permanent mold castings shall be aluminum alloy S-5A or CS-72A conforming to the requirements of and as listed in ASTM Designation B-108-60T, or the latest revision thereof.

B. Plastic shall be ultraviolet and heat stabilized and conforming to ASTM specifications. Plastic housings may be either molded in one piece or may be fabricated from two or three pieces joined into a single piece using thermal, chemical, or ultrasonic bonding.

2. Each door shall be made of a material that is one of the above materials and which is compatible with the material of the housing.

3. The lens opening in the doors shall provide a visible diameter of not less than 7¾ inches nor more than 8 inches for a nominal 8-inch round lens, and a visible diameter of not less than 11 inches nor more than 11¾ inches for a nominal 12-inch round lens.

4. All exterior metal fasteners, including hinge pins, shall be made from stainless steel.

5. Metal visors and backplates shall be made from 0.05-inch minimum thickness aluminum alloy sheets. Plastic visors and backplates shall be a minimum of 0.100 inch thick, either formed from sheet plastic or assembled from one or more injection, rotational, or blow-molded plastic sections.

6. Gasketing material for the optical unit shall withstand temperatures up to 250°F without permanent deformation and discoloration, without adversely affecting the lens, reflector, or lamp.

5.00 Optical Unit

Each optical unit shall consist of an assembly of a lens, a reflector, a lamp, a lamp receptacle, and other components as required.

Each optical unit shall provide as a minimum the light distribution set forth in Section 11.00 when used with the proper lamp and with the appropriate colored lens. Each optical unit shall also meet the chromaticity limits as defined in Section 8.00.

5.01 Sun Phantom

Each optical unit, including lens, reflector, lamp, and visor, shall be designed to minimize the return through the lens of outside light entering the lens at low sun angles, to prevent the effect termed Sun Phantom.

Sun Phantom is defined as the effect of an outside light source entering the optical unit and being reflected in such a manner as to present the appearance of the optical unit being illuminated.

5.02 Separate Illumination

Each optical unit shall be so designed that its lens shall be illuminated separately and so assembled within its signal section housing that no light can escape to an adjacent signal section(s).

6.00 Mounting Assemblies

All traffic signal mounting brackets and fittings shall be assembled raintight. Each mounting fitting in contact with a signal section shall have serrations to match those specified in Section 3.01.

All brackets shall be of sufficient strength to withstand both the vertical loading of the signal faces as well as the horizontal wind loading specified in Section 3.02.

All brackets shall provide a wireway free of sharp edges and protrusions that might damage conductor insulation.

Mast arm slip-fitters and span-wire suspension fittings shall include means for adjusting the signal head to the proper vertical alignment. Signal heads to be span-wire mounted, in addition to the upper suspension fitting, shall be provided with a means for mounting attachments to secure the signal to a lower span wire.

7.00 Exterior Finish

7.01 All exterior parts of metallic signal heads, excepting the lens and parts specified in Section 6.00, but including the mounting and assemblies, shall be finished of the best quality synthetic resin enamel of the color specified by the purchaser. Nonmetallic materials shall have the color completely impregnated in the material.

7.02 The exterior color of the entire signal head, including the outside of visors, shall be user specified. However, the inside of visors and all surfaces of backplates shall be dull black in color.

8.00 Traffic Signal Lenses

8.01 Purpose

The purpose of this section is to define the limits of chromaticity for signal indication colors by combinations of illuminant and redirecting cover lens material.

The specification covers the particular red, yellow, and green colors used in signals.

The lens size shall be 8½ inches for nominal 8-inch signal lenses and 12 inches for 12-inch lenses with a minimum rim thickness of 8/32 inches.

8.02 Basis of Chromaticity Requirements

The values given in the specifications were derived from spectrophotometric data obtained by the Colorometry Section, National Bureau of Standards, with
defining glasses selected by a technical committee of the Institute of Transportation Engineers. These values were computed on the following basis:


2. Illuminant: CIE Illuminant A. Planckian Radiator at 2856 K for values of \(x, y, z\).

3. Angular distribution of illumination: Approximately at right angles to the surface of the glass.

4. Angle of view: Approximately at right angles to the surface of the glass.

The conditions specified above shall be used in testing lens materials for conformation to this section and the following section of this specification, except that to test a lens for conformance to this section, a photometric procedure must be used similar to that indicated in Section 11.00.

Any color, in general, be adequately specified in terms of three colorimetric quantities. In the case of the signal colors, the three quantities adequate for the purpose are two numbers defining the chromaticity of the color, i.e., its hue and saturation, and one number defining the luminous transmission of the lens material. Since no two observers would, in general, get the same numbers by direct observation (because of the difference in luminosity function and chroma vision), it is desirable to express such numbers in terms of a hypothetical average normal observer. Such an observer was defined by resolutions adopted at the 1931 meeting of the International Commission on Illumination at Cambridge. (See Figure 1.)

The chromaticity of a color expressed in terms of this 1931 ICI standard observer is given by number \(x, y, z\) (called trichromatic coefficients or trilinear coordinates), which may be considered as expressing roughly the respective red, green, and blue contents of the color. Since the sum of \(x, y, \) and \(z\) always equals unity, the chromaticity is adequately specified by giving \(x\) and \(y\) only.

The chromaticity of all colors may, therefore, be represented graphically on a “mixture diagram” with values of \(y\) plotted against values of \(x\), as seen in Figure 1. Permissible values of chromaticity for the signal colors are represented by certain areas on this diagram; the boundaries of these areas may be expressed as functions of \(x\) and \(y\).

8.03 Materials

Lenses shall be made of either glass or ultraviolet stabilized plastic; the quality and processing of the material from which the lenses are made shall be of the best for the purpose. The composition shall be durable, made from the same body of the material, true to size and form and free from any defects, wrinkles, chips, or bubbles that in any way prohibit the optical assembly from meeting the candidepower and chromaticity requirements of this specification. If plastic, the material shall conform to the appropriate ASTM specification of the plastic being used.

8.04 Limits of Chromaticity Coordinates

Lenses shall be tested as specified in Section 11.00 as part of the optical assembly. The measured chromaticity coordinates shall fall within the following limits:

1. Red lens color: The value of \(y\) shall not be greater than 0.308 nor less than 0.098-x.
2. Yellow lens color: The value of \(y\) shall not be less than 0.411 nor less than 0.995-x, nor greater than 0.452.
3. Green lens color: The value of \(y\) shall not be less than 0.506-0.519x nor less than 0.150 + 1.068x nor more than 0.730-x.

8.05 Chromaticity Tests

The purpose of this section is to define the equipment and method of testing for chromaticity of the optical unit.

Trichromatic Coefficients

Trichromatic coefficients of \(x\) and \(y\) are used to define the color of light emitted by the optical unit. The lamp used in the optical unit must be operated at voltage and current necessary to supply a color temperature of CIE illuminant A at 2856 K when measurements are taken.

Equipment

A spectroradiometer, spectrophotometer, or colorimeter equipped with tristimulus filters is to be used to measure chromaticity of the optical unit. The calibration of the instrument should be tested by measurement of a set of certified limit filters used with a test lamp operating at 2856 K.

Position of Reading

The signal section containing the optical unit should be mounted on the goniometer and aimed as defined in Section 11.00. The readings should be taken when the signal is aimed at 0 degrees horizontal and 7\(\frac{1}{2}\) degrees vertical.

8.06 Tests by Approved Labs

If required by the purchaser, certification of conformance shall be furnished by the manufacturer based on results of tests made by an approved laboratory.

8.07 Labeling

The lens manufacturer shall place on each lens a label that shall indicate the lens meets the requirements of this specification.

8.08 Markings on Lens

Each lens shall have pressed on its flange the word “TOP,” if applicable, to indicate the proper positioning of the lens in the door for obtaining the light distribution required, together with the diameter and other designations including the name or trademark of the manufacturer needed for proper identification and help in purchasing replacements.

9.00 Arrow Lenses

9.01 General

For use in directing traffic moving in a certain direction during a specific interval, this specification provides for an arrow indication in a standard size signal lens of the type shown on Figure 2.

9.02 Design

All lenses shall have a uniform prismatic diffusing or equal interior surface.

9.03 Color

The lens shall be of an approved color conforming to previous sections of these standards for the particular color of the lens.

9.04 Backing

All lenses shall be covered, except for the arrow, with an opaque material of a thickness sufficient to totally hide the light from a 2000-lumen lamp placed behind it operating at rated voltage. The opaque material shall be hard and durable and shall be bonded such that it will not peel or flake when subject to the heat.
of the proper wattage signal lamp when
the lens is in use or when the lens is
washed. The arrow shall be the only il-
luminated portion of the lens.

9.05 Marking
All lenses will be clearly marked to
indicate the maximum wattage of the
lamp to be used.

10.00 Reflectors

10.01 General
1. Reflectors may be either silvered
glass, specular aluminum with
anodic coating, or metalized plastic.
2. Reflectors shall be attached to the
housing or shall be supported in such
a fashion so that the alignment of all
optical components is maintained ex-
cept when purposely disassembled.

Figure 1. Institute of Transportation Engineers color specification for traffic signal lenses. Chromaticity diagram according to 1931 Commission Internationale d'Eclairage standard observer and coordinate system.
3. The reflector support assembly if used shall be pivoted to the housing, and shall be designed so that it can be swung out or easily removed without the use of any tools.

4. The method of mounting and fastening reflectors shall be sufficiently rigid to secure proper alignment between the lens and reflector when the door is closed.

5. The construction of the signal head and its components shall be such that the fit between the reflector and the lens will eliminate all possibility of false indications.

6. Reflectors shall have an opening in the back for the lamp socket.

10.02 Glass Reflectors

1. Glass reflectors shall be made from best-quality clear glass reasonably free from bubbles or ripples with its back surface coated with evenly applied metallic silver, protected with metallic copper, and covered with backing of sufficient thickness so that light from a 2000-lumen incandescent lamp is not visible.

10.03 Aluminum Reflectors

Aluminum reflectors shall be formed or spun from 0.025-inch minimum thickness aluminum sheet. The outer edge shall be provided with a bead or flange to ensure the reflector being held to shape.

The reflecting surface shall be specular with a protective anodic coating and shall be electrochemically brightened prior to anodizing. The finished surface shall be highly resistant to corrosion, abrasion, staining, and discoloration; the long-term effects of light, heat, and aging; and shall be such that fingerprints may be easily removed with a soft cloth. In addition, the reflecting surface shall be free of scratches in the anodized coating. Acceptance testing of aluminum reflectors will, in addition to candlepower distribution and chromaticity of the optical unit, include subjecting the sample reflectors to the tests and inspection of Section 10.06.

10.04 Metalized Plastic Reflectors

Plastic reflectors shall be made of a material that will not distort when the reflector is used with a lamp of the wattage necessary to meet the candlepower distribution requirements of Section 11.00. The reflector surface, prior to being coated with reflective material, shall be reasonably free of surface imperfections. In addition, the UL non-mechanical loading temperature rating of the material shall exceed, by at least 18°F, the maximum observed temperature in the optical unit with the lamp "ON" and measured in an ambient air temperature of 77°F in accordance with UL Publication UL746B. Acceptance testing of plastic reflectors will, in addition to candlepower distribution and chromaticity of the optical unit, include subjecting the sample reflectors to the tests and inspection of Section 10.05.

10.05 Test and Inspection

The reflector shall meet the following test: the reflector shall first be immersed for 24 hours at room temperature in a solution composed of tap water and 20 percent by weight of salt. It shall then be removed from the salt solution and rinsed in clear water, after which it shall be placed in clean water that is maintained at a temperature of 185°F for 4 hours. After that heating, the reflector shall be removed from the water and placed in dry air at 185°F for 4 hours.

After the above test the reflector shall show no chipping, cracking, or softening of the coatings and shall show no separation of the coatings into layers or from the reflective surface of the reflector. Although a change in the color of the clear coating on aluminum and plastic reflectors will likely occur during this test, a reflector is considered to have failed only if there is an absence of the protective coating following this test.

If required by the purchaser, certification as to conformance to these specifications shall be furnished by the manufacturer.

11.00 Laboratory Tests & Inspection of Optical Unit

A signal section containing an optical unit of the type to be provided shall be laboratory tested. Separate tests will be conducted on each color lens. Each signal section must provide the candlepower values as called for in Section 11.04 for the color and nominal size being tested. Each optical unit will provide chromaticity coordinates which lie

Figure 2. Twelve-Inch Arrow Lens.
within the boundaries defined in Section 8 and as shown on Figure 1.

No visor is to be attached to the signal section during testing. The lighted signal shall appear to be illuminated over its entire surface when viewed from the usual angles encountered in service.

11.01 Candlepower Tests

The purpose of this section is to define the test equipment to be used, alignment procedures, and candlepower values required from the optical units.

11.02 Test Apparatus

1. Goniometer—The goniometer shall be similar to the type shown in Figure 3, but must provide the rotational axes as depicted in this figure.

   The mounting table for the signal section shall be parallel to the plane defined by the horizontal axis and the aiming axis of the goniometer ± 0.25 degrees.

2. Photometer—The response of the photoreceptor cell or photomultiplier tube of the measuring device shall be calibrated to match the human eye response curve of the CIE 1931 Standard Observer, and shall be linear in relation to signal light intensity to be encountered during testing.

3. Power Supply—A regulated power supply is to be used in the operation of the lamp while testing is being con-

ducted. Direct current power supplies are preferred for their stabilized output.

4. Lamps—Only seasoned and calibrated test lamps shall be used. Test lamps shall be seasoned for 1% of the rated lamp life but no less than 100 hours prior to calibration. The lamp envelope shall be clear with the opening between filament ends up.

   Test lamps will be operated at the voltage and current necessary to maintain a color temperature of CIE Illuminant A between 2600 K and 2856 K during the photometry testing of the signal.

   Test lamps will have a nominal 2-7/16-inch light center length for 8-inch signals and a 3-inch light center length for 12-inch signals.

   Intensity readings from the signal section being tested will be corrected by a lamp correction factor (LCF) necessary to adjust the difference of the lumen output of the test lamp at 2856 K to 665 lumens for 8-inch signals and 1950 lumens for 12-inch signals.

   For example, the LCF for a 60-watt test lamp having an output of 632 lumens is as follows:

   \[
   \text{LCF} = \frac{\text{Lumen Requirement}}{\text{Test Lamp Lumens}} = \frac{665}{632} = 1.052
   \]

   Test reading at 2½° down, 2½° left, is 352 candelas x 1.052 = 370 candelas (Report Value x LCF). Note: It is possible to have an LCF less than 1.00.

11.03 Alignment of Optical Unit for Test

1. It is recommended that the test distance between the goniometer pivot and the light sensor shall be 25 feet.

2. The aiming axis shall be perpendicular to the horizontal and vertical axes of the goniometer. (See Figure 3).

3. The light center (lamp filament) shall be located on the vertical and horizontal axes of the goniometer.

4. The front face of the signal section shall be parallel to the plane defined by the horizontal and vertical axes of the goniometer ± 0.25 degrees

5. The face of the light sensor shall be perpendicular to the aiming axis of the goniometer.

11.04 Test Points and Minimum Values

1. Above the horizontal, no maximum or minimum values of light intensity are
specified. Candlepower readings are to be taken at each of the 44 test points defined on the chart in Table 1. All values shown on the chart are minimum candlepower values below the horizontal.

2. Minimum candlepower requirements at each of the 44 test points shall not be lower than 80 percent of the values in Table 1. In addition, no more than 8 points of these test points having values less than 90 percent of Table 1 values will be allowed.

12.00 Lamps

Wattage and Output Standards

Lamps to be used in traffic signal heads must conform to the standards set forth in the Institute of Transportation Engineers’ latest Standard for Traffic Signal Lamps.

Test lamps shall be seasoned according to Section 11.102(4).

13.00 Electrical

13.01 Lamp Receptacles

The lamp receptacles shall be of heat-resisting material designed to properly position a traffic signal lamp with means for correct filament positioning. Lamp receptacles designed to properly position a medium screw base traffic signal lamp shall accommodate a lamp having a light center length of 2-7/16 inches for an 8-inch section or a light center length of 3 inches for a 12-inch section. The receptacle shall be provided with a lamp grip to prevent the lamp from working loose due to vibration. Provision shall be made on either the lamp receptacle or the reflector holder to permit rotation of the lamp so that the opening between filament ends is up and secure fastening for the retention of the lamp in that position, but shall not permit any change in position of the socket with respect to the optical center of the reflector. The metal portion of the lamp receptacle shall be compatible with brass, copper, or phosphor bronze.

13.02 Wiring

Each lamp receptacle shall be provided with two color-coded No. 18 or larger lead wires, 600-volt appliance wiring material (AWM), with 30 mil insulation rated at 190°F or with insulation that conforms to Military Specification MIL-W-16878D, Type B, with vinyl jacket rated at 190°F securely fastened to the socket, and with sufficient length to reach the terminal block with the reflector fully open. The thermoplastic insulation shall at -34°F be capable of being bent six times around a one-inch mandrel without damage to its insulating properties at rated voltage. Each lead shall have a terminal attached to its end, connection of which to the terminal block in signal shall not require any tools other than a screwdriver. A suitable terminal block for connection of the wires from the signal circuits shall be provided in the signal housing.
VTCSH Part 2: Light Emitting Diode (LED)
Vehicle Signal Modules (Interim)

Vehicle Traffic Control Signal Heads—
Part 2: Light Emitting Diode (LED)
Vehicle Traffic Signal Modules—An
Interim Purchase Specification of the
Institute of Transportation
Engineers, prepared by the ITE Joint
Industry and Traffic Engineering
Council Committee.

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International Corp, Latham, NY.
Preface

This Interim Purchase Specification has been prepared to provide guidance to agencies and individuals making decisions regarding the use of Light Emitting Diode (LED) technology as a light-source alternative to incandescent lamps.

The LED modules covered by this specification are sealed units incorporating an LED array, circuitry to drive the assembly, and those optical components needed to satisfy the light distribution pattern. Other devices using LEDs as the light source are available which screw-in to the AC socket in an existing traffic signal housing and use elements of the existing optical assembly to control the light distribution pattern. Optical assemblies made in conformance with ITE's Vehicle Traffic Control Signal (VTCSH) standard were designed to operate with a point light source located at a specified distance behind the lens. The use of non-point light source configurations was determined to be outside the scope of this committee's activity. Therefore, screw-in LED lamps used as replacements for incandescent lamps are not covered by this specification.

The specification has been written to reflect what is currently known about LED technology and the needs of the drivers on our streets and highways. While the committee responsible for its preparation believes that it reflects what is known as of the time of preparation, the committee also recognizes that LED technology is evolving rapidly and that we have more to learn about driver needs.

There were several issues upon which the committee was able to reach consensus but unable to reach a unanimous conclusion. The following specification uses the consensus values as default values. The default values used in the specification should be adequate to meet the needs of most agencies under the majority of conditions. However, those individuals using this specification should carefully review the Technical Notes included in the Appendix and discuss the issues of local concern with anticipated suppliers. Issues which should be evaluated on a local basis include:

- LED traffic signal modules use very little power and, as a result, have failed to operate properly when used with some older load switches and conflict monitors. While such occurrences are infrequent, failure modes may include flickering and complete blackouts. Jurisdictions with cabinet hardware which does not meet current NEMA standards should review Technical Note #2 and may choose to either replace older cabinet hardware or to specify modules specifically designed to be compatible with such hardware. In all cases, the matter should be discussed with the selected supplier prior to the awarding of a contract to ensure that the vendor and the agency staff fully understand the underlying issues and the performance criteria to be met before the modules are accepted by the agency.

- The operating temperature range reflected in the specification was selected to accommodate most geographical areas. Jurisdictions which use dark colored signal heads and experience temperatures in excess of 100°F should review Technical Note #3 before making a decision to rely on the default temperature range values.

- The warranty period reflected in the specification was selected as being adequate to allow sufficient energy cost savings to cover the cost of the conversion to the LED modules. Jurisdictions should review Technical Note #5 and evaluate local energy and conversion cost data before making a decision to rely on the default warranty period.

The National Cooperative Highway Research Program (NCHRP) has funded project 5-15, Visibility Performance Requirements for Vehicular Traffic Signals, to undertake human factors research to determine the light output required for vehicular traffic signals. Based on a request from ITE, NCHRP has asked that the 5-15 contractor provide preliminary, research-based findings on driver traffic signal intensity needs on an accelerated schedule. It is anticipated that those preliminary findings will be available by mid-1998. ITE will review the preliminary findings and consider revisions to this "Interim" specification. The final results of that research will not be available from NCHRP until the fall of 1999. When that research is available, ITE will review the results and make appropriate changes to this specification. Following approval of any recommended change, the word "Interim" will be removed from the title of this specification.
The purpose of this specification is to provide the minimum performance requirements for 300 mm (12 in) and 200 mm (8 in) LED traffic signal modules. 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 refers to definitions and practices described in “Vehicle Traffic Control Signal Heads” published in the Equipment and Materials Standards of the Institute of Transportation Engineers, referred to in this document as “VTCSH.” This specification applies to the circular LED vehicle signal modules purchased after June 17, 1998. Pedestrian and arrow signal modules will be addressed in updates to this specification. This specification is not restricted to any specific LED technology.
The following definitions are in addition to the definitions in the VTCSH.

1. **LED Light Source.** A single light emitting diode (LED) or an array of LEDs.

2. **LED Signal Module.** An array of LEDs and lens that are capable of providing a circular signal indication. An LED signal module shall be capable of replacing the optical unit of an existing vehicle traffic signal section.

3. **Luminous Intensity.** The luminous flux per unit solid angle in a given direction, expressed in Candels (cd).

4. **Power Consumption.** The electrical power in Watts consumed by an LED signal module when operated at nominal operating voltage and ambient operating temperature range.

5. **Volt-Amperes.** The product of root-mean-square (rms) line voltage and rms line current measured with true rms meter.

6. **Nominal Operating Voltage.** The ac rms voltage, 120VAC, at which photometric performance and power consumption are specified.

7. **Duty Cycle.** The amount of time during a specified time period that an LED signal module is energized, expressed as a percent of the specified time period.

8. **Burn-In Procedure.** The procedure by which a LED signal module is energized at an ambient temperature for a specified time duration to cause any early electronic component mortality failures to occur and to detect any component reliability problems before the product is shipped to the end user for installation.

9. **Light Stabilization Procedure.** The procedure by which an LED signal module is energized at a given temperature for a specified time duration to cause stabilization in light output.

10. **Chromaticity.** The color of the light emitted by an LED signal module, specified as x-y or x and y chromaticity coordinates on the chromaticity diagram according to the 1931 Commission Internationale d’Eclairage (CIE) standard observer and coordinate system.

11. **Long Term Luminous Intensity Degradation.** The reduction in luminous intensity that normally occurs when an LED is illuminated over an extended period of time.

12. **Power Factor (PF).** PF equals Watts divided by Volt-Ampere (VA) or the ratio of power consumption in Watts to Volt-Amperes.

13. **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.
3.1 General

LED traffic signal modules designed as retrofit replacements for existing signal lamps shall not require special tools for installation. Retrofit replacement LED signal modules shall fit into existing traffic signal housings built to the VTCSH Standard without modification to the housing.

Installation of a retrofit replacement LED signal module into an existing signal housing shall only require the removal of the existing optical unit components, i.e., lens, lamp module, gaskets, and reflector; shall be weather tight and fit securely in the housing; and shall connect directly to existing electrical wiring.

3.2 LED Signal Module

3.2.1 The retrofit LED signal module shall be capable of replacing the optical unit.

3.2.2 Tinting (Optional)—The lens shall be tinted or shall use transparent film or materials with similar characteristics.

3.2.3 The LED signal module lens may be a replaceable part without the need to replace the complete LED signal module.

3.3 Environmental Requirements

3.3.1 The LED signal module shall be rated for use in the ambient operating temperature range, measured at the exposed rear of the module, of -40°C (-40°F) to +74°C (+165°F).

3.3.2 The LED signal module shall be protected against dust and moisture intrusion per the requirements of NEMA Standard 250-1991, sections 4.7.2.1 and 4.7.3.2, for Type 4 enclosures to protect all internal LED, electronic, and electrical components.

3.3.3 The LED signal module lens shall be UV stabilized.

3.4 Construction

3.4.1 The LED signal module shall be a single, self-contained device, not requiring on-site assembly for installation into an existing traffic signal housing. The power supply for the LED signal module may be either integral or packaged as a separate module. The power supply may be designed to fit and mount inside the traffic signal housing adjacent to the LED signal module.

3.4.2 The assembly and manufacturing process for the LED signal assembly shall be designed to assure all internal LED and electronic components are adequately supported to withstand mechanical shock and vibration from high winds and other sources.

3.5 Materials

3.5.1 Materials used for the lens and signal module construction shall conform to ASTM specifications for the materials where applicable.

3.5.2 Enclosures containing either the power supply or electronic components of the signal module shall be made of UL94VO flame retardant materials. The lens of the signal module is excluded from this requirement.

3.6 Module Identification

Each individual LED signal module shall be identified for warranty purposes.

3.6.1 Each LED signal module shall be identified on the backside with the manufacturer's name and serial number.

3.6.2 The following operating characteristics shall be identified: nominal operating voltage, power consumption, and Volt-Ampere.

3.6.3 Modules shall have a prominent and permanent vertical indexing indicator, i.e., UP ARROW or the word UP or TOP, for correct indexing and orientation inside a signal housing.

3.6.4 Modules conforming to this specification, may have the following statement: "Manufactured in Conformance with the Interim Purchase Specification of the ITE for LED Vehicle Traffic Signal Modules" on an attached label.
4.1 Luminous Intensity & Distribution

4.1.1 The maintained minimum luminous intensity values for LED traffic signal modules throughout the warranty period, under the operating conditions defined in Sections 3.3 and 5.2.1, and at the end of the warranty period, shall not be less than the values shown in Table 1.

4.1.2 When operating within the temperature range specified in Section 3.3.1 during the warranty period, the maximum luminous intensity for the 8-inch or 12-inch signals shall not exceed 800 candelas for the Red, 1,600 candelas for the Green, and 3,700 candelas for the Yellow.

4.2 Chromaticity

The measured chromaticity coordinates of LED signal modules shall be between 500 nm and 650 nm, conforming to the chromaticity requirements of Section 8.04 and Figure 1 of the VTCSSH standard.

4.3 Photometric Maintenance

The manufacturer shall make available a process to test compliance of minimum intensity values in a controlled and independent laboratory during anytime in the warranty period. Alternately, the manufacturer shall make available a portable, calibrated light meter to allow for field measurement of luminous intensity of LED traffic signal modules.

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<thead>
<tr>
<th>Vertical Angle</th>
<th>8-inch Signal</th>
<th>12-inch Signal</th>
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<tbody>
<tr>
<td>2.5° Left &amp; Right</td>
<td>133 267 339</td>
<td>1571 678</td>
</tr>
<tr>
<td>2.5° Down</td>
<td>75 449 251</td>
<td>1159 501</td>
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<tr>
<td>12.5°</td>
<td>57 262 141</td>
<td>655 283</td>
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<tr>
<td>17.5°</td>
<td>26 112 77</td>
<td>355 154</td>
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<td>2.5°</td>
<td>101 466 226</td>
<td>1047 452</td>
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<td>7.5°</td>
<td>89 411 222</td>
<td>935 404</td>
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<td>12.5°</td>
<td>65 299 145</td>
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<td>27.5°</td>
<td>10 47 16</td>
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<td>6 28 20</td>
<td>94 41</td>
</tr>
<tr>
<td>27.5°</td>
<td>4 19 16</td>
<td>75 32</td>
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</tbody>
</table>
5.1 General
All wiring and terminal blocks shall meet the requirements of Section 13.02 of the VITSS standard. Two secured, color coded, 914 mm (36 in) long 600 V, 20 AWG minimum, jacketed wires, conforming to the National Electrical Code, rated for service at +105°C, are to be provided for electrical connection.

5.2 Voltage Range
5.2.1 LED signal modules shall operate from a 60±3 cycle ac line power over a voltage range from 80 Vac rms to 135Vac rms. 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 the procuring traffic authority customer has in use.

5.2.2 Nominal operating voltage for all measurements shall be 120±3 volts rms.

5.2.3 Fluctuations in line voltage over the range of 80Vac to 135Vac shall not affect luminous intensity by more than ±10 percent.

5.2.4 The LED circuitry shall prevent flicker at less than 100 Hz over the voltage range specified in Section 5.2.1.

5.3 Transient Voltage Protection
5.3.1 The signal module on-board circuitry shall include voltage surge protection to withstand high-repetition noise transients and low-repetition, high-energy transients as stated in Section 2.1.6, NEMA Standard TS-2, 1992.

5.4 LED Drive Circuitry
5.4.1 The individual LED light sources shall be wired so that a catastrophic failure of one LED light source will result in the loss of not more than 20 percent of the signal module light output.

5.5 Dimming (optional)
5.5.1 The LED signal module circuitry shall be designed to reduce the intensity of the light output in response to diminished ambient light levels. The design of the dimming circuitry shall cause all modules on the same traffic signal light circuit to operate at the same percentage of the maintained minimum luminous intensity at all times.

5.5.2 Dimming, if provided, shall diminish light output to levels established to match threshold ambient light conditions. The dimming may be in stepped increments or may be continuously variable. The minimum light output when dimmed at −2.5°V and 2.5°L and R shall not be less than 30 percent of the maintained minimum luminous intensity for the same coordinates.

5.6 Electronic Noise
The LED signal and associated on-board circuitry must meet Federal Communications Commission (FCC) Title 47, SubPart B, Section 15 regulations concerning the emission of electronic noise.

5.7 Power Factor (PF) and AC Harmonics
5.7.1 LED signal modules shall provide a power factor of 0.90 or greater when operated at nominal operating voltage, and 25°C (77°F).

5.7.2 Total harmonic distortion induced into an ac power line by an LED signal module, operated at nominal operating voltage, with a power consumption equal to or greater than 15 watts at 25°C (77°F) shall not exceed 20 percent. Total harmonic distortion induced into an ac power line by an LED signal module, operated at nominal operating voltage, with a power consumption less than 15 watts at 25°C (77°F) shall not exceed 40 percent.

5.8 Failed State Impedance (Optional)
5.8.1 The module shall be designed to sense a loss of light output due to catastrophic LED failures of between 25 and 40 percent. Loss of light output due to LED failure will not be detected for losses of less than 25 percent but will be detected for any loss of light greater than 40 percent. The unit, upon sensing a valid loss of light, shall present an impedance of 500 Kohms to the AC line.
section 6

Quality Assurance

6.1 General
6.1.1 Quality Assurance Program
LED signal modules shall be manufactured in accordance with a vendor quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) design quality assurance, and (2) production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of LED signal modules built to meet this specification.

6.1.2 Record Keeping
QA process and test results documentation shall be kept on file for a minimum period of seven years.

6.1.3 Conformance
LED signal module designs not satisfying design qualification testing and the production quality assurance testing performance requirements in Sections 6.3 and 6.4 shall not be labeled, advertised, or sold as conforming to this specification.

6.2 Manufacturers Serial Numbers
Each LED signal module shall be identified by a manufacturer's serial number for warranty purposes. Identification of the component and sub-assembly level may be required if the reliability and performance of the module must be traceable to the original item manufacturer(s).

6.3 Production Quality Assurance (QA) Testing
All new LED signal modules shall undergo the following Production Quality Assurance testing prior to shipment. Failure of any LED signal module to meet requirements of these QA tests shall be cause for rejection. QA test results shall be maintained per the requirement of Section 6.1.2.

6.3.1 Signal Module Burn-in
All LED signal modules or the electronic circuitry sub-assemblies, including all LEDs, shall be energized for a minimum of 24 hours, at 100 percent on-time duty cycle, in an ambient temperature of 60°C (+140°F).

Any failure within an LED signal module after burn-in shall be cause for rejection.

6.3.2 Maintained Minimum Luminous Intensity
All LED signal modules shall be tested for maintained minimum luminous intensity after burn-in. A single point measurement (at: -2.5°C, 2.5°C R or L) with a correlation to the intensity requirements of Table 1 in Section 4.1.1 may be used. The LED signal module shall be operated at nominal operating voltage and at an ambient temperature of 25°C (77°F).

LED signal modules not meeting maintained minimum luminous intensity requirements as per Table 1 in Section 4.1.1 shall be rejected.

6.3.3 Power Factor
All LED signal modules shall be tested for power factor after burn-in per the requirements of Section 5.7.1. A commercially available power factor meter may be used to perform this measurement.

6.3.4 Current
All LED signal modules shall be measured for current flow in Ampere after burn-in. The measured current values shall be compared against current values resulting from design qualification measurements in Section 6.4.1. Measured current values in excess of 120 percent of the design qualification current values shall be cause for rejection.

6.3.5 Visual Inspection
All LED signal modules shall be visually inspected for any exterior physical damage or assembly anomalies. Careful attention shall be paid to the surface of the lens to ensure there are no scratches (abrasions), cracks, chips, discoloration, or other defects. Any such defects shall be cause for rejection.

6.4 Design Qualification Testing
Design qualification testing shall be performed on new LED signal module designs, and when a major design change has been implemented on an existing design. The minimum sample quantity of LED signal modules shall be as stated for each test. Failure to meet requirements of any of these tests shall be cause for rejection.

Testing shall be performed once every 5 years or when the module design or LED technology has been changed. Test data shall be retained by the testing laboratory and the LED signal module manufacturer for a minimum period of 5 years.

6.4.1 Burn-in
LED signal modules shall be energized for a minimum of 24 hours, at 100 percent on-time duty cycle, in an ambient temperature of +60°C (+140°F) before performing any design qualification testing. Any failure within an LED signal module after burn-in shall be cause for rejection.
6.4.2 Maintained Minimum Luminous Intensity

6.4.2.1 After burn-in, a random sample of six LED signal modules shall be tested for maintained minimum luminous intensity at each of the 44 points indicated in Table 1, Section 4.1.1. These measurements shall be recorded at an ambient temperature of 25°C after the signal has been operated for 60 min.

6.4.2.2 After burn-in, a random sample of six LED modules shall be tested for maintained minimum luminous intensity. Signals to be tested shall be mounted in a temperature testing chamber so that the lensed portion of the signal is outside the chamber and all portions behind the lens are within the chamber at a temperature of 74°C (165°F). The air temperature in front of the lens of the signal shall be maintained at a minimum of 49°C (120°F) during all tests.

Signals shall be tested for luminous output at 74°C, allowing the signals to achieve thermal equilibrium for 60 minutes, while the signal is energized at nominal operating voltage, at a 100% duty cycle, a single luminous intensity measurement at (-2.5 V, 2.5°R or L) shall be recorded.

A single point correlation measurement, accounting for measurement variables, shall be made at 25°C (77°F). A measurement shall be made at 74°C (165°F) (lens at 49°C (120°F)). The 74°C measurement factored to the 25°C measurement shall be able to be correlated to the requirements of Table 1, Section 4.1.1. Signal modules not meeting this correlation shall be cause for rejection.

6.4.3 Chromaticity

A sample of two LED signal modules shall be measured for chromaticity per the requirements of Section 4.2. A spectroradiometer shall be used for this measurement. The ambient temperature for this measurement shall be +25°C (+77°F).

6.4.4 Electrical

6.4.4.1 Current. A sample of six LED signal modules shall be measured for current flow in Amperees. The measured current values shall be used for quality comparison of Production Quality Assurance current measurements on production modules. The manufacturer shall provide information (charts, tables, and/or graphs) on the variation in current over time within operating temperatures for the period of the warranty.

6.4.4.2 Power Factor (PF). A sample of six LED modules shall be measured for power factor per the requirements of Section 5.7.1. A commercially available power factor meter may be used to perform this measurement.

6.4.4.3 Total Harmonic Distortion (THD). A sample of six LED modules shall be measured for total harmonic distortion per the requirements of Section 5.7.2. A commercially available total harmonic distortion meter may be used to perform this measurement.

6.4.4.4 Electronic Noise. Sample LED signal modules shall be tested per the requirements of Section 5.6, with reference to Class A emission limits referenced in Federal Communications Commission (FCC) Title 47, SubPart B, Section 15.

6.4.4.5 Controller Assembly Compatibility.

Due to the low load current draw and high off-state impedance of LED signal modules, the following design qualification tests shall be performed to ensure the signal module design is compatible and operates properly with load current switches and conflict monitors in NEMA and Type 170 traffic signal control units.

Before performing the following testing, an LED signal module manufacturer should ascertain which type of signal controller unit(s) the procuring traffic authority customer has in use and tailor these tests to meet the requirements of that type of controller unit(s).

6.4.4.5.1 Load Switch Compatibility. A sample of six LED signal modules shall be tested for compatibility and proper operation with load current switches. Each LED signal module shall be connected to a variable ac voltage supply. The ac line current into the LED signal module shall be monitored for sufficient current draw to ensure proper load switch operation while the voltage is varied from 80 V rms to 135 V rms. Failure of the current draw to ensure proper load current switch operation shall be cause for rejection.

6.4.4.5.2 Signal Conflict Monitor Compatibility. A sample of six LED signal modules shall be tested for compatibility and proper operation with signal conflict monitors. Each LED signal module shall be operated from a 135 V ac voltage supply. A 19.5 kΩ resistor shall be wired in series in the hot line between the LED signal monitor and the ac power supply. A single-pole-single-throw switch shall be wired in parallel across the 19.5 kΩ resistor. A 220 kΩ shunt resistor shall be wired between the hot line connection and the neutral line connection on the LED signal module. Conflict monitor compatibility shall be tested by measuring the voltage decay across the 220 kΩ shunt resistor as follows: The single-pole-single-throw switch shall be closed, shorting out the 19.5 kΩ resistor, allowing the ac power supply to illuminate the LED signal module. Next the switch shall be opened, and the voltage across the 220 kΩ shunt resistor shall be measured for a decay to a value equal to or less than 10 V rms within a time period equal to or less than 100 milliseconds. This test shall be repeated a sufficient number of times to ensure testing occurs at the peak of the ac line voltage cycle.
A voltage decay across the 220 kΩ shunt resistor to a value greater than 10 V rms or a decay time to 10 V rms greater than 100 milliseconds shall be cause for rejection.

6.4.4.6 Nondestruct Transient Immunity. A sample of six LED modules shall be tested for transient immunity using the procedure described in Section 2.1.8, NEMA Standard TS 2-1992.

6.4.5 Mechanical Vibration
Mechanical vibration testing shall be performed on a sample of three LED signal modules per MIL-STD-883, Test Method 2007, using three 4-minute cycles along each x, y, and z axis, at a force of 2.5 Gs, with a frequency sweep from 2 Hz to 120 Hz. The loosening of the lens, of any internal components, or other physical damage shall be cause for rejection.

6.4.6 Environmental

6.4.6.1 Temperature Cycling. Temperature cycling shall be performed on a sample of three LED signal modules per MIL-STD-883, Test method 1010. The temperature range shall be per Section 3.3. A minimum of 20 cycles shall be performed with a 30-minute transfer time between temperature extremes and a 30-minute dwell time at each temperature. Signals under test shall be non-operating. Failure of a module to function properly or any evidence of cracking of the module lens or housing after temperature cycling shall be cause for rejection.

6.4.6.2 Moisture Resistance. Moisture resistance testing shall be performed on a sample of three LED signal modules per NEMA Standard 250-1991 for Type 4 enclosures. Any evidence of internal moisture after testing shall be cause for rejection.
7.1 Certificate of Compliance
Manufacturers shall provide a Certificate of Compliance to this specification for each shipment of LED signal modules to an end user. Each LED signal module shall be identified per Section 6.2.

7.2 Warranty Provisions
Manufacturers shall provide the following minimum warranty provisions:

7.2.1 LED signal modules shall be replaced or repaired if an LED signal module fails to function as intended due to workmanship or material defects within the first 60 months from the date of delivery.

7.2.2 LED signal modules which exhibit luminous intensities less than the minimum values specified in Section 4.1.1 within the first 36 months of the date of delivery shall be replaced or repaired.
Dimming (optional)

The specification provides the user the option to require dimming capability on LED signal modules in response to ambient lighting conditions.

The technology used to dim may be incorporated into the design of the LED traffic signal module. Where dimming is currently provided at an intersection, the existing sensing device can be used to trigger dimming of new LED modules. Note of CAUTION: The use of devices or technologies designed to dim incandescent traffic signal lamps may damage LED traffic signal modules or cause the modules to malfunction. Purchasers should inform the supplier of the LED modules of their intent to use the existing sensing device and of the nature of the existing control mechanisms and hardware characteristics.
Technical Note #2: Compatibility of LED Modules with Load Switches and Conflict Monitors

Background
Since LED modules use very little power, some agencies have encountered incompatibility problems with existing load switches and signal conflict monitors in the field, especially if the field equipment is older. Such problems may include flickering of the LED modules, or complete blackouts. Though the occurrence is not very common, it is difficult to estimate the number of incompatible units in the field and the actual potential for such a problem. An agency may choose to replace field equipment, or specify a module that will be compatible with its field equipment, whichever is more economical or feasible to the agency.

Recommendation
While the incompatibility problem with conflict monitors may be avoided by conducting the test specified in section 6.4.4.5.2 of the specification, load switches operating at the reduced levels of LED module load current may still fail to operate correctly. If the agency chooses to specify a compatible unit, the following verbiage may be included in the specifications:

"A sample of LED signal modules shall be tested for compatibility with existing load switches. Each signal module shall be connected to an AC voltage supply between the values of 80 Vac and 135 Vac, and the line current shall be measured under conditions where the LED signal module has the minimum power consumption. Within each half line cycle, the load current shall temporarily exceed 150 mA to ensure proper triggering of the load switch. The load current shall, after reaching 150 mA, remain continuously above 100 mA for a time span long enough to ensure that the rms load current during this time span is at least 50% of the total rms load current."

It may be wrongly concluded that this requirement may increase the wattage of the LED unit significantly. Please note that the current needed for proper triggering and holding of load switch triacs will not require a continuous high current level but a modification in the current profile. This uneven flow may increase the total harmonic distortion (THD) in the current drawn. This specification will allow for design of low wattage units, if the maximum THD requirement for such low wattage units is set at 0.4, unlike high power units, where the maximum should be 0.2 (see section 3.7.2 of the specification).
Technical Note #3:
Operating Temperature Range and the Impact of Environmental Conditions

Background
An operating temperature range is included in the Interim Specification that is based on standards typical in the electronics industry. Since the light output of LEDs diminishes as ambient temperature increases, internal temperatures substantially in excess of the 165°F upper limit included in the specification could result in unacceptable LED module performance. A study undertaken by ITE as a part of the specification development process indicates that the internal temperature within a traffic signal section is likely to exceed the upper limit of the operating range under certain combinations of signal material, signal color, solar load, and ambient temperature.

Established study boundaries included the following:

- Both 8-inch and 12-inch heads were tested.
- Traffic signal head types included aluminum and polycarbonate both yellow and black in color.
- Ambient temperatures of 90° to 120°F were evaluated.
- Solar loads of 900, 960, 985 and 1,000 watts/m² (representative of those experienced at latitudes of 20°, 30°, 40°, and 50° respectively) were evaluated.

In addition to the basic signal head, color, and size combinations previously described, one 8-inch head and one 12-inch head were equipped with vents to permit convection cooling within the signal head cavities. Vents were installed in the back of the red sections and at the bottom of the green sections. The vents used were 2-inches and 3-inches in diameter for the 8-inch and 12-inch heads respectively.

Conclusions
The underlying question, which prompted ITE to initiate the testing, was “Are there environmental and/or geographic conditions that present operating temperatures and conditions beyond what is reflected in the interim specification which would cause an additional reduction in the luminous intensity of an LED module?”

The following test conditions produced temperatures internal to the red indication housing which exceeded the upper limit of the operating temperature range defined in the interim specification:

- Solar loads equivalent to those typically encountered at 40° or less latitude with ambient temperatures of 110°F or higher within 8-inch black plastic heads
- Solar loads equivalent to those typically encountered at 30° or less latitude with ambient temperatures of 120°F or higher within 12-inch black plastic heads

None of the other color/material combinations resulted in internal temperatures in excess of 164°F at any solar load/ambient temperature combination. Venting of the signal heads was found to be an effective means of reducing temperatures within the heads to a point within the operating temperature range reflected in the specification.

Recommendation
Agencies which use 8-inch black plastic signal housings and are located at or less than 40° latitude and regularly experience ambient air temperatures in excess of 110°F should approach the use of LED modules (with an upper limit operating temperature of 164°F) with caution. The use of 12-inch modules in black plastic housings should also be approached with caution but the critical range is limited to 30° latitude or less and an ambient air temperature of 120°F or higher.

Modification of the operating temperature range to provide an upper limit of 81°C (178°F) would result in maintenance of the required light output under all of the conditions tested. The use of vents or other means of controlling the internal temperature may be an appropriate alternative to modifying the operating temperature range.
Technical Note #4: Design Qualification Testing in an Environmental Chamber

Introduction
This technical note addresses the issues implicit in Section 6.4.2.2 Design Qualification Testing. Specifically, this note relates to the testing methodology employed to ascertain compliance with the maintenance of the specified minimum luminous intensity for LED modules at the specified temperatures. The operating temperature for this test has been established to be 74°C (165°F) for the air at the rear of the LED module, and 49°C (120°F) for the air in front of the module.

A method to establish this “dual environment” for design qualification testing and/or subsequent validation of production samples is outlined below.

Test Hardware Description
The testing hardware described below involves an adaptation of existing environmental testing chambers which are normally configured to provide an adjustable hot or cold environment and have provisions for visual or instrumental inspection.

On page 14 is a diagram showing how to achieve a dual temperature environment with an existing commercial environmental test chamber. A plywood chamber divider, with provision for mounting one or more LED signal modules, is equipped with adequate edge insulation to partially isolate the front partition of the test chamber from the rear section.

The front chamber section can be maintained at the required 49°C (120°F) while the rear portion is held at 74°C (165°F) by applying the correct amount of insulation to the chamber divider wall. This passive method, while certainly very low in cost, requires a fair amount of experimentation. In light of currently available, moderately priced temperature controllers, an active system is clearly preferable and is described below.

Shown in the page 14 diagram, a small centrifugal blower is used to induce ambient air (nominally 20°C [68°F]) into the front portion of the chamber. This ambient air is used to dilute the heated air that collects in the forward chamber due to heat transfer through the divider wall. A diffuser allows for proper air mixing, and an exhaust port permits heated air to escape from the front chamber to ambient. As noted, a self-optimizing (auto-tuning) P.I.D. set point controller is used to maintain the front chamber at an air temperature of 49°C (120°F). A type K thermocouple, mounted nominally 20 mm from the front lens of the LED module, may be used as the sensing element. The temperature controller specified can be used to operate the small blower in on-off, time proportioning mode so that the preset (49°C) air temperature is maintained. All heat addition is due to conduction through the divider wall, from the environmental chamber (74°C), and minimally from the operating LED module. Front chamber temperature is maintained by controlling the heat loss by means of ambient air induction.

Note that while this approach is very easy to implement, its success is only possible because of the sophisticated, yet low-cost controller. The specified microprocessor-based, auto-tuning controller (or equivalent device) allows for (2°C set point maintenance over a wide range of operating variables. Establishing the correct loop parameters is made easier because the controller learns the optimal control variables in under two hours of operation. These settings are then stored in memory and are automatically applied to all subsequent tests that require similar testing environments.
8.4a Figure 1: Diagram of Proposed Testing Hardware

Specified Components:
1. Chamber partition: Plywood, 3/4 inch to fit chamber interior dimensions
2. Insulation: Rigid Styrofoam insulation board, 1 in. (Dow)
3. Blower: Ametek 11-6679-100; 100 cfm nom., 2 in. discharge port (throttle to 1 inch dia. discharge)
4. Temperature controller: Watlow 965 Series; type K thermo couple
Technical Note #5
Warranty

Warranty
The specification includes a suggested warranty period of 36 months for the loss of luminous intensity. The time period selected is based on an estimate of the module life required to recover the cost of the module through savings from reduced energy use. Users may specify a warranty period that better meets their needs.

The warranty period may be determined by the users from a life cycle cost analysis procedure that reflects local energy costs and other factors such as the cost of labor and equipment to replace modules that fail, and the cost of routine and emergency replacement of incandescent lamps.
Pedestrian Traffic Control
Signal Indications

This report was approved as an Equipment Standard of the Institute of Transportation Engineers in March 1985. It supersedes the Proposed Standard dated July 1984.

This equipment standard was developed and approved in accordance with formally adopted Institute procedures which are designed to help assure that all interested parties are given opportunities to provide input. All input received has been considered in order that the report would represent the best consensus obtainable on the state of the art at the time of approval.

Any requests for revisions must be submitted to the Director of Technical Affairs; Institute of Transportation Engineers; 525 School St. S.W., Suite 410; Washington, D.C. 20024.

The Technical Council Committee 4S-11 was responsible for the development of this standard. Members of ITE Technical Council Committee 4S-11 were: Barry W. Fairfax (A); (Chairman); James S. Gould (M); Vernon H. Waite (M); James L. Brown (M); Craig E. Leiser (M); H. Douglas Robertson (M). Chairman of Technical Council Department 7 — Equipment Standards is Herman E. Haenel, and Frank Dolan is Assistant Department Chairman.

Certain individual volunteer members of the Institute Equipment Standards developing bodies are employed by Federal agencies, other governmental offices, private enterprise, or other organizations. Their participation in these activities does not constitute endorsement by any government agency or other organization of any of the Institute Equipment Standards developing bodies or any Institute reports which are developed by such bodies.

1.0 Purpose

This standard sets forth minimum acceptable physical, electrical, and visual characteristics for pedestrian traffic control signal indications. It is not intended to be used as, or in lieu of, a purchase specification, however, all purchase specifications should conform to or include the criteria contained herein.

2.0 Definitions

The following are definitions of words and terms used in this standard.

2.1 Message Bearing Surface (MBS)

The projected area of a pedestrian traffic control signal upon or from which the letter or symbolic message is displayed when illuminated. The message bearing surface may be lens alone or it may be a combination of lens and opaque surrounding area, such as the front of the door of a signal housing or back plate.

2.2 Pedestrian Traffic Control Signal

An electrically operated traffic control device composed of one or more indications which is erected for the exclusive purpose of directing pedestrian traffic at signalized locations.

2.3 Pedestrian Traffic Control Signal Indication

A visual image composed of a word or words, or a symbol which directs and controls pedestrians at a signalized location.

2.4 Signal Face

An assembly containing one or more message bearing surfaces.

3.0 Physical and Electrical Characteristics

3.1 Shape

The message bearing surface of a pedestrian traffic control signal shall be rectangular in shape.

3.2 Size

The minimum size of the message bearing surface of a pedestrian traffic control signal indication shall be determined by the length of the intended crosswalk but in no case shall it be less than 9" x 9" (22.9cm x 22.9cm). The sizes of the messages shall be in accordance with the dimensions given in Tables 1 and 2.

3.3 Light Source

Pedestrian traffic control signal indications shall be internally illuminated.

3.4 Operating Voltage

Pedestrian traffic control signal indications shall operate over a range of 105 VAC to 130 VAC, 60 hertz.

4.0 Message

4.1 Symbols

When symbols are used in lieu of
words, the "WALKING PERSON" symbol (Figure A) shall have the same meaning as the word "WALK." The "HAND" symbol (Figure B) shall have the same meaning as the words "DON'T WALK." The height and width of each symbol shall be as shown in Table 1.

4.2 Words

4.2.1 When words are used to convey the pedestrian traffic control signal indication, only the words "WALK" and "DON'T WALK" shall be used in the United States of America or equivalent words in countries whose principal language is other than English.

4.2.2 Letter style and shape shall maximize legibility and shall be generally consistent with either the 1966 edition of "Standard Alphabets for Highway Signs" or the 1977 Metric Edition of the same book as published by the Federal Highway Administration of the United States Department of Transportation. Letter height and stroke width shall be as shown in Table 2. Letter width shall be greater than Series B and less than Series D alphabet, and shall fit within the dimensions for width shown in Table 2.

4.2.3 All letters shall be uppercase.

4.3 Mask

All message bearing surfaces shall have flat black surface over the entire projected area except where the message or symbol is located. Where the message bearing surface is a glass lens or other translucent material, the material used to mask the lens shall be hard and durable and shall bond such that it will not peel or flake when subjected to the heat of a signal lamp when the lens is in

Table 1. Symbol Message

<table>
<thead>
<tr>
<th>Class</th>
<th>MBS*</th>
<th>Nominal Message Bearing Surface Size (Height x Width)</th>
<th>Crosswalk Length</th>
<th>Minimum Message Size Height</th>
<th>Minimum Message Size Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>9&quot; x 9&quot; (22.9cm x 22.9cm)</td>
<td>60' max</td>
<td>6&quot;</td>
<td>3.5&quot;</td>
</tr>
<tr>
<td>2</td>
<td>2***</td>
<td>12&quot; x 12&quot; (30.5cm x 30.5cm)</td>
<td>&gt;60'</td>
<td>9&quot;</td>
<td>5.25&quot;</td>
</tr>
<tr>
<td>3****</td>
<td>1</td>
<td>16&quot; x 18&quot; (40.6cm x 45.7cm)</td>
<td>&gt;60'</td>
<td>11&quot;</td>
<td>7&quot;</td>
</tr>
<tr>
<td>4****</td>
<td>1</td>
<td>16&quot; x 18&quot; (40.6cm x 45.7cm)</td>
<td>&gt;60'</td>
<td>12&quot;</td>
<td>7.5&quot;</td>
</tr>
</tbody>
</table>

*MBS—Message Bearing Surface

**Class 2, 3, & 4 may be used when crosswalk length is less than 60' (18.3 meters)

***One MBS may be used for fiber optic or dual indication displays.

****These dimensions apply to side by side symbols. If the "HAND" symbol is displayed above the "WALKING PERSON" symbol, these dimensions will vary, but in no instance shall the minimum message sizes be reduced.

Table 2. Word Message

<table>
<thead>
<tr>
<th>Class</th>
<th>MBS*</th>
<th>Nominal Message Bearing Surface Size (Height x Width)</th>
<th>Crosswalk Length</th>
<th>Minimum Message Size Height</th>
<th>Minimum Message Size Width</th>
<th>Stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>9&quot; x 9&quot; (22.9cm x 22.9cm)</td>
<td>60' max</td>
<td>3&quot;</td>
<td>6&quot;</td>
<td>0.375&quot;</td>
</tr>
<tr>
<td>2</td>
<td>2+</td>
<td>12&quot; x 12&quot; (30.5cm x 30.5cm)</td>
<td>&gt;60'</td>
<td>4.5&quot;</td>
<td>9&quot;</td>
<td>0.5&quot;</td>
</tr>
<tr>
<td>3**</td>
<td>1</td>
<td>16&quot; x 18&quot; (40.6cm x 45.7cm)</td>
<td>&gt;60'</td>
<td>4.5&quot;</td>
<td>12.5&quot;</td>
<td>0.625&quot;</td>
</tr>
<tr>
<td>4***</td>
<td>1</td>
<td>16&quot; x 18&quot; (40.6cm x 45.7cm)</td>
<td>&gt;60'</td>
<td>5.5&quot;</td>
<td>14.5&quot;</td>
<td>0.625&quot;</td>
</tr>
</tbody>
</table>

*MBS—Message Bearing Surface

**3-line message

***2-line message

****Class 2, 3, & 4 may be used when crosswalk length is less than 60 feet (18.3 meters)

+ One MBS may be used for fiber optic or dual indication displays.
use or when the lens is washed. The legend or symbol shall be the only illuminated portion of the lens.

4.4 Display

4.4.1 Pedestrian traffic control signal faces may be constructed such that both messages may be displayed from the same message bearing surface or each message may be displayed from separate but adjacent message bearing surfaces.

4.4.2 Where a single message bearing surface is used to display both messages, the illumination of one message shall not result in the illumination of the other message. The “WALKING PERSON” symbol (Figure A) may be located either to the right of or below the “HAND” symbol (Figure B). The “WALK” message may be on the “WALK” portion of the “DON’T WALK” message or a third line located below the two lines of the “DON’T WALK” message.

4.4.3 Where separate message bearing surfaces are used, they shall be assembled in such a manner that the “WALKING PERSON” symbol (Figure A) is located below the “HAND” symbol (Figure B). The “WALK” message shall be located below the “DON’T WALK” message. Separation between two message bearing surfaces (MBS) shall be no greater than necessary to couple the housings together.

4.5 Legibility

4.5.1 The lighted signal shall be illuminated over the entire message bearing surface without shadows when viewed anywhere from 10 degrees left through 10 degrees right of a line perpendicular to the message bearing surface.

4.5.2 There shall be four classes of pedestrian signals. The lowest numerical class is intended for the shortest crosswalks and least demanding applications while the highest numerical class is intended for universal use including the longest crosswalk and most demanding application. The characteristic of each class shall be as shown in Table 1 and Table 2.

4.6 FailSAFE

The light source shall be designed and constructed so that in case of an electrical or mechanical failure of the word “DON’T,” the word “WALK” of the “DON’T WALK” message will also remain dark.

5.0 Visual Characteristics

5.1 Sun Phantom

All pedestrian traffic signal control signal faces shall be equipped with a screen, visor or other device which minimizes the optical illusion, known as sun phantom, which causes extinguished messages to appear to be illuminated. All physical devices used to minimize sun phantom shall have a lusterless black surface.

5.2 Message Visibility

The pedestrian indications should attract the attention of, and be readable to, a viewer (both day and night) at all distances from 10 feet (3m) to the full width of the area to be crossed.

5.3 Color

5.3.1 The standard colors for pedestrian traffic control signals shall be Portland Orange and White for the “DON’T WALK” (hand) and “WALK” (walking person) indications, respectively. The basis for determining these colors shall be the system developed by the Commission International d’Eclairage (CIE). Using this system, the chromaticity of a color is expressed in terms of two values identified as x and y. Equations using these two values define the range of the Portland Orange and White colors. Refer to Figure C.

5.3.2 In terms of the CIE values, the two acceptable colors shall be defined as:

5.3.2.1 PORTLAND ORANGE (INCANDESCENT OR LUMINOUS TUBE

At the time this standard was developed data did not exist to establish minimum required light source luminance levels. ITE has requested the Federal Highway Administration to conduct this research.

Figure C. Institute of Transportation Engineers Pedestrian Signal Color Specification. Chromaticity diagram according to 1931 Commission International d’Eclairage Standard Observer Coordinate System.
SOURCE): The value of \( y \) shall not be greater than 0.390 and shall not be less than 0.331, nor less than 0.997 - \( x \).

5.3.2.2 WHITE (INCANDESCENT SOURCE): The value of \( x \) shall not be less than 0.390 and shall not be greater than 0.430. The maximum value of \( y \) shall be the Blackbody (Planckian) Locus plus 0.005 or 0.4775\( (x) + 0.2012 \), whichever is greater. The minimum value of \( y \) shall be the Blackbody (Planckian) Locus minus 0.005 or 0.4775\( (x) + 0.182 \), whichever is less.

5.22.3 WHITE (LUMINOUS TUBING SOURCE): The value of \( x \) shall not be less than 0.280 and shall not be greater than 0.320. The maximum value of \( y \) shall be the Blackbody (Planckian) Locus plus 0.015 or 1.055\( (x) + 0.0072 \), whichever is greater. The minimum value of \( y \) shall be the Blackbody (Planckian) Locus minus 0.005 or 1.055\( (x) - 0.0128 \), whichever is less.

6.0 Certification Tests

6.1 Sample

6.1.1 At least one sample pedestrian traffic control signal per manufacturer's product line equipped with the exact source of light for which the unit was designed shall be tested for compliance with this standard as stipulated below.

6.1.2 For color testing, the visor and/or sun phantom screen shall be removed but otherwise the unit shall be complete.

6.2 Independent Testing Laboratory

The required certification tests shall be performed by a qualified independent testing laboratory.

6.3 Test Instrument Calibration

Instruments for color testing shall have been previously calibrated using National Bureau of Standards traceable lamps and filters. Calibration shall be rechecked at the time of testing within the color regions being measured, for an absolute accuracy of \( \pm 0.005x \) and \( \pm 0.005y \) for chromaticity measurements. The actual deviation obtained during the rechecks should be added or subtracted from the results accordingly.

6.4 Written Certification

Written certification that the product line complies with this standard shall be prepared by the independent testing laboratory and maintained on file by the Manufacturer. The Manufacturer shall make copies available to the Purchaser upon request.

6.5 Test Voltage

6.5.1 During the measurement of color of a pedestrian traffic control signal indication using an incandescent lamp or lamps as a light source, the voltage to the lamp(s) shall be maintained so as to produce a color temperature between 2500°K and 2700°K.

6.5.2 During the measurement of color of a pedestrian traffic control signal indication using luminous tubing as the light source(s), the voltage to the transformer primary shall be maintained at 120 VAC (\( \pm \frac{1}{2} \) VAC.)

6.6 Color

Testing for correctness of color shall be made by use of a tristimulus colorimeter or spectroradiometer such as (but not limited to):

* Beckman Model DR-1A with Davidson & Hennedinger Model 132-DE Tristimulus Integrator.
* Spectra Pritchard Model 1980A with optional Tristimulus Filters.
* TRI-RAD Model KCS-14 with capability to standardize with calibration sources other than 2556K.

7.0 Labeling

The manufacturer shall permanently label or mark, on the interior of each and every pedestrian traffic control signal, the type and power (wattage) of the light source and the nominal voltage for which the unit was designed. The label or mark shall read, "USE _____ WATT, _____ VOLT, _____ HOUR, TRAFFIC SIGNAL LAMP," or an equivalent descriptive phrase.
This report was approved as a Revised Standard of the Institute of Transportation Engineers by the ITE International Board of Direction in August 1981, in concurrence with the Institute's Technical Council. It supersedes the Tentative Revised Standard dated February, 1979.

The Standard was developed by Technical Council Committee 4L-S. Committee members were: Curtis G. Fields (A); Sheldon I. Pivrik (F); William Schepers, Jr. (F); Joe Viracola; Harold P. Garfield (A); Donald E. Hollo- man (M); Lionel M. Rodgers (F); Walter E. Schwanhauser (M); Wayne N. Volk (FL); and Herman Haenel, Chairman.

VEHICLE DETECTORS

A. Purpose
The purpose of the following Sections is to set up standard specifications for loop, magnetic, magnetometer, radar and ultrasonic (sonic) vehicle detectors.

B. Definitions
Terms used in the following Sections that are not specifically defined within these specifications shall be as those provided in the National Electrical Manufacturers Association (NEMA) Standards Publication No. TS 1-1976, "Traffic Control Systems." The following terms are taken from and/or are consistent with the terms provided in the NEMA Standard.

1. Actuation. The operation of any type of detector.
2. Amplifier, Detector. A device that is capable of intensifying the electrical energy produced by a sensor.
3. Antenna. The radiating or receiving elements utilized in transmitting or receiving electromagnetic waves.
4. Detection.
   a. Passage Detection. The ability of a vehicle detector to detect the passage of a vehicle moving through the detection zone and to ignore the presence of a vehicle stopped within the detection zone.
   b. Presence Detection. The ability of a vehicle detector to sense that a vehicle, whether moving or stopped, has appeared in its field.
5. Detection Zone. That area of the roadway within which a vehicle will be detected by a vehicle detector.
6. Vehicle Detector. A device for indicating the presence or passage of vehicles including sensor, lead-in cable and detector unit.
   a. Loop Detector. A detector that senses a change in inductance of its inductive sensor loop caused by the passage or presence of a vehicle in the detection zone of its sensor.
   b. Magnetic Detector. A detector that senses changes in the earth's magnetic field caused by the movement of a vehicle in the detection zone of its sensor.
   c. Magnetometer Detector. A detector that measures the difference in the level of the earth's magnetic forces caused by the passage or presence of a vehicle in the detection zone of its sensor.
   d. Radar Detector. A detector that is capable of sensing the passage of a vehicle through its field of emitted microwave energy.
   e. Ultrasonic Detector. A detector that is capable of sensing the passage or presence of a vehicle through its field of emitted ultrasonic energy.
7. Detector Mode. A term used to describe the conditions of occurrence of a detector output.
   a. Pulse Mode. Detector produces a short output pulse when detection occurs.
   b. Continuous-presence Mode. Detector output continues if any vehicle (first or last remaining) remains in the field of influence.
   c. Limited-presence Mode. Detector output continues for a limited period of time if vehicles remain in the field of influence.
8. Lead-in Cable. The electrical cable which serves to connect the sensor to the input of the detector unit.
9. Output
   a. Carryover Output. The ability of a detector to continue its output for a selectable predetermined length of time following an actuation.
   b. Delayed Output. The ability of a detector to delay its output for a selectable predetermined length of time during an extended actuation.
10. Power Supply. The part of the detector which furnishes the necessary DC electrical energy for the detector circuit.
12. Transceiver. That portion of an ultrasonic detector which furnishes the necessary electrical energy to the transducer, amplifies and discriminates all reflected signals returned from the transducer, and provides detection output.
13. Transducer. A sensor which transmits energy to the detection zone and interprets the signal received from the detection zone.
14. Transmitter. That portion of a detector which transmits energy to a sensor.
15. Vehicles. Every device in, upon or by which any person or property is or may be transported or drawn upon a
highway, excepting (1) devices used exclusively upon stationary rails or tracks, (2) devices moved by human or animal power, and (3) motorized devices with an engine capacity of less than 100cc.*

C. Scope
These specifications are intended to cover the above named vehicle detector requirements as described in the following Sections:
- General Requirements for Vehicle Detectors
- Loop Vehicle Detectors
- Magnetic Vehicle Detectors
- Magnetometer Vehicle Detectors
- Radar Vehicle Detectors
- Ultrasonic Vehicle Detectors

The specifications will not include a description of the lead-in cable from the detector to the sensor.

SECTION I
GENERAL REQUIREMENTS FOR VEHICLE DETECTORS

Note: All subsections and paragraphs identified with "(PURCHASER)" indicate required decision and action by the purchaser in the development of an item description and/or supplementary specification for use by a Bidder for preparing his bid. All subsections and paragraphs identified with "(OPTIONAL)" are provided only if specifically called for by the purchaser.

1.0 Purpose
It is the purpose of this Section of the specifications to set forth requirements applicable to all detectors described.

* It is recognized that the above definition for "vehicles" is not identical to the vehicle definition contained in the United States Uniform Vehicle Code (UVC). The UVC definition does not exclude devices moved by human or animal power or motorized devices with an engine capacity of less than 100ccs. The ITE Revised Standard for Vehicle Detectors sets forth standard specifications for vehicle detectors that have been used to detect primarily those vehicles that satisfy this standard's definition of "vehicle" as contained in item B.15 above. However, some of the vehicle detectors described in this standard may be capable of detecting "devices moved by human or animal power" and/or "motorized vehicles with an engine capacity of less than 100ccs." Therefore, ITE has initiated the development of an Institute recommended practice dealing with the application of vehicle detectors to detect other vehicles included in the UVC Definition. This recommended practice will provide guidance on which vehicle detectors to use in order to detect specific vehicle types, guidance on how to use the vehicle detectors to detect specific vehicle types, and guidance on when the use of specific detectors is justified. In this effort the ITE is soliciting input and assistance from other concerned individuals and groups.

2.0 General
2.1 It shall be possible to install connecting cables between the detector and the sensor(s) in the same conduit with signal wires and cables, power wires and cables, and other detector cables without affecting the normal operation of the detector.
2.2 The operating ambient temperature range shall be from –30°F (–34.4°C) to +165°F (73.9°C). The storage temperature range shall be from –50°F (–45.6°C) to +200°F (+93.3°C).
2.3 The relative humidity shall not exceed 95 percent over the temperature range of +40°F (+4.4°C) to –110°F (–43.9°C).
Above 110°F (43.9°C), constant absolute humidity shall be maintained. This will result in the relative humidities shown in Table I.

Note: Subsections 2.2 and 2.3 are based on NEMA Standard Publication No. TS 1-1976.

2.4 Detector enclosures which are not required to be permanently sealed shall be easily disassembled to gain access for service. For cleaning and maintenance.

3.0 Electrical Requirements
3.1 The detector shall operate over a voltage range of 95 VAC to 135 VAC, 60 Hertz ± 3.0 Hertz and the operation shall not be affected by a change in voltage or frequency within this range.

3.2 All printed circuit boards shall be made from NEMA (FR-4) glass-epoxy, flame retardant or equivalent and shall be at least 1/16" (1.6mm) nominal thickness. Plated-through holes shall have a copper plating thickness of 0.001" (0.0254mm) minimum per wall in the plated-through holes or be plated with the equivalent of one ounce per square foot of copper. All circuit tracks shall have a conductivity equivalent to at least two ounces per square foot (5.37g/m²) of copper. All electrical mating surfaces shall be made of non-corrosive material.

3.3 Vehicle detectors using an external power supply are considered to be DC units. Vehicle detectors shall be considered to be AC units if they obtain their power from the 120 VAC, 60 Hertz power source through an AC to DC supply enclosed in the same housing as the detection circuitry. The AC to DC supply of the vehicle detector must meet the requirements of this paragraph and paragraph 3.4, and the vehicle detector shall maintain all of its functions when the following independent transient levels occur on the AC power source.

1. High Repetition Noise Transient
a. Amplitude-300 volts, both positive and negative polarity
b. 2500 watts peak power
c. Repetition-One pulse approximately every other cycle moving uniformly over the full wave in order to sweep across 350 degrees of the line cycle once every three seconds.

| Table I. Wet-Bulb/Dry Bulb Relative Humidity at Barometric Pressure of 29.92 In. Hg |
|-----------------------------|-------------|-----------------------------|
| Dry Bulb Degrees F | Degrees C | Relative Humidity, Percent | Wet Bulb Degrees F | Degrees C |
| 40 | 4.4 | 75 | 37 | 2.8 |
| 50 | 10.0 | 80 | 47 | 8.3 |
| 60 | 15.6 | 83 | 57 | 13.9 |
| 70 | 21.1 | 86 | 67 | 19.4 |
| 80 | 26.7 | 87 | 77 | 25.0 |
| 90 | 32.2 | 89 | 87 | 30.6 |
| 100 | 37.8 | 89 | 97 | 36.1 |
| 110 | 43.3 | 90 | 107 | 41.7 |
| 120 | 48.9 | 70 | 107 | 42.8 |
| 130 | 54.4 | 89 | 109 | 42.8 |
| 140 | 60.0 | 38 | 109 | 42.8 |
| 150 | 65.6 | 26 | 109 | 42.8 |
| 160 | 71.1 | 21 | 109 | 42.8 |
| 170 | 73.9 | 16 | 109 | 42.8 |

* For dynamic testing.
d. Pulse rise time—One microsecond
e. Pulse width—Ten microseconds

2. Low-Repetition, High-Energy Transients
   a. Amplitude—600 volts, both positive and negative polarity
   b. Energy source—Capacitor, oil-filled, 10 microfarads ± 10%, internal surge impedance less one ohm
   c. Repetition—One discharge every 10 seconds
d. Pulse position—Random across 360 degrees of the line cycle

3.4 The vehicle detector shall be capable of withstanding a high energy transient applied repeatedly to the AC input terminals (no other power connected to terminals) without failure. The transient shall have the following characteristics:
   1. Amplitude—1000 volts, both positive and negative polarity
   2. Energy source—Capacitor, oil-filled, 5 microfarads ± 10%, internal surge impedance less than one ohm
   3. Repetition—Applied to the detector assembly once every two seconds for a maximum of three applications for each polarity

Upon application of nominal alternating current power after this test, the vehicle detector shall function normally.

3.5 All vehicle detector operating characteristics shall be maintained when the detector is subjected to the test pulse described below. This pulse shall be applied between logic ground and the +24 VDC input of the DC powered unit, between the logic ground and any control inputs of both the AC and DC powered units, and between the output terminals of both the AC and DC powered units. Loop detector inputs are excluded from this requirement.

The test pulse is characterized as follows:
   1. Amplitude—300 volts, positive and negative polarity
   2. Pulse Source—1000 ohms nominal impedance
   3. Repetition—One pulse per second, for a minimum of five pulses per selected terminal
   4. Pulse Rise Time—One microsecond
   5. Pulse Width—Ten microseconds

3.6 Lightning protection shall be installed within the vehicle detector. The protection shall enable the amplifier to withstand the discharge of a 10 microfarad capacitor charged to ±2000 volts directly across the detector input pins with no load present. The protection shall enable the amplifier to withstand the discharge of a 10 microfarad capacitor charged to ±2000 volts directly across either the detector inputs or from either side of the detector inputs to earth ground. The detector chassis shall be grounded and the detector inputs shall have a dummy resistive load attached equal to 5.0 ohms.

3.7 An overcurrent protection device shall be provided on all vehicle detectors. For self-mounted vehicle detectors the fuse or circuit breaker shall be accessible from the front panel. Any other overcurrent protection device may be mounted internally.

4.0 Documentation

A minimum of three documentation packages shall accompany each order and be delivered to the purchaser. Where more than 30 detectors are purchased, one documentation package per 10 detectors shall accompany each order and be delivered to the purchaser. A documentation package shall consist of the following:
   1. Complete schematic diagram of the control unit and the sensing element.
   2. Complete physical description of the control unit and the sensing element.
   4. Complete installation procedure for sensing elements, cables, and control units.
   5. Complete maintenance manual. The maintenance manual shall include, but need not be limited to, the following items:
      a. Specifications
      b. Design characteristics
      c. Step by step explanation of circuit theory and operation
d. Function of all controls
e. Maintenance and troubleshooting procedure (diagnostic routine)
f. Block circuit diagram
g. Geographical or pictorial layout of components
h. Complete parts list with stock numbers—listing full names and addresses of vendors for parts not identified by universal part numbers such as RETMA, EIA or JEDEC

5.0 Guaranty

5.1 (Optional) The equipment furnished shall be guaranteed to be free from defects in workmanship and material for a period of either one and a half years from date of acceptance by the purchaser or one year from date of installation whichever comes first.

5.2 (Optional) The equipment furnished shall be new, of the latest model, fabricated in a first class workmanlike manner from good quality material. The manufacturer shall repair or replace, free of charge to the purchaser, any part that fails in any manner during the period of the guarantee.

5.3 (Optional) The manufacturer warrants that the equipment furnished is merchantable and is suitable for use in detecting vehicles as specified above.

SECTION II

LOOP VEHICLE DETECTOR

1.0 Purpose

It is the purpose of this Section (Section II) of these specifications to set forth functional requirements for loop vehicle detector amplifiers. A vehicle either moving or stopped over a loop vehicle detector sensor shall cause an actuation.

2.0 General

2.1 The term "loop vehicle detector", hereinafter termed "loop detector", applies to a complete installation consisting of a loop detector amplifier, one or more wire loops (sensors) installed in the roadway, and lead-in cable between the loop vehicle detector amplifier and sensor(s). The "loop vehicle detector amplifier" shall hereinafter be called the "loop amplifier" and the "loop vehicle detector sensor(s)" shall hereinafter be called the "loop sensor(s)".

2.2 The loop detector is capable of being operated by sensing a change in inductance of its associated loop sensor/lead-in combination.

3.0 Design Requirements

3.1 (Purchaser) The loop amplifier shall have either one, two, or four channels as called for by the purchaser.

3.2 The loop amplifier or each channel of a loop amplifier shall detect and provide an output closure to indicate the presence or passage of vehicles in lanes equipped with loop sensors at any
speed from 0 to 80 mph (0 to 128 km per hour).

3.3 Parked or stopped vehicles over the loop sensor(s) of one channel shall have no effect on the operation of any other channel.

3.4 Each channel shall provide an output closure in the event of a loss of power to the loop amplifier.

3.5 Damage to the loop sensor(s) or cable(s) of one channel shall not affect operation of any other channel.

3.6 The detector shall be capable of detecting vehicles on a 6' x 6' (1.83m x 1.83m) wire loop, turn sensor separated from the loop amplifier by 800 feet (245m).

3.7 Upon restoration of electrical power after a power failure of any length, the detector shall be capable of automatically returning to its normal state of operation within 15 seconds.

3.8 (Purchaser) The loop amplifier shall be solid state except that the output circuit may be controlled by a relay when specified by the purchaser. The output circuit provided shall meet the requirements for the solid state output described in paragraph 1 below or (when called for by the purchaser) the output relay described in paragraph 2 below.

1. A solid state output circuit shall be provided which is capable of switching an external voltage of +35 VDC at 300 milliamperes to ground.

2. A plug in relay shall provide a minimum of single pole, double throw contacts rated at 115 VAC and one amper resistive load for 10 million operations. This relay shall be wired such that it is normally energized and it de-energizes upon vehicle detection.

3.9 (Purchaser) The loop detector called for by the purchaser shall be either: (a) self-tuning, or (b) capable of being manually tuned to an inductance range (loop plus lead-in) of from 50 to 700 microhenries at 50 KHz, Q greater than five, and a resistance to ground greater than 10,000 ohms. If the manual tuning is switch selectable, at least 10 different ranges of inductance shall be provided. If the loop detector is self-tuning, the tuning process must be completed within seven seconds (except with initial turn-on).

The detector shall have, as a minimum, the sensitivity to detect a 0.02% change in inductance of the loop described in Subsection 3.6; or a 0.02% change in inductance of a 75 microhenry loop.

3.10 (Purchaser) The Purchaser shall specify whether the loop detector amplifier is to be either: (a) analog, (b) digital, or (c) either analog or digital (if no preference is desired).

3.11 If a vehicle stops over the loop sensor(s) or a portion thereof, the loop detector shall eventually recover to normal operation and detect subsequent vehicles. The time required for recovery shall be selected by a minimum of a two position selector switch or continuously adjustable control mounted on the front panel of the detection unit.

1. Limited Presence Mode—A vehicle with a weight of 2,000-2,700 lbs. and approximate dimensions as follows: (1) 173" (439cm) in length, (2) 62" (157cm) in width and (3) 6½" (165.1cm) ground clearance stopping over a 6' x 150' (1.83 x 45.75m) one turn loop with a 350' (106.68m) shielded, polyethylene insulated lead-in or a 6' x 27' (1.83 x 8.24m) two turn loop with a 550' (167.64m) shielded polyethylene insulated lead-in, shall be detected and cause actuation of the output circuit for a minimum of six minutes. The detector, after being actuated continuously for six minutes, shall regain 90% of its sensitivity within two seconds after the loop is cleared of vehicles.

2. Pulse Mode—A vehicle passing over a loop shall cause an actuation of the output relay lasting between 50 milliseconds and 1.0 second. If a vehicle stops in the loop area, within one minute, subsequent vehicles passing over the unoccupied area of the loop shall be detected.

3.12 (Purchaser) The detector shall provide a sensitivity switch as described in paragraph 1, below. If called for by the purchaser, the control described in paragraph 2 below shall be provided in lieu of the switch.

1. A multiple position selector switch shall provide for the selection of at least three sensitivity ranges, low, medium and high. In the high position, the detector shall meet or exceed the requirements called for in subsection 3.9.

2. A continuously adjustable sensitivity control shall be provided to adjust the sensitivity from low to high. In the high position, the detector shall meet or exceed the requirements called for in subsection 3.5.

3.13 A minimum of a two position range switch shall be provided to shift the operating frequency to prevent crosstalk between two adjacent detectors. The tuning range and sensitivity requirements as called for in subsection 3.9 shall still be met for any position of this range switch. This switch shall shift the operating frequency of a minimum of 10%.

3.14 The detector shall require no test equipment or special tools for tuning. A readily visible indicator lamp or meter shall be provided to indicate vehicle detection. If a manually tuned detector is called for, the light or meter shall also be used for tuning purposes. The indicator light must be visible during any normal external lighting conditions including direct sunlight.

3.15 The detector shall not drift sufficiently to issue false calls, fail to detect or lock-up over the temperature and humidity range called for in subsection 2.2 and 2.3 of Section I. Either automatically or manually tuned detectors, once tuned, shall stay tuned and shall compensate for long term drift of internal components as well as loop and lead-in variations equivalent to a change of capacitance at the detector loop terminals of ± 5000 picofarads at a maximum rate of 100 picofarads per minute.

3.16 (Purchaser) There are two types of housings for loop amplifier units included in these specifications. The first type, Type A, is designed for shelf-mounting within the controller cabinet. The second type, Type B, is designed for rack-mounting within the controller cabinet. The purchaser shall designate which type is to be provided.

1. Type A loop amplifier housings shall conform to the following requirements:

a. The loop amplifier shall be housed in an enclosure which shall provide mechanical protection for the control unit, and shall protect the control unit from dust and moisture. The case shall be limited to 100 cubic inches (1639em³) for one and two channel amplifiers and 200 cubic inches (3278cm³) for four channel amplifiers with no dimension exceeding eight inches (20.32cm).

b. The loop amplifier power supply shall be an integral part of the control unit.

c. The loop amplifier shall not be position sensitive.

d. All input and output circuits for each amplifier shall enter via the following MS type male connector(s):

(1) Individual loop amplifier shall be equipped with Type MS-3102-A-18-1P receptacle with 10 male contacts for input/output connections.
The pin functions of the connector shall be assigned as follows:

<table>
<thead>
<tr>
<th>PIN NO.</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>120 VAC (neutral)</td>
</tr>
<tr>
<td>B</td>
<td>Output common (relay common or solid state output emitter)</td>
</tr>
<tr>
<td>C</td>
<td>120 VAC (line)</td>
</tr>
<tr>
<td>D</td>
<td>Loop input</td>
</tr>
<tr>
<td>E</td>
<td>Loop input</td>
</tr>
<tr>
<td>F</td>
<td>Output (normally open)**</td>
</tr>
<tr>
<td>G</td>
<td>Output (normally closed)**</td>
</tr>
<tr>
<td>H</td>
<td>Chassis ground</td>
</tr>
<tr>
<td>I</td>
<td>Solid state output (collector)</td>
</tr>
<tr>
<td>J</td>
<td>Delay inhibit or carryover enable (120 VAC to actuate)*</td>
</tr>
</tbody>
</table>

*When required
**With unit energized and no call. Multichannel loop amplifier units (three or more channels) shall be equipped with connectors as called for by the purchaser.

(2) A compatible female connector shall be provided for each male receptacle with a minimum of a four foot long cable harness consisting of color coded or clearly marked leads. The loop wires shall consist of a twisted, shielded pair with the shield connected to the chassis ground.

2. Type B loop amplifier shall conform to the following requirements:

a. Each loop amplifier shall consist of either two or four separate and complete input-output circuits (channels) mounted on an edge-connected printed circuit board(s). The front panel shall be provided with a hand pull to facilitate insertion and removal from the detector rack.

b. The +24 volt DC power supply for the control unit may be mounted in the PCB board rack with the loop amplifier or may be located elsewhere in the controller cabinet. Each control channel shall not draw more than 150 milliamperes from the +24 volt DC supply.

c. The printed circuit board shall be 4.5 inches (114.3mm) by 6.5 inches (165.1mm). The width of the front panel shall be 2.3 inches (58.4mm).

d. The printed circuit board shall intermate with a 44 terminal, double row, 0.156-inch (3.96mm) contact spacing cardedge connector.

3.17 (Optional) A detector called for by the purchaser as "Detector with Delayed Output", a variable, externally adjustable delay circuit shall be furnished to provide a delayed output. This circuit shall be variable from 0 to 20 seconds. Detection of a vehicle shall be delayed for the amount of time selected, therefore providing no detector output until a vehicle has been present in the loop for this length of time. This timing circuit shall be reset each time the loop is vacated; however, the delay circuit shall be disabled immediately when 120 VAC is presented on Pin J of Subsection 3.16, 1.d.(1). (or other pin designated by the purchaser for a Type B loop amplifier housing). When the 120 VAC is removed from Pin J, the delay circuit shall immediately go back into effect.

3.18 (Optional) A detector called for by the purchaser as "Detector with Carryover Output" shall be furnished with a variable, externally adjustable extension circuit to provide a carryover output. This circuit shall be variable from 0 to twenty (20) seconds. Detector actuation shall be extended after the vehicle leaves the loop. The timing circuit shall be reset after the extension has expired; however, the extension circuit shall be disabled when the 120 VAC is presented on Pin J of Subsection 3.16, 1.d.(1). (or other pin designated by the purchaser for a Type B loop Amplifier housing). When the 120 VAC is removed from Pin J, the carryover circuit shall immediately go back into effect.

SECTION III

MAGNETIC VEHICLE DETECTORS

1.0 Purpose

It is the purpose of this Section (Section III) of these specifications to set forth requirements for magnetic vehicle detector sensors (sensing elements) and magnetic vehicle detector amplifiers. A vehicle moving over a magnetic vehicle detector sensor shall cause an actuation.

2.0 General

2.1 The term "magnetic vehicle detector", hereinafter termed "magnetic detector" applies to a complete installation consisting of a magnetic vehicle detector amplifier, one or more magnetic vehicle detector sensors, and lead-in cable between the magnetic detector amplifier and sensor(s). The magnetic vehicle detector amplifier shall hereinafter be called the "magnetic amplifier" and the "magnetic vehicle detector sensor(s)" shall hereinafter be called the "magnetic sensor(s)".

2.2 The magnetic detector is capable of being operated by a voltage induced in the sending element caused by the passage of a vehicle over the sensing element.

3.0 Design Requirements

3.1 General

1. (Purchaser) The magnetic amplifier shall house either one, two or four channels as called for by the purchaser.

2. The magnetic amplifier or each channel of a magnetic amplifier shall detect and provide an output closure to indicate the passage of vehicles in lanes equipped with magnetic sensors (installed 12 inches (304.8mm) below the roadway surface) from three to 80 miles per hour (five to 128 km per hour).

3. Parked or stopped vehicles over the magnetic sensor(s) of one channel shall have no effect on the operation of any other channel.

4. Damage to the magnetic sensor(s) or lead-in cables of one channel shall not affect the operation of any other channel.

5. Each magnetic amplifier or magnetic amplifier channel shall provide an output closure in the event of a loss of power to the magnetic amplifier or channel.

6. The detector shall operate at any distance up to 1000 feet (304.8m) between the magnetic amplifier and a magnetic sensor installed 12 inches (304.8mm) below the roadway surface.

7. Following a power interruption, the magnetic amplifier shall return to normal operation within one minute.

3.2 Magnetic Sensor

1. (Purchaser) Magnetic sensors are commonly of two types—single-lane and multi-lane. Their placement is as follows:

a. Single-lane roadway sensors are normally placed either flush with the roadway surface or below the top course of paving material approximately in the center of the lane to be detected.

b. Multi-lane sensors are normally placed in a non-metallic conduit placed transversely to the movement of traffic at a depth of 6-30 inches (152.4-762.0mm).

The purchaser shall call for the type sensor to be purchased.
2. With a magnetic sensor placed 12 inches (304.8mm) or less beneath the roadway surface, those vehicles shall be detected which pass over the magnetic sensor; (a) within 18 inches (457.2mm) of either end of the single lane type sensor or (b) within five feet (1.52m) of either end of the multi-lane type sensor.

3. The magnetic sensor shall be moisture proof and capable of withstanding exposure to high concentrations of salt in water and earth without degradation of leakage resistance. Leakage resistance shall be a minimum of 10 megohms when tested with a 400 volt DC between lead wires and the fluid of a salt water bath after the unit, including lead wire entrance, has been entirely immersed in the salt water for a period of 24 hours. One fourth ounce (7 g.) of salt per gallon of water shall be used for the bath which shall be at approximately room (68°F; 20°C) temperature.

4. The multi-lane type magnetic sensor shall fit freely in three-inch (76.2mm) diameter non-metallic pipe, and shall not exceed 20 inches (508.0mm) in length.

5. A minimum of 50 feet (15.24m) of lead-In wire shall be an integral part of each magnetic sensor.

3.3 Magnetic Amplifier

1. The magnetic amplifier shall be entirely solid state with the exception of an output relay. A magnetic amplifier shall:
   a. Operate satisfactorily with each of the two types of magnetic sensors.
   b. Operate with substantially no change in gain or frequency response within a range of ± 10% from rated power line voltage.
   c. Operate on a single cycle of 0.10 Hz sine wave with an amplitude of five millivolts.
   d. Operate on a single cycle of a sine wave between 0.25 Hz and 1.0 Hz inclusive with an amplitude of two millivolts.

2. A magnetic amplifier shall not:
   a. Operate with a sinusoidal 60 Hz wave applied to the input having an amplitude of 1.0 volt.
   b. Give multiple pulses of output from single input voltage cycles.

3. The front panel of the magnetic amplifier shall contain:
   a. An indicator light for each channel to indicate detection of a vehicle
   b. Overcurrent protection
   c. Controls for varying gain for each channel (the gain control means shall be essentially linear over its entire range)
   d. Controls for varying sensitivity

4. A connector for a wiring harness when used

5. All switches and controls shall be clearly and permanently identified and shall be operable without the use of tools or external meters. No mechanical wiring of magnetic sensors shall be required.

6. Indicator light(s) must be visible during any normal external lighting condition including direct sunlight.

6. (Purchaser) There are two types of housing for magnetic amplifiers included in these specifications. The first type, Type A, is an amplifier housing designed for shelf-mounting within the controller cabinet. The second type, Type B, is an amplifier designed for rack-mounting within the controller cabinet. The purchaser shall designate which type housing is to be used.

a. Type A magnetic amplifier housing shall conform to the following requirements:
   (1) The amplifier shall be housed in an enclosure which shall provide mechanical protection for the control unit, and shall protect the control unit from dust and moisture. The case shall be limited to 200 cubic inches (3278cm³), with no dimension exceeding 10 inches (254.0mm).
   (2) The amplifier power supply shall be an integral part of the control unit.
   (3) The amplifier shall not be position sensitive.

4.0 Electrical Requirements

4.1 The magnetic sensor shall have a d-c resistance of not over 3500 ohms.

4.2 Input power to amplifiers with integral power supplies shall be provided with overcurrent protection. The overcurrent protection shall be accessible from the front and without removing the case.

SECTION IV MAGNETOMETER VEHICLE DETECTORS

1.0 Purpose

The purpose of this Section (Section IV) of the specifications is to set forth requirements for magnetometer vehicle detector sensors (sensing elements or probes) and magnetometer vehicle detector amplifiers. A vehicle either moving or stopped over a magnetometer vehicle detector sensor shall cause an actuation.

2.0 General

2.1 The term "magnetometer vehicle detector" hereinafter referred to as the "magnetometer detector" applies to a complete installation consisting of a magnetometer vehicle detector amplifier, one or more magnetometer vehicle detector sensors, and lead-in cable between the magnetometer vehicle detector amplifier and sensor(s). The "magnetometer vehicle detector amplifier" shall hereafter be called the "magnetometer amplifier" and the circuits (channels) mounted on an edge-connected printed circuit board. The front panel shall be provided with a hand pull to facilitate insertion and removal from the detector rack.

2.2 The +24 volt DC power supply for the control unit may be mounted in the PC board rack with the amplifiers, or may be located elsewhere in the controller cabinet. Each channel shall not draw more than 60 milliampere from the +24 volt DC supply.

2.3 The printed circuit board shall be 4.5 inches by 6.5 inches (114.3 × 165.1mm). The width of the front panel shall be 2.3 inches (58.4mm).

2.4 The printed circuit board shall interface with a 22-pin double-sided edge connector.
"magnetometer vehicle detector sensor(s)" shall hereafter be called the "magnetometer sensor(s)."

2.2 The magnetometer detector is capable of being operated by sensing a change in the vertical component of the earth's magnetic field caused by the passage or presence of a vehicle over the detector sensing element.

3.0 Design Requirements

3.1 General
1. Each magnetometer amplifier shall house two complete, fully independent detection channels. Each channel shall operate with one to six magnetometer sensors connected to it, and shall provide a separate output closure.

2. Each channel shall detect and provide an output closure to indicate the presence or passage of vehicles in lanes equipped with magnetometer sensors at any speed from 0 to 80 miles per hour (0 to 128 km per hour).

3. Parked or stopped vehicles over the magnetometer sensor(s) of one channel shall have no effect on the operation of the other channel.

4. Damage to the magnetometer sensor(s) or lead-in cables of one channel shall not affect operation of the other channel.

5. Each channel shall provide an output closure in the event of a loss of power to the magnetometer amplifier.

6. The detector shall operate at any distance up to 3000 feet (914.4m) between the magnetometer amplifier and a magnetometer sensor.

7. Following a power interruption, the control unit shall return to normal operation within three minutes.

3.2 Magnetometer Sensor
1. With a magnetometer sensor buried under the roadway surface, those vehicles passing or standing over the sensing elements shall be detected. The actual position of the vehicle when detected may vary from vehicle to vehicle but the variation in that position shall not exceed ± 3 feet (91.44cm) from the perimeter of the vehicle under conditions of normal magnetic field inclination and vehicle magnetization.

2. The magnetometer sensor shall be cylindrical in shape, shall be no larger than two inches (50.8mm) in diameter or more than 4.25 inches (107.95mm) in length and shall contain no moving parts.

3. The magnetometer sensor shall have a moisture-proof housing, shall not be affected by extremes of temperature or humidity and shall be capable of withstanding all types of soil conditions.

4. A minimum of 50 feet (15.24m) of lead-in wire shall be an integral part of each magnetometer sensor.

3.3 Magnetometer Amplifier
1. (Purchaser) The magnetometer amplifier shall be a solid state except that the output circuit may be controlled by a relay when specified by the purchaser. The output circuit described in paragraph "a" below or (when called for by the purchaser) the output relay described in paragraph "b" below.

a. A solid state output circuit shall be provided which is capable of switching an external voltage of ±35 VDC at 300 milliamperes to ground.

b. A plug-in relay shall provide a minimum of single pole, double throw contacts rated at 115 VAC and one ampere resistive load for 10 million operations. This relay shall be wired such that it is normally energized and it de-energizes upon vehicle detection.

2. A minimum of two modes of operation shall be available as follows:

a. Pulse Mode. The pulse mode of operation shall provide an output closure of 50 to 100 milliseconds duration for each vehicle entering the area of detection.

b. Continuous-Presence Mode. The presence mode of operation shall indicate continually the presence of a vehicle until the vehicle leaves the area of detection, whereupon the indication shall cease within 100 milliseconds.

3. The front panel of the magnetometer amplifier shall contain:

a. Indicator light or meter for each channel to indicate detection of a vehicle,

b. Overcurrent protection,
c. Switch for selecting the mode of operation,
d. Controls for calibrating the detector,
e. Controls for varying the call "hold" time, and
f. Connector for wiring harness, when used.

4. All switches and controls shall be clearly and permanently identified and shall be operable without the use of tools or external meters. No mechanical tuning of sensing elements shall be required.

5. Indicator lights must be visible during any normal external lighting condition including direct sunlight.

6. (Purchaser) There are two types of housings for magnetometer amplifiers included in these specifications. The first type, Type A, is an amplifier housing designed for shelf-mounting within the controller cabinet. The second type, Type B, is an amplifier designed for rack-mounting within the controller cabinet. The Purchaser shall designate which type housing is to be used.

a. Type A Magnetometer amplifier housing shall conform to the following requirements:

(1) The amplifier shall be housed in an enclosure which shall provide mechanical protection for the control unit, and shall protect the control unit from dust and moisture. The case shall be limited to 200 cubic inches (3278cm³), with no dimension exceeding 10 inches (254.0mm).

(2) The amplifier power supply shall be an integral part of the amplifier.

(3) The amplifier shall not be position sensitive.

(4) All input and output circuits for each amplifier shall enter via a single MS type male connector.

(5) A compatible female connector shall be provided with a minimum of a four foot long cable harness consisting of color coded or clearly marked leads.

b. Type B Magnetometer amplifier housing shall conform to the following requirements:

(1) The amplifier shall be housed in an enclosure which shall provide mechanical protection for the control unit, and shall protect the control unit from dust and moisture. The case shall be limited to 200 cubic inches (3278cm³), with no dimension exceeding 10 inches (254.0mm).

(2) The amplifier power supply shall be an integral part of the amplifier.

(3) The amplifier shall not be position sensitive.

(4) All input and output circuits for each amplifier shall enter via a single MS type male connector.

(5) A compatible female connector shall be provided with a minimum of a four foot long cable harness consisting of color coded or clearly marked leads.

b. Type B Magnetometer amplifier housing shall conform to the following requirements:

(1) Each amplifier shall consist of two separate and complete input-output circuits (channels) mounted on an edge-connected printed circuit board. The front panel shall be
provided with a hand pull to facilitate insertion and removal from the detector rack.

2. The +24 volt DC power supply for the amplifier may be mounted in the PC board rack with the amplifiers, or may be located elsewhere in the controller cabinet. Each channel shall not draw more than 60 milliampers from the +24 volt DC supply.

3. The printed circuit board shall be 4.5 inches by 5.5 inches (114.3 x 165.1mm). The width of the front panel shall be 2.3 inches (58.4mm).

4. The printed circuit board shall intermate with a 22-pin double-sided edge connector.

4.0 Electrical Requirements

4.1 Input power to the magnetometer amplifiers with integral power supplies shall be provided with overcurrent protection. The overcurrent protection shall be accessible from the front and without removing the case.

SECTION V
RADAR VEHICLE DETECTORS

1.0 Purpose

It is the purpose of this Section (Section V) of the specifications to set forth requirements for the radar vehicle detector chassis and the radar vehicle detector antenna. A vehicle moving past an antenna or within the antenna range shall cause an actuation.

2.0 General

2.1 The term “radar vehicle detector” hereinafter referred to as the “radar detector” applies to a complete installation consisting of the radar vehicle detector antenna and radar vehicle detector chassis and any lead-in cable which might be needed between the chassis and the antenna. The term “radar vehicle detector chassis” shall hereinafter be called the “chassis” and the “radar vehicle antenna” shall hereinafter be called the “antenna.”

2.2 The radar detector is capable of being operated by sensing the passage of a vehicle through its field of emitted microwave energy.

3.0 Design Requirements

3.1 The antenna shall be designed for mounting either above or to the side of the roadway surface.

3.2 The lateral coverage of the surface of the roadway shall be adjustable within the limits of 4.5 feet to 15 feet (4.57m) on each side of the antenna when it is mounted with its under surface 17 feet (5.18m) above the roadway. When the antenna is mounted to the side of the roadway three feet (0.914m) from the curb or pavement edge at a height of 12 feet (3.66m) and at an angle of 45 degrees, the unit shall be capable of detecting vehicles in a lane 40 feet (12.19m) distance from the antenna. Means shall be provided to adjust the coverage within these limits.

3.3 The radar detector shall be capable of actuating by vehicles passing within its field of coverage at any speed within the range of two to 80 miles per hour (3 to 128 km per hour). The operation of the detector shall be unaffected by parked cars or other stationary objects in or upon the roadway.

3.4 The normal direction for operation of the antenna unit shall be clearly marked on its surface.

3.5 (Purchaser) There are two types of radar detectors included in these specifications. The first type, Type A, is designed so that the antenna and the chassis are combined as an integral detector unit. The second type, Type B, is designed so that the antenna is remote from the chassis. The purchaser shall call for the type radar detector to be purchased.

1. The Type A Detector Unit with Integral Antenna shall conform to the following requirements:

a. The detector unit shall be mounted either above or to the side of the roadway surface from where it shall transmit a radio frequency beam toward oncoming cars. Reflection of a portion of the beam from a moving vehicle shall be picked up by the antenna portion of the detector and shall result in the closure of a normally open contact in the output circuit of the radar detector.

b. The detector unit shall be equipped with a slip fitter connection for a standard two-inch (50.8mm) mast arm.

c. A junction box equipped with sensitivity control, test jacks, and 40 feet (12.19m) of 5/c weatherproof cable shall be furnished to provide for remote sensitivity control and check of output relay control voltage.

d. The housing for the detector unit shall not exceed a diameter of 12 inches (304.8mm) and a height of 15 inches (381.0mm). The lower portion of the housing through which the radio frequency beam is transmitted shall be constructed of suitable material to insure the maximum transmission and reception of the radio frequency energy and shall be finished in white. The material shall not require any painting or other maintenance procedure.

e. The top of the housing shall be fitted with a cover that can be removed without the use of any tools and permit the removal of the integral electronic chassis and antenna unit through the open top of the housing.

2. The Type B Detector with Remote Antenna shall conform to the following requirements:

a. The chassis shall be mounted in the cabinet at a roadside location within 100 feet (30.48m) of the antenna. The antenna unit shall be mounted above or to the side of the road surface and shall transmit a radio frequency beam toward oncoming vehicles. Reflection of a portion of the beam from a moving vehicle shall be picked up by the antenna and shall result in the closure of a normally open contact in the output circuit of the detector.

b. The chassis shall measure approximately 13" high x 7" wide x 5½" (330.2 x 177.8 x 139.7mm) deep and shall be shock mounted and shall not exceed 11 pounds (5 kg) in weight.

c. A conveniently accessible sensitivity control and an output circuit indicator lamp shall be provided on the chassis.

d. The chassis shall contain a regulated power supply to minimize the effects of line voltage fluctuations to assure maximum life and reliability of all components.

e. Temperature compensated circuits, shall be provided. Vacuum tubes, other than the final R.F. output amplifier shall not be used. The design life of the R.F. tube shall be 20,000 hours.

f. The amplifier and output printed wiring boards shall be plug mounted.

g. All electrical connections to the chassis shall be by means of quick disconnect connectors. The chassis shall be replaceable with a similar unit without the necessity of disconnecting and reconnecting the wires therefrom.

h. The antenna housing through which the radio frequency beam is transmitted shall be constructed of suitable material to insure the maximum transmission and reception of the radio
frequency energy. This material shall not require any painting or other maintenance procedures.

i. The antenna shall not weigh more than six pounds (2.75 kg) and shall be equipped with a slip fitter connection for a standard two inch (50.8mm) mast arm.

j. A weather tight metal cabinet of adequate size to house the chassis and provide convenient dressing of cables shall be provided. The cabinet shall contain mounting fixtures so that the chassis may be mounted vertically against the back of the cabinet without the use of tools.

4.0 Electrical Requirements

4.1 The radio frequency output of the transmitter section of the unit shall be a maximum of sixty (60) milliwatts at a frequency of 2455 megahertz. The power input to the final amplifier or oscillator shall be three watts nominal. The frequency of the output energy shall not vary more than plus or minus three megahertz.

4.2 The output circuit shall consist of one normally open contact, which shall be closed upon the passage of a vehicle within the range of the antenna. In the event of very slow moving, closely spaced vehicles which would otherwise keep the relay closed, the relay shall operate to make a closure approximately every one to two seconds so as to give indication of this condition.

4.3 The unit shall be suitably fused with the fuse readily accessible and replaceable without the use of tools.

4.4 Three wires shall be used to connect the unit to the traffic signal controller. One wire shall be a common for the power line and the return detector contact circuit, the second shall supply power at 120 volts, 60 Hertz from the control box to the unit, and the third shall be the normally open detector circuit.

4.5 All electrical connections to the electronic chassis shall be by means of quick disconnect connectors. The chassis shall be replaceable with a similar unit without the necessity of disconnecting and/or reconnecting the wire therefrom.

4.6 A terminal block with a minimum of three positions shall be provided for the purpose of making field wiring connections as follows:

1. AC(-) common (Power Supply and Detector Return)

2. AC + 120 volts 60 Hz.

3. N.O. Detector Circuit

SECTION VI
ULTRASONIC VEHICLE DETECTORS

1.0 Purpose

The purpose of this Section (Section VI) of the specifications is to set forth requirements for ultrasonic vehicle detector transducers and ultrasonic vehicle detector transceivers. A vehicle either moving past or stopped within the field of coverage of a transceiver shall cause an actuation.

2.0 General

2.1 The term "ultrasonic vehicle detector" hereinafter referred to as the "ultrasonic detector" applies to a complete installation consisting of an ultrasonic vehicle detector transducer, ultrasonic vehicle detector transceiver and lead-in cable from the transducer to the transceiver. The term "ultrasonic vehicle detector transducer" shall hereafter be called the "transducer" and the term "ultrasonic vehicle detector transceiver" shall hereafter be called the "transceiver".

2.2 The ultrasonic detector is capable of being operated by sensing the reflection from a vehicle of a portion of ultrasonic energy transmitted by the transceiver.

3.0 Design Requirements

3.1 General

1. The ultrasonic detector transceiver shall detect and provide an output closure to indicate the presence or passage of vehicles within the effective energy range of the transducer at any speed from 0 to 70 miles per hour (0 to 113 km per hour).

2. The transceiver shall provide an output closure in the event of a loss of power to the transceiver.

3. The ultrasonic detector shall operate at any distance up to 400 feet (121.92m) between the transducer and the transceiver. The transceiver shall be capable of operating two separate transducers. The output of the transceiver shall be to one phase of a traffic signal controller. Where two transducers on opposite approaches are operated by a single transceiver, total of the two lead-ins may be up to 400 feet (121.92m). Where two transducers on the same approach are operated by a single transceiver, a single lead-in may be used. The maximum allowable 400 foot (121.92m) length of this single lead-in shall be to the furthest of the two transducers.

4. Following a power interruption, the ultrasonic detector shall commence immediately upon the restoration of power.

3.2 Transducer

1. The transducer shall be designed for mounting either above or to the side of the roadway surface.

2. The lateral coverage at the surface of the roadway shall be adjustable within the limits of 4.5 feet to 13 feet (1.37 to 3.95m) on each side of the transducer when it is mounted with its surface 17 feet (5.18m) above the roadway. When the transducer is mounted to the side of the roadway eight feet (2.49m) to 11 feet (3.35m) above the roadway surface, the unit shall be capable of detecting vehicles in a lane from nine feet to 26 feet (7.92m) distance from the transducer. Means shall be provided to adjust the coverage within these limits.

3. The transducer shall be enclosed in a metal weatherproof housing and shall be furnished with a slip fitter for mounting on a standard two-inch mast arm.

3.3 Transceiver

1. Three speeds of output contact operation shall be provided. Selection shall be by means of a switch on the front panel of the transceiver and shall not require any circuit changes, substitutions, modifications or additions.

2. The transceiver shall be solid state with the exception of the plug-mounted output relay which shall be normally energized.

3. The transceiver shall be provided with a light which shall provide for setting the "Range" and "Gain" controls and shall also serve as an operation indicator and illuminate each vehicle actuation occurs.

4. The front panel of the transceiver shall contain:

  a. Indicator light for setting "Range" and "Gain".
  b. "Range" dial for adjustment of the transceiver to the mounting height of the transducer.
  c. "Gain" dial for adjustment of the lateral coverage of the transducer.
  d. Overcurrent protection.
5. Adjustment of "Range" and "Gain" shall not require a meter or tools and shall not require any circuit changes, substitutions, modifications or additions to the transceiver.

6. The indicator light must be visible during any normal external lighting condition including direct sunlight.

7. The transceiver shall be housed in a metal case. Maximum volume of the case shall not exceed 200 cubic inches (3278cm$^3$).

8. Electrical connections of both the incoming and outgoing circuits shall be made by means of a single MS type plug. The transceiver unit shall be replaceable with a similar unit without the necessity of disconnecting and reconnecting individual wires leading therefrom. The MS type plug shall be of protected male construction and rigidly fixed to the front of the unit. The mating MS plug receptacle shall be attached to one end of a connecting cable at least four feet long. The other end of the connecting cable shall have tagged leads, each of which shall be fitted with a spade type lug for easy attachment to terminal blocks.

4.0 Electrical Requirements

4.1 The transceiver shall have a self-contained synchronization circuit for coordinating its repetition rate with that of other transceivers to permit up to eight transceivers to be used in a single installation. Use of this feature shall not require any circuit changes, substitutions, modifications or additions to the transceiver.

4.2 The transceiver shall be suitably fused. The overcurrent protection shall be readily replaceable from the front of the unit without the use of tools.

4.3 The transducer shall require no connection to commercial AC power.
Pretimed Traffic Signal Controllers

This report was approved as a Revised Standard of the Institute of Transportation Engineers by the ITE Board of Directors on November 14, 1978 in concurrence with a recommendation of the Institute's Technical Council. It supersedes "Pre-Timed Fixed Cycle Traffic Signal Controllers," adopted as a Standard in 1958.

The Standard was developed by Technical Council Committee 4C-S.

Members of Committee 4C-S were: Alvin A. Acton (F); William R. Babitz (M); David H. Bailey (A); Ars M. Balsay (F); Karl A. Bevins (F); John F. Bickel (M); Donald Blaisdell (M); Gary S. Creager (A); Seward E. Crox (F); Gerald A. Edelstein (M); Harold P. Garfield (A); Stanford P. Gross (F); Cheryl M. Hunt (A); Lawrence E. Keeser (A); Joseph Lipari; Eugene R. Lucka; Earl E. Newman (A); W. E. Schwanhauser (M); J. Patrick Short (AF); Lee J. Simonson (A); Rodney L. Starke (A); and Benjamin W. McKay (M), Chairman.

A. Purpose
The purpose of this standard is to set up purchase specifications for pretimed traffic signal controllers.

B. Definitions
1. Controller (Controller Assembly): A complete electrical mechanism mounted in a cabinet for controlling the operation of a traffic control signal.
2. Pretimed Controller: A controller for the operation of traffic signals with predetermined:
   (a) Fixed cycle length(s).
   (b) Fixed interval duration(s).
   (c) Interval sequence(s).
3. Noninterconnected Controller: A controller for operating traffic signals not under master supervision.
4. Future-Interconnected Controller: A controller equipped for operating traffic control signals not under master supervision, but constructed to allow conversion to supervision by a master controller.
5. Interconnected Controller: A controller which operates traffic signals under the supervision of a master controller.
6. Master Controller: An automatic device for supervising a system of controllers, maintaining definite time interrelationship, selecting among available modes of operation or accomplishing other supervisory functions.
7. Master-Secondary Controller Assembly: A controller for operating a traffic control signal and for providing supervision of other interconnected controllers.
8. Traffic Control Signal (Traffic Signal): Any power-operated traffic-control device, whether manually, electrically or mechanically operated, by which traffic is alternately directed to stop and permitted to proceed.
9. Signal Indication: The illumination of a traffic signal lens or combination of signal lenses at the same time.
11. Cycle Length: The time required for one complete sequence of signal indications.
12. Traffic Phase: Those right-of-way and clearance intervals in a cycle assigned to any independent movement(s) of traffic.
13. Interval: The part or parts of the signal cycle during which signal indications do not change.
15. Split: A division of the cycle length allocated to each of the various phases (normally expressed in percent).
16. Offset: The number of seconds or percent of the cycle length that a defined time-reference point (normally the start of major street green) at a traffic signal occurs after the time-reference point of a master controller or of an adjacent traffic signal.
17. Major Street: The roadway approach or approaches at an intersection carrying the major volume of vehicular traffic.
18. Yellow Change Interval: The first interval following the green right-of-way interval in which the signal indication for that phase is yellow.
19. Red Clearance Interval: A clearance interval which may follow the yellow change interval during which both the terminating phase and the next right-of-way phase display red.
20. Pedestrian Clearance Interval: The interval(s) during which the DON'T WALK is flashed, starting after a walk indication and ending before opposing vehicles receive a green indication.
21. Electromechanical Device: A device which is characterized by electrical circuits using relays, step switches, motors, etc.
22. Solid-state Device: A device characterized by electrical circuits, the active components of which are semiconductors to the exclusion of electromechanical devices or vacuum tubes.
23. **Digital Timing:** Pertaining to a method of timing that operates by counting discrete units.

24. **Synchronous:** Pertaining to a method of timing that is controlled by and dependent on a suitable frequency standard such as the frequency of the alternating-current power source.

25. **Controller Unit (Timer):** That part of the controller assembly which performs the basic timing and logic functions.

26. **Cycle Unit (Timing Dial):** That part of a controller unit (or timer) which times one cycle length and its associated split(s) and offset(s).

27. **Timing Control:** A calibrated device that provides a time setting for an interval or portion of an interval.

28. **Panel:** A board within the controller cabinet upon which are mounted field terminals, fuse receptacles or circuit breakers and other portions of the controller unit not included in the controller unit or auxiliary devices.

29. **Cabinet:** An outdoor enclosure for housing the controller unit and associated equipment.

30. **Power Line Switch (Disconnect Switch):** A manual switch for disconnecting power to the controller assembly and traffic control signals.

31. **Time Switch:** A device for the automatic selection of modes of operation of traffic signals in a manner prescribed by a predetermined time schedule.

32. **Manual Operation:** The operation of a controller assembly by means of a hand-operated device(s) (i.e., push-button).

33. **Automatic Switch:** A device which, when operated, discontinues normal signal operation and permits manual operation.

34. **Manual Pushbutton:** An auxiliary device for hand operation of a controller.

35. **Flash Control Switch:** A device which, when operated, discontinues normal signal operation and causes the flashing of any predetermined combination of signal indications.

36. **Flasher:** A device used to open and close signal circuits at a repetitive rate.

37. **Cycle Selection Switch:** A device which, when operated, discontinues automatic selection of cycle unit with associated split(s) and offset(s), and permits hand selection of cycle unit.

38. **Split Selection Switch:** A device which, when operated, discontinues automatic selection of split changes which are independent of cycle length changes and permits hand selection of such split changes.

39. **Signal Shut-Down Switch:** A manual switch to discontinue the operation of traffic control signals without affecting the power supply to other components in the controller cabinet.

40. **Signal Circuit Contact:** A device arranged to energize or deenergize signal light circuits during a specified interval.

41. **Signal Load Switch:** A device used to switch power to the signal lamps.

42. **Signal Conflict Monitor:** A device used to continually check for the presence of conflicting signal indications and to provide an output in response to conflict.

43. **Judge:** A set of clips, plugs, or receptacles in a controller cabinet by means of which a plug-in device may be connected.

44. **Radio Interference Suppressor:** A device inserted in the power line in the controller assembly (cabinet) that minimizes the radio interference transmitted back into the power supply line, which interference may be generated by the controller or other mechanisms in the cabinet.

45. **Field Terminals:** Devices for connecting all wires entering the controller cabinet.

46. **Yellow-Red Flash Terminals:** Terminals which are wired to give the option of flashing either yellow or red on each traffic signal face by rearranging jumpers and/or field wires.

47. **Preampt:** The transfer of the normal control of signals to a special control mode which may be required by railroad trains at crossings, emergency vehicles, mass transit equipment or other special needs.

48. **Offset Control Switch:** A device which when operated stops the timing of the cycle length and intervals in order to manually adjust the offset.

49. **Offset Interrupter:** A device which will distribute over two or more cycles the time required for large offset changes.

50. **Power Failure Feature:** A switching mechanism which operates in case of power failure and, upon restoration of power, either illuminates a power failure indicator or preempts the traffic signal into flashing operation until the mechanism is manually reset.

51. **Power Failure Indicator:** A device which gives a visual indication that a power interruption has occurred since offsets were manually set, resulting in probable loss of offsets to adjacent signals.

**C. Scope**

The control equipment hereafter described and classified as to type is to be used in operating traffic control signals in accordance with one or more of the following plans (Purchaser will here designate the specific plan or plans of operation proposed for the equipment to be purchased.)

**Plan 1.** One controller operating an isolated intersection, or noninterconnected controllers operating two or more intersections and maintaining definite offsets with each other by synchronous timing.

**Plan 2.** Future interconnected controllers operating temporarily as noninterconnected controllers and maintaining definite offsets with each other (as in Plan 1 above) but designed for conversion to interconnected controllers at some future time.

**Plan 3.** Interconnected controllers operating two or more intersections and supervised by a master controller. The interconnected controllers are to be independently adjustable as to interval timing in accordance with traffic requirements at each of the several intersections, and the green indication at each intersection shall be adjustable to start at any instant as required by the offset timing schedule.

**Plan 4.** A master-secondary controller which operates an interconnected intersection and supervises other interconnected controllers which operate as in Plan 3 above.

**SECTION I GENERAL DESIGN REQUIREMENTS**

Note: All paragraphs numbered with two digits to the right of the decimal are optional and can be deleted, if desired.

1. **Purpose**

The purpose of Section 1 of this specification is to set forth minimum design and operating requirements for all controllers of the various types included in this entire specification.

2. **Cabinets**

2.1 The controller unit and associated equipment shall be furnished completely housed in a cabinet of clean-cut design and appearance. The cabinet size shall provide ample space for housing the controller unit and all associated electrical devices furnished with it, together with any other auxiliary devices herein specified.

2.2 A hinged door shall be provided permitting complete access to the interior of the cabinet. When closed, the door shall fit closely to gasketing material, making the cabinet wind and rust-resistant and dust-tight. The door shall be provided with a strong lock and key.
2.21 (Optional) A small, hinged and gasketed door-in-door shall be included on the outside of the main controller door. The door-in-door shall not allow entrance to the controller mechanism nor to exposed electrical terminals, but shall provide access to a small switch panel and compartment which contains a single channel red light switch, a flash control switch and other features required by the purchaser. (Purchaser will insert list of features required.)

2.3 The cabinet shall contain a suitably designed rain-tight vent or vents equipped with screens or filters. The vent(s) shall allow the release of excessive heat and of any explosive gases which might enter the cabinet. If a fan is required for the controller to meet the temperature requirements for constancy of time cycle and internal timing, the fan shall be thermostatically controlled, and at least two vents shall be located so as to provide air circulation inside the cabinet.

2.4 The cabinet and all mounting attachments are to be finished with two coats of high-grade enamel paint. (Color to be specified by purchaser.)

2.5 The cabinet shall be provided with necessary openings for mounting and connection as follows:
(Purchaser to specify type of mounting, i.e., pedestal, pole attachment clamps, or integral with post; also complete instructions as to drilling, tapping, etc.)

2.6 The cabinet shall contain a strong mounting table, sliding ways, hinged or a folding support of such construction that it will permit the controller unit to be withdrawn from the cabinet for inspection or maintenance without breaking any electrical connections or interrupting normal operation of the controller system.

2.7 The electrical connections from the controller unit to the outgoing and incoming circuits shall be made in such a manner that the controller unit may be replaced with a similar unit, without the necessity of disconnecting and reconnecting the individual wires leading therefrom. This can be accomplished by means of a multiple plug and jack, a spring-connected mounting, or equivalent arrangement.

2.8 Each controller is to be furnished with a panel in the cabinet mounted in such a way as to provide visibility and accessibility.

2.81 (Optional) The cabinet shall also provide space and wiring to permit the installation of a time switch at any time that such equipment may be desired. (Purchaser will insert here the functions required of the time switch, and specify space required or type of time switch.)

3. Wiring

3.1 All panel wiring shall be neat and firm. All portions of the electrical circuit between the incoming power line terminal and the branching to the signal circuit contacts or signal load switches, including wiring, disconnect plugs and sockets, relay contacts and other switching devices, fuses and circuit breakers, shall have a minimum amperage capacity as follows:
(a) 15 amperes for controllers equipped for less than 10 signal circuit contacts,
(b) 20 amperes for controllers equipped for at least 10 but less than 20 signal circuit contacts,
(c) 30 amperes for controllers equipped for at least 20 but less than 30 signal circuit contacts,
(d) 40 amperes for controllers equipped for 30 or more signal circuit contacts.

3.2 The panel shall have mounted on it at least the following short circuit protection devices and suitably identified field terminals:
(a) Terminal with N.E.C. cartridge fuse receptacle, fuse, power line switch, or magnetic trip circuit breaker, or integral power line switch, for the incoming power line.
(b) Terminal, unfused, for the neutral side of the incoming power line.
(c) Terminals for the conductors of the signal light cable; one for each signal circuit.
(d) Terminals for common return conductors of the signal light cable, at least one for each three signal circuits for which the controller is equipped.
(e) Terminal, grounded to the cabinet, for an equipment grounding conductor.

3.3 Adequate electrical clearance shall be provided between terminals. The controller unit, panel, terminals and other equipment shall be so arranged within the cabinet that they will not upset the entrance, training and connection of the incoming conductors.

3.4 The outgoing traffic signal circuits shall be of the same polarity as the line side of the power-service; the common return of the traffic signal circuits shall be of the same polarity as the grounded side of the power service. The grounded side of the power service shall be carried throughout the controller in a continuous circuit but shall not be grounded to the controller cabinet.

3.5 An equipment-grounding conductor bus shall be provided in each cabinet. The bus shall be grounded to the cabinet in an approved manner.

3.6 The controller shall withstand without failure a high-energy transient applied to the incoming power supply line. The transient shall be 1,000 volts, both positive and negative, applied three times for each polarity at a rate of once every two seconds from a 15 microfarad oil-filled capacitor.

4. Contacts

All contacts, if and where required, shall be of coin or fine silver or material of similar conductivity, shall be of sufficient cross-section to perform their normal functions with minimum pitting or burning under maximum current, and shall not require fine adjustment or readjustment for satisfactory and continuous operation.

5. Mechanical Requirements

All mechanism, motors, operating cells, bearings, contacts, relays, flashers and similar components, if and where required, shall be sufficiently large, rugged, and accessible to insure reliability and minimum maintenance. All equipment shall be neatly and systematically arranged and mounted to allow thorough inspection while the controller is being tested, and to permit easy removal of removable components without interfering with other portions of the controller. Components shall be securely fastened in place if necessary to prevent accidental contact with moving parts or electrical power and to permit the cabinet door to be opened and closed without interference or damage to the controller and wiring. Component accessibility shall permit easy access for any needed lubrication.

6. Constancy of Cycle Length and Intervals

The cycle length and the time duration of each interval shall be constant and accurate, regulated by the power line frequency. If the voltage of the power line varies between the limits of 10 percent above and 10 percent below 120 volts, 60 hertz standard service voltage, and if the outside temperature changes to any value between -30°F (-34°C) and +122°F (+50°C), the time duration of each cycle and of each interval shall not vary by more than ±500 milliseconds, for electromechanical control units, ±100 milliseconds, for solid state controllers, and timing of successive cycles and intervals shall be without cumulative errors that would affect the accuracy of the cycle length. Inside cabinet temperature shall not exceed +165°F (+74°C) when outside temperature is +122°F (+50°C) and the controller is in normal operation. Suitable cooling and/or heating devices shall be furnished if required for reliable controller operation within the foregoing temperature tolerances for timing accuracy, but it is preferred that cooling and/or heating devices not be required.
7. Cycle Length Adjustment

7.1 It shall be possible to accurately set or adjust the cycle length between the limits of 30 and 120 seconds with accurate and definite settings within this range in 5-second steps up to 50 seconds, and in 10-second steps above 50 seconds. If gears are required for adjusting the cycle length, each cycle unit shall be equipped with one gear, and additional gears shall be furnished if required by the purchaser. (The purchaser will insert here which cycle-length gears are to be furnished with each controller.)

7.11 (Optional) It shall be possible to accurately set or adjust the cycle length to 130 seconds in addition to the other required adjustment values.

7.12 (Optional) The controller shall be constructed to permit operation with three different cycle units by the addition, if required, of plug-in components, such as timer, transfer relay, and/or other necessary equipment. Such equipment for three-cycle units shall not be furnished with the controller unless required by the user.

7.13 (Optional) The controller shall be fully equipped to permit operation with three (two) cycle units, each capable of operating with a cycle length other than the same as the other cycle units. Provision shall be included for transfer from each cycle unit to any other cycle unit by electrical selection switch and, if required by purchaser, by time switch. (Purchaser will state whether time switch is required. The controller shall transfer from one cycle unit to another only during the major street green interval (interval number to be specified if other than the beginning of major street green), to avoid any chance of improper timing of other intervals during change-over. From the time of electrical call for transfer, not more than two cycles shall be required for complete transfer from one cycle unit to another cycle unit.

7.2 It shall be possible to set each cycle unit in a controller to operate at any of the above cycle lengths by adjusting an accurately calibrated dial, digital thumbswitch or similar device, or by the changing of marked gears, which latter action shall entail no more time than the use of simple tools. When the controller is operating within specified voltage and temperature limits, the time duration of each cycle shall be within ±500 milliseconds, for electromechanical controllers, and ±100 milliseconds, for solid state controllers, of the time setting for that cycle, and timing of more than cycles shall be without cumulative errors.

7.21 (Optional) The controller shall, at all times, give or be capable of giving a visual indication of the exact cycle length at which the controller is operating.

8. Interval Sequence

8.1 Each controller shall provide for a specified minimum number of consecutive intervals within the cycle. (Purchaser will insert here the number 12, 16, 18, or other required minimum number of intervals.)

8.2 The controller unit shall provide and be set up for the purchaser's required interval sequence. The desired interval sequence is to be inserted here by the purchaser. Figure 1a and b is a suggested interval sequence form which the purchaser may use or adapt.

9. Interval Setting and Adjustment

9.1 The controller shall provide for the setting up of the interval of the cycle by means of a positive setting on a calibrated dial, digital thumbswitch or similar device. The setting shall be made at all times show or be capable of giving a visual indication of the amount of time allocated to each interval, in units of percent of the cycle length or seconds. When the controller is operating within specified voltage and temperature limits, the time duration of each interval shall be within ±500 milliseconds for electromechanical controllers, and ±100 milliseconds for solid state controllers, of the time indicated by the setting of the interval setting. The time of successful intervals shall be without cumulative errors that would affect the accuracy of the cycle length.

9.2 Each cycle unit shall be provided with a scale calibrated in steps of 1 percent of the cycle length or one second, and shall provide for the accurate setting of any interval within the range of adjustment of from 2 percent to 90 percent of the cycle length or from one second to 99 seconds. The minimum time for any interval is not required to be less than one second whenever that is greater than 2 percent of the cycle length, nor is the minimum time for any interval required to be less than 2 percent of the cycle length when that is greater than one second.

9.3 The timing controls shall be on the front of the controller unit, easily identifiable, and it shall not be necessary to remove or change wires or contacts or to use any tools in making interval adjustments.

9.4 Interval timing which is set up in percent of the cycle length shall increase or decrease in exact proportion to any increase or decrease of the cycle length setting.

9.5 For each cycle unit furnished, a separate independent group of interval time setting devices shall be provided in order to make possible a different split for each cycle unit. Transfer of cycle units shall also bring about transfer of split and of time setting for each interval.

9.51 (Optional) For each cycle unit furnished, three separate independent groups of interval time setting devices for each interval shall be furnished to permit split change without cycle unit transfer. Provision shall be included for transfer from each split to any other split electrically by split selection switch and, if required by purchaser, by time switch. (Purchaser will state here whether time switch is required.) If a controller is equipped with three cycle units it shall have nine separate independent splits. The controller shall transfer from one split to another only during the major street green interval (interval number to be specified if other than the beginning of major street green).

From the time of electrical call for transfer, not more than one cycle shall be required for complete transfer from one split to another.

9.52 (Optional) The requirement for one or more separate independent groups of interval time settings for each cycle unit and split shall not apply to yellow vehicle change intervals, to red vehicle clearance intervals, nor to pedestrian clearance intervals. Each vehicle change or red clearance interval shown on the purchaser's desired interval sequence shall be provided with one positive, accurate setting adjustable from zero to seven seconds. Each pedestrian clearance interval prior to beginning of the yellow interval shall be provided with one positive, accurate setting adjustable from one to 30 seconds. Vehicle change or red clearance intervals and pedestrian clearance intervals shall not change in time duration with changes of cycle length.

10. Signal Load Switches

10.1 Controllers shall be provided with electromechanical signal load switch contacts, solid state signal load switches or similar equivalent devices for closing and opening of signal light circuits. The signal load switches shall be capable of being arranged or rearranged to cause any signal light circuit to be energized or de-energized during any one of the intervals in order to change the interval sequence. Interval sequence change shall be easy to perform by the use of simple tools without removing the controller or any part thereof to the factory.

10.2 At least the number of signal load switches which is required in order to operate the purchaser's desired interval sequence shall be provided.

10.21 (Optiona) Signal load switches for at least 19 separate independent signal circuits shall be provided, unless purchaser requires a different number. (Purchaser will insert here the number of signal circuits required if different from 19.)

10.3 The energizing and de-energizing of signal light circuits shall be accomplished by electromechanical signal load switch contacts, solid state signal load switches or similar equivalent devices. The closing or opening of signal load switches shall be positive without objectionable dark intervals, flickering of lights or conflicting signal indications. If solid state signal load switches are used, a signal conflict monitor shall be provided which shall prevent display of a
green indication or a walk indication to two conflicting traffic phases at the same time for longer than 500 milliseconds and with more than 25 volts A.C. output to each indication. Each signal load switch shall have a capacity adequate to make and break a tungsten lamp load current of 10 amperes at 120 volts, 60 hertz AC of a total of one million times without excessive pitting or burning of contacts or other switching device damage when operated at 120 times per hour with approximately 60 percent "on" time, 40 percent "off" time.

10.4 Signal load switches for flashing signal circuits shall be provided if the purchaser’s desired interval sequence includes pedestrian signal indications. The number of flashing signal circuits shall be adequate to provide flashing and steady DON’T WALK for all pedestrian signals and flashing WALK where required by the desired interval sequence, unless purchaser requires a larger number of flashing signal circuits. (Purchaser will insert here the number of flashing circuits required if larger than the foregoing requirement.) Flashing shall be at the rate of not less than 50 nor more than 60 flashes per minute with approximately 50 percent on and 50 percent off periods. The opening and closing of the flashing circuit shall be accomplished in such manner as to avoid undue pitting or burning of contacts or other switching device damage at 10 amperes of tungsten lamp load at 120 volts, 60 hertz AC for 50 million times.

11. Signal Shutdown Switch
Each controller shall be provided with a signal shutdown switch for turning off the signals at the intersection. This switch shall affect the power to the signals only and no other part of the controller.

12. Flashing of Vehicle Signal Indications

12.1 Means shall be provided for substituting of flashing vehicular signal indications for the normal specified interval sequence. (Purchaser will insert here the indications to be flashed.) Flashing shall be at the rate of not less than 50 nor more than 60 flashes per minute with approximately 50 percent on and 50 percent off periods. The flashing rate shall not vary with time cycle changes. The opening and closing of the flashing circuit shall be accomplished in such manner as to avoid undue pitting or burning or other damage of signal load switches at 10 amperes of tungsten lamp load at 120 volts, 60 hertz AC for 50 million times.

12.2 Flashing of vehicular and pedestrian signal indications shall be obtained from one or more flashers, each of which is a self-contained device designed to plug into a socket mounted on the back panel of the cabinet.

12.3 If a solid-state flasher is used, the flasher shall have no contact points or moving parts. The solid-state flasher shall use zero-point switching with turn-on at the zero-voltage point, ±5 degrees, and turn-off at the zero-current point, ±5 degrees, of the power line sinusoid.

12.4 Each controller shall be equipped with additional terminals which are so wired that, by an interchange of jumpers, flashing operation may be arranged to display either flashing yellow or flashing red on each of the vehicular signals.

12.5 Each controller shall be provided with a flash control switch for actuating the flashing of vehicular signals. This switch may be combined with the signal shutdown switch, if desired. The controller shall be constructed so that flashing operation can be obtained by operating the flash control switch even if the controller unit malfunctions or is removed from the circuit.

12.51 (Optional) The substitution of flashing vehicular signal indications for the normal specified interval sequence shall be obtainable by time switch as well as by the flash control switch.

12.6 Each controller shall be equipped with adequate means to suppress or prevent radio interference from flashing of vehicular and pedestrian signal indications. A radio interference suppressor, if used, shall be installed close to the flashing contacts or, if required by the purchaser, at the input power point.

12.7 Automatic change from flashing to stop-and-go operation shall be made at the beginning of the major street green interval, preferably at the beginning of the common major street green interval when a green indication is shown in both directions on the major street. Automatic change from stop-and-go to flashing operation shall be made at the end of the common major street red interval when a red indication is shown in both directions on the major street. The change from flashing to stop-and-go operation or from stop-and-go to flashing operation by flash control switch may be made at any time.

13. Manual Control

13.11 (Optional) For use under special conditions, intersection controllers shall be provided with means for substituting manual operation of interval timing for the normal automatic interval timing. Manual operation of interval timing shall provide the same interval sequence as when the controller is operating automatically. Manual interval timing shall be obtainable by means of a weather-resisting manual push-button mounted on a flexible weatherproof extension cord. The transfer from manual to automatic operation, or vice versa, shall be accomplished by an automatic switch. It shall not be necessary, when switching from manual to automatic operation, or vice versa, to do so at any certain time or to make any time adjustments.

14. Uninterrupted Timing
Any changes in operation of traffic control signal lights as described in paragraphs 11 and 12.1 shall not interfere with the continued in-time operation of the cycle timer in each controller. A transfer from such special operations back to normal automatic operation shall immediately re-establish the normal cycle length and subsequently the in-time relationship.

15. Guarantee

15.1 Each manufacturer shall include in his proposal all warrants and/or guarantees with respect to materials, parts, workmanship or performance of the equipment which the products covered by the proposal bear. The units furnished shall be new, of the latest model, fabricated in a first-class workmanlike manner from good quality material. The manufacturer shall replace free of charge to the purchaser any part that fails in any manner by reason of defective material or workmanship within a period of 18 months from the date of shipment from the supplier’s factory, but not to exceed one year from the date that the equipment was placed in operation after installation.

SECTION II
NONINTERCONNECTED CONTROLLERS

1. Purpose
The purpose of Section II of this specification is to set forth functional requirements which apply specifically to controllers of the noninterconnected type.

2. Design Requirements
The general design requirements in Section I apply in addition to specific functional requirements hereinafter described.

3. Offset

3.1 Each noninterconnected controller shall be provided with a simple, readily accessible offset control switch or equivalent for stopping the cycle and interval timing of the controller within two seconds or at the start of the proper offset position.

3.11 (Optional) The above switch for use in making accurate setting of the offset is to be provided with a simple locking device so that simple tools will be necessary for the operation of the same.
4. Power Failure Feature

4.11 (Optional) Noninterconnected controllers shall include apparatus whereby an automatic transfer will be made from the normal interval sequence to the same flashing combination set forth in paragraph 4.12 of Section I upon resumption of power supply after a failure, thereby indicating that the controller may have an incorrect offset with other controllers in the system.

4.12 (Optional) (Alternative to Paragraph 4.11 above.) Noninterconnected controllers shall include apparatus whereby a pilot lamp, mounted on, or in, the cabinet, will be lighted and remain illuminated upon resumption of power supply after a failure, thereby indicating that the controller may have an incorrect offset with other controllers in the system.

4.13 (Optional) The return to normal interval sequence shall be made by a manual relay reset rather than by a switch.

SECTION IV
INTERCONNECTED CONTROLLERS

1. Purpose
The purpose of Section IV of this specification is to set forth certain functional requirements which apply to interconnected controllers.

2. Design Requirements
The general design requirements in Section I apply in addition to specific functional requirements hereinafter described.

3. Offset For Progressive Timing
3.1 Each interconnected controller shall be provided with an adjustment for setting the offset of the start of major street green at the interconnected controller with respect to a similar interval at other interconnected controllers and to an electrical reference time at a master controller. For each cycle unit furnished, a separate offset adjustment shall be provided and shall be constructed so that transfer of cycle unit shall also bring about transfer of offset. The offset scale shall be calibrated in percent steps from 0 to 100 percent, and shall give a visual indication of the percent offset lag at which the controller is operating. When the controller is operating within specified voltage and temperature limits, the time of occurrence of each offset shall be within ±500 milliseconds, for electromechanical controllers, and ±100 milliseconds, for solid state controllers, of the time indicated by the setting for that offset, and timing of successive offsets shall be without cumulative errors that would affect the accuracy of the cycle length.

3.11 (Optional) Each interconnected controller cycle unit shall be provided with an adjustment for setting three (two) offsets (positive or negative) to specify either or both the number desired of the start of major street green with respect to other interconnected controllers and a master controller. If a controller is equipped with three cycle units, it shall have nine (six) separate independent offset adjustments. The offset scale shall be calibrated in percent steps from 0 to 100 percent and shall give a visual indication of the percent lag of each offset setting. When the controller is operating within specified voltage and temperature limits, the time of occurrence of each offset shall be within ±500 milliseconds, for electromechanical controllers, and ±100 milliseconds, for solid state controllers, of the time indicated by the setting for that offset, and timing of successive offsets shall be without cumulative errors that would affect the accuracy of the cycle length.

3.3 In changing the offset at a given intersection with respect to the system, it shall not be necessary to change or rearrange the individual interval adjusting devices.

3.4 The offset shall be constant and accurate, regulated by the power line frequency. If the voltage of the power line varies between the limits of 10 percent above and 10 percent below 120 volts, 60 hertz standard service voltage, and if the outside temperature changes to any value between −30°F (−34°C) and +122°F (+50°C), the time of occurrence of each offset with respect to master controller electrical reference time shall not vary by more than ±500 milliseconds, for electromechanical controllers, and ±100 milliseconds, for solid state controllers, and timing of successive offsets shall be without cumulative errors that would affect the accuracy of the cycle length.

4. Interval Setting and Adjustment
4.11 (Optional) Interconnected controllers having (double) (triplex) percentage settings of intervals and splits, Section I, paragraphs 7.13, 9.5, and 9.51, shall be designed for remote selection of interval timing and split from a master controller.

5. Remote Change
5.11 (Optional) When interconnected controllers are operated in a system and supervised by a master controller so as to provide remote change of cycle unit, changes in the controller cycle settings, Section I, paragraph 7.13, shall be obtainable at the master controller.

6. Remote Control of Preemption Sequences
6.11 (Optional) Controllers shall be equipped to provide special preemption sequences specified by purchaser upon remote control from railroad track circuit, emergency vehicle preemption, mass transit equipment or similar device which may connect either through a master controller or directly to the interconnected controller.

7. Remote Control of Flashing
7.11 (Optional) Interconnected controllers shall be provided with relays so that when interconnected in a system and supervised by a master controller, the flashing feature for signal lights at all local controllers, Section I, paragraph 12, shall be obtainable at the master controller.

8. Equipment
The panel shall be provided with a terminal and either a N.E.C. cartridge fuse receptacle and fuse or a magnetic tripping circuit breaker for each interconnecting conductor except the neutral, and with a terminal for the neutral conductor.

SECTION V
MASTER-SECONDARY CONTROLLER

1. Purpose
The purpose of Section V of this specification is to set forth functional requirements...
which apply to an interconnected controller which is also equipped to serve as a master controller.

2. Design Requirements

The general design requirements in Sections I and IV apply in addition to specific functional requirements hereinafter described.

3. Equipment

A master-secondary controller shall consist of a complete interconnected controller as described in Section IV in addition to the necessary apparatus to provide supervisory functions for operation of a system of interconnected controllers.

4. Supervisory Functions

The supervisory functions obtainable at the master-secondary controller are:

4.1 Means for automatically establishing offsets of a system of interconnected controllers.

4.11 (Optional) An offset interrupter or equivalent device for decreasing the disruption to interval timing caused by large offset changes.

4.12 (Optional) Hand-operated cycle selection switch for selecting the cycle unit of a system of interconnected controllers together with the offset and split which occur automatically upon cycle unit change. (See Section 1, paragraph 9.42 for number of cycle units.)

4.13 (Optional) Hand-operated flash control switch for transfer of traffic control signal lights at each interconnected controller to give flashing indications.

4.14 (Optional) Hand-operated switch for preemption of traffic control signal lights at each interconnected signal controller for railroad trains, emergency vehicles, mass transit equipment or similar needs.

4.15 (Optional) Hand-operated offset selection switch for selecting the offset for a system of interconnected controllers from among the offsets available without cycle unit change. (See Section IV, paragraph 3.11 for number of offsets.)

4.16 (Optional) Hand-operated split selection switch for selecting the interval timing and split for a system of interconnected controllers from among the interval timings and splits available without cycle unit change. (See Section 1, paragraph 9.51 for number of splits.)

4.2 The functions described in paragraphs 4.12, 4.13, 4.14, 4.15 and 4.16 shall each be obtainable, when specified, by means of time switches, operating on an automatic switching schedule as follows: (Attach schedule.)

SECTION VI
TABULATION
OF OPTIONAL FEATURES

1. Purpose

The purpose of Section VI of this specification is to provide a convenient check list of the information which must be specified by the purchaser and the optional features available which may be included in the requirements if desired.

2. Plan of Operation

2.11 Designate plan #1, #2, #3, or #4. (See Section I Data)

2.12 (see paragraph 2.21) List of features inside door-in-door.

3.11 (see paragraph 2.21) Door-in-door.

3.12 (see paragraph 2.21) List of features inside door-in-door.

3.13 (see paragraph 2.4) Color of cabinet paint.

4.14 (see paragraph 2.5) Cabinet mounting attachments.

5.15 (see paragraph 2.81) Time switch space, function and type.

6.16 (see paragraph 7.1) Cycle gears.

7.17 (see paragraph 7.11) Extended range of cycle length settings.

8.18 (see paragraph 7.12) Expandability to three cycle units.

9.19 (see paragraph 7.13) Provision of three (or two) cycle units.

3.20 (see paragraph 7.13) Time switch for cycle unit transfer.

3.21 (see paragraph 7.13) Cycle unit transfer interval, if other than major street green.

3.22 (see paragraph 7.21) Visual indication of cycle length.

3.23 (see paragraph 8.1) Required minimum number of intervals.

3.24 (see paragraph 8.2) Desired interval sequence.

3.25 (see paragraph 9.51) Provision of three splits per cycle unit.

3.26 (see paragraph 9.51) Time switch for split transfer.

3.27 (see paragraph 9.51) Split transfer intervals, if other than major street green.

3.28 (see paragraph 9.52) Fixed change or red clearance interval timing.

3.29 (see paragraph 10.21) Number of signal load switches.

3.30 (see paragraph 10.4) Number of flashing DON'T WALK circuits if greater than required for specified interval sequence.

3.31 (see paragraph 12.1) Vehicular signal indications to be flashed.

3.32 (see paragraph 12.51) Time switch for flashing operation.

3.33 (see paragraph 15.11) Manual control.

3.34 (see paragraph 15.11) One-year guarantee.

4. Section II Data

4.11 (see paragraph 3.11) Lock for offset control switch.

4.12 (see paragraph 4.11) Flashing after power failure.

4.13 (see paragraph 4.12) Pilot light after power failure.

4.14 (see paragraph 4.13) Power failure reset by manual relay.

5. Section III Data

5.11 (see paragraph 3b) List of desired remote controlled features.

6. Section IV Data

6.11 (see paragraph 3.11) Provision of three (two) offsets per cycle unit.

6.12 (see paragraph 4.11) Provision of remote split selection.

6.13 (see paragraph 5.11) Provision of remote cycle unit selection.

6.14 (see paragraph 6.11) Provision of remote preemption sequence selection.

6.15 (see paragraph 7.11) Provision of remote flash control.

7. Section V Data

7.11 (see paragraph 4.11) Offset interrupter.

7.12 (see paragraph 4.12) Cycle unit selection switch.

7.13 (see paragraph 4.13) Flash control switch.


7.15 (see paragraph 4.15) Offset selection switch.

7.16 (see paragraph 4.16) Split selection switch.

7.17 (see paragraph 4.2) Time switches for remote cycle unit, flash, offset and split selection.

7.18 (see paragraph 4.2) Switching schedule for time switches.
Figure 1a. Suggested interval sequence form in percent of cycle.

Figure 1b. Suggested interval sequence form in seconds.
Solid-State Pretimed Traffic Signal Controller Units

The purpose of this standard is to provide a guide for the preparation of specifications for a solid-state pretimed traffic signal controller unit. This standard represents the requirements for the equipment described herein and is not intended to impose restrictions on design and materials that conform to the purpose and intent of this standard.

The intent of this standard is to describe a controller unit that may be used at an isolated location, in conventional multidiurnal pretimed systems, or under control of a central master system.

Definitions


EIA—Electronics Industry Association.

NEMA—National Electrical Manufacturers Association.

NEMA Standard—Whenever a reference is made to a NEMA Standard, it shall mean the NEMA Standard for Traffic Control Systems in effect on the day the contract/purchase order is awarded. The definition of other terms used in this section may be found in the NEMA Standards Publication, Traffic Control Systems.

Section 1—Performance and Design Requirements for Solid-State Pretimed Controller Units

1.1 Physical Standards

1.1.1 Dimensions

The controller unit shall be capable of being shelf-mounted. The height of the controller unit shall not exceed 24 inches. The depth of the unit, including connectors, harnesses, and protrusions, shall not exceed 15 inches.

1.1.2 Design

The controller unit shall be of modular design. Circuit boards shall be readily accessible for maintenance.

Timing shall be accomplished by digital methods and shall utilize the power line frequency or a frequency generated by a crystal-controlled oscillator as a time base.

All controller unit circuits shall consist of solid-state electronic circuitry.

1.1.3 Material and Construction of Rigid Printed Circuit Assemblies

Materials, conductors, and component identification for all printed circuit boards shall conform to the requirements in Part 14.2.3 of "Material and

1.2 Environmental Standards and Test Procedures
Controller units shall conform to the requirements in Section 2 of "Environmental Standards and Test Procedures," of the NEMA Standard.

1.3 Front Panel Displays
The controller unit shall be capable of displaying the following information on the front panel of the unit:
- Cycle length or dial in effect.
- Offset in effect and its value.
- Split in effect.
- Interval timing.
- Data entry acceptance.
- Signal circuit on/off.

1.4 Programming
The front panel of the controller unit shall have a keyboard or other method for entering timing and data by the operator.

Section 2—Functional Requirements
The following functions, with associated minimum timing ranges and maximum increments, shall be provided.

2.1 Cycles
2.1.1
A minimum of three cycles shall be provided. Total cycle length is the sum of all interval times.

2.1.2
Each cycle shall be adjustable over a range of 30 to 250 seconds in one-second intervals.

2.2 Splits
2.2.1
A minimum of two splits per cycle shall be provided. Each split shall provide an adjustable interval time for each interval in the sequence in accordance with paragraph 2.4.3.

2.2.2
Each split shall be adjustable in one-second increments or in one-percent increments of the cycle length.

2.3 Offsets
2.3.1
A minimum of three offsets per cycle shall be provided.

2.3.2
Each offset shall be (a) adjustable over a range of 0 to 249 seconds in one-second increments, or (b) adjustable as a percentage of the cycle length in one-percent increments from 0% to 99%.

2.4 Intervals
2.4.1
The controller unit shall be capable of providing a minimum of 18 intervals per sequence.

2.4.2 (Optional)
The controller unit shall be capable of providing (24)(32)(40) intervals per sequence.

2.4.3
The timing range of each interval shall be
- Zero to 9.9 seconds in 0.1-second increments.
- Zero to 99 seconds in 1.0-second increments.
or
- Settable as a percentage of the cycle length in one-percent increments.

2.5 Output Circuits
2.5.1
The controller unit shall provide a minimum of 18 output circuits for controlling signal indications.

2.5.2 (Optional)
The controller unit shall be capable of providing a minimum of (24)(32)(40) intervals per sequence.

2.6 Flashing Operation
2.6.1
The controller unit shall be programmable so that a minimum of three output circuits may be programmed to flash during pedestrian protection intervals and another four output circuits shall be programmed to flash during flashing operation.

2.6.2
A programmable flash interval shall be provided following a power on. The length of the flashing interval shall be programmable from 0 to 99 seconds in one-second increments.

2.7 Preemption
The controller unit shall provide for at least one preemption sequence.

2.8 Offset Correction
The controller unit shall provide for offset correction whenever the unit is out-of-step with the system master.
Traffic-Actuated Traffic Signal Controllers—Solid-State

This report was approved as a revised standard of the Institute of Transportation Engineers by the ITE Board of Directors on September 30, 1973, in accordance with a recommendation of the Institute’s Technical Council. It superseded “Traffic Actuated Controller and Detector,” adopted as a standard in 1958.

The standard was developed by Technical Council Committee 4-15-S.

Members of Committee 4-15-S were: John J. Bobek (M), Gerald A. Elseltin (M), Donald E. Holoman (A), Cheryl M. Hunt (A), Robert S. Jolliff (M), Ralph G. Lewis, Jr. (F), Benjamin W. McKay (M), Peter S. Parmenter (F), Sheldon Pavlik (F), Harold M. Paynor, Jr. (F), Lionel M. Rogers, Cwyn K. Sanderlin (M), William Schepers, Jr. (F), W. E. Schwartzmesser (M), and Wayne N. York (F).

In accordance with Institute procedures, equipment standards are reviewed at least once every five years. In 1984, this standard was reviewed by ITE Technical Committee 75-S (Solid-State Controllers and Cabinets) and by the ITE Technical Council. The resulting recommendation to extend the standard for another five-year period with only editorial changes was published for comment in April 1985 and confirmed by the ITE Standards Approval Board in December 1985.

A. Purpose
The purpose of the following is to describe standard specifications for traffic actuated traffic signal controllers.

B. Definitions
Actuation. The operation of a detector in registering the presence or passage of a vehicle or pedestrian.

Analog. Pertaining to a method of timing that measures continuous variables such as voltage or current.

Automatic Switch. A device which, when operated, discontinues normal signal operation and permits manual operation.

Automatic Recommutation. A controller feature, which, upon power interruption, will cause the controller to automatically resume normal operation of any or to revert to its start-up sequence, depending on the length of the power interruption. Such recommissioning shall be accomplished without any manual initiation or switching.

Auxiliary Equipment. Separate control devices used to add supplementary features to a controller.

Cabinet. An outdoor enclosure for housing the controller and associated equipment.

Call. A registration of a demand for right-of-way by traffic (vehicular or pedestrian) to a controller.

Change Clearance Interval (s). The interval between the right-of-way of one phase and the beginning of a conflicting phase.

Check. An outgoing circuit that indicates the existence of an unwanted call.

Concurrent Timing. A mode of controller operation whereby a traffic phase can be selected and timed independently and simultaneously with another traffic phase.

Conflicting Phases. Two or more phases which will cause interfering traffic movements if operated concurrently.

Controller Assembly. A complete electrical mechanism mounted in a cabinet for controlling the operation of a traffic control signal.

Controller/Controller Unit. That part of the controller assembly which performs the basic timing and logic functions.

Coordination (Coordination Unit). A device used to interrelate the timing of one controller to others in a traffic signal system.

Cycle. Any complete sequence of signal indications.

Density. A measure of the concentration of vehicles usually stated as the number of vehicles per mile per lane.

Detector. A device for indicating the presence or passage of vehicles or pedestrians.

Digital. Pertaining to a method of timing that operates by counting discrete units, usually based on the frequency of the power source.

Dwell. (See Rest) Electromechanical Device. A device which is characterized by electrical circuits utilizing relays, step switches, motors, etc.

Electronic Circuitry. Electrical circuits utilizing vacuum tubes, transistors, resistors, capacitors, inductors and other similar non-mechanical devices.

Extensible Portion (Extensible Portion). That part of the green interval in an actuated phase following the initial portion which may be extended by traffic actuations.

Flash Control Switch. A device which, when operated discontinues normal signal operation and causes the flashing of a predetermined combination of signal lights.

Faster. A device used to open and close signal circuits at a repetitive rate.

Force Off. A command to the controller that will force the termination of the current right-of-way interval during the extensible portion.

Full Traffic-Actuated Controller. A type of traffic-actuated controller in which means are provided for traffic actuation on all approaches to the intersection.

Gap Reduction. A feature whereby the unit extension or allowed time spacing between successive vehicle actuations on the phase displaying the green in the extendable portion of the interval is reduced, usually in proportion to another parameter.

Hold. A command to the controller which causes it to retain the existing right-of-way interval.

Initial Portion. The first timed part of the green interval of an actuated phase.

Interconnected Controller. A controller which operates traffic signals under the supervision of a master controller.

Interval. The part or parts of the signal cycle during which signal indications do not change.

Interval Sequence. The order of appearance of signal indications during successive intervals of a cycle.

Interval Sequence Chart. A chart designating the order in which the phases of a cycle occur and the associated signal display for each interval.

Jack. A set of clips, plugs, or receptacles in a controller cabinet by means of which a plug-in device may be connected.
Major Street. The roadway approach or approaches at an intersection normally carrying the major volume of vehicular traffic.


Master Controller. An automatic device for supervising a system of controllers, maintaining definite time interrelationships, selecting among alternate modes of operation, and accomplishing other supervisory functions.

Maximum (Maximum Green). The maximum time the right-of-way can be extended by actuations on a phase provided an actuation has been registered on a conflicting phase.

Memory Detector. The retention of an actuation for future utilization by the controller.

Minimum (Minimum Green). (1) The shortest time for which the right-of-way shall be given to a non-actuated phase. (2) The shortest time for which the right-of-way shall be given to an actuated phase provided an actuation has been registered for that phase.

Minor Movement Controller. An auxiliary device that can be added to a controller to provide an additional actuated phase or subordinate phase.

Minor Street. The roadway approach or approaches at an intersection normally carrying the minor volume of vehicular traffic.

Modular. Equipment which is designed such that functional sections are plug-in and can be readily exchanged with similar units.

NEMA. National Electrical Manufacturers Association.

Non-Actuated Phase. A controller phase with no means for receiving actuations from vehicles and pedestrians.

Non-Conflicting Phases. Two or more traffic phases which will not cause interfering traffic movements if operated concurrently.

Non-Interconnected Controller. A controller which operates traffic signals not under master supervision.

Non-Locking Memory. A feature that permits detection to be ignored if it is not continued.

Offset. The number of seconds or percent of the cycle length that a defined reference point at a traffic signal occurs after the time reference point of a master controller or of an adjacent traffic signal.

Overlap. A right-of-way indication that is derived from the service of two or more traffic phases.

Passage (Passage Time). (1) The time allowed for a vehicle to travel at a given speed from the detector to the nearest point of conflicting traffic. (2) Also, a term functionally equal to and often used interchangeably with Unit Extension.

Pedestrian-Actuated Controller. A controller in which part of the intervals or groups of intervals, particularly pedestrian WALK and clearance intervals, are initiated by the actuation of a pedestrian detector.

Pedestrian Clearance Interval. The first clearance interval following the pedestrian WALK indication, normally during which a flashing DONT WALK is provided.

Pedestrian Phase. A traffic phase allocated to pedestrian traffic which may provide a right-of-way pedestrian indication either concurrently with one or more vehicular phases, or to the exclusion of all vehicular phases.

Phase Sequence. A predetermined order in which the phases of a cycle occur.

Phase Skip. Function used to provide omission of a phase in the absence of actuations on that phase.

Portion. A subdivision of an interval.

Power Line Switch (Disconnect Switch). A manual switch for disconnecting power to the controller assembly and traffic control signals.

Preemption. The transfer of the normal control of signals to a special control mode which may be required by railroad trains at crossings, emergency vehicles, mass transit vehicles, or other special needs.

Preemptor. A device which provides preemption.

Radio Interference Suppressor. A device inserted in the power line in the controller assembly (cabinet) that minimizes the radio interference which may be generated by the controller or auxiliary equipment and is transmitted back into the power supply line or other mechanisms in the cabinet.

 Recall Switch. A manual switch which shall cause the automatic return of the right-of-way to a normally actuated phase regardless of the absence of actuation on that phase.

Red Clearance Interval. A clearance interval which may follow the yellow change interval during which both the terminating phase and the next right-of-way phase display red (indications).

Rest. The interval portion of a phase when present timing requirements have been completed.

Right-of-Way. The operation of a controller in causing traffic signals to display indications permitting vehicles or pedestrians to proceed in a lawful manner in preference to other vehicles or pedestrians.

Semi-Traffic-Actuated Controller. A type of traffic-actuated controller in which means are provided for traffic actuation on one or more but not all approaches to the intersection.

Signal Conflict Monitor. A device used to continually check for the presence of conflicting signal indications and to provide an output in response to conflict.

Signal Load Switch. A device used to switch power to the signal lamps.

Signal Shut-down Switch. A manual switch to discontinue the operation of traffic control signals without affecting the power supply to other components in the controller cabinet.

Solid-State Device. A device characterized by electrical circuits whose active components are semi-conductors and which exclude electro-mechanical devices or vacuum tubes.

Split. A division of the cycle length allocated to each of the various phases (normally expressed in percent).

Split Phase. That portion of a traffic phase that is separated from the primary movement to provide a special phase that is related to a parent phase and characterized by the inability to rest in a minor phase.

Stop Timing. Provision within a controller to suspend timing operations upon assertion of an external command.

Subordinate Phase (Minor Phase). A traffic phase in which the right-of-way is dependent on the related operation (leading or lagging) of a specific independent phase.

Terminals. Devices for connecting wires inside the controller cabinet.

Time Switch. A device for the automatic selection of modes of operation of traffic signals in a manner prescribed by a pre-determined time schedule.

Timing Control. Calibrated control on a controller or auxiliary device that
provides setting of each interval and interval portion.

*Time Waiting Gap Reduction.* A feature whereby the unit extension in the phase having the green is reduced in proportion to the time vehicles have waited on the phase(s) having the red. This feature is designed to provide a more efficient traffic control system by reducing the waiting time for vehicles on the subsequent phases.

**Traffic Phase.** Those right-of-way change, and clearance intervals in a cycle assigned to independent movement(s) of traffic.

*Unit Extension.* The timing period during the extendible portion of a right-of-way interval which is settable by each controller actuation within the limits of the maximum period (extension limit).

*Variable Initial Portion.* A feature in which the initial portion of the green interval of an actuated phase is varied in accordance with traffic demand.

*Vehicular Phase.* A traffic phase allocated to vehicular traffic.

*Yellow Change Interval.* The first interval following the green right-of-way interval in which the signal indication for the phase is yellow.

*Yield.* A command which permits a controller to transfer the right-of-way.

*Zero point switching.* Switching method in which turn-on is accomplished within five degrees of the zero voltage point of the alternating current line sinusoid and turn-off is accomplished within five degrees of the zero current point of the alternating current load current sinusoid.

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C. Scope

The specifications which follow are intended to cover traffic actuated traffic signal controllers and include four principle sections.

Section 1 — General Design Requirements
Section 2 — Two-Phase Traffic-Actuated Controllers
Section 3 — Three-Phase Traffic-Actuated Controllers
Section 4 — Multi-Phase Traffic-Actuated Controllers

Throughout the specifications, subsections designated as Optional may be selected when the user desires those features. However, Optional subsections may be deleted by the user when desired.

Additionally, certain subsections require user input to complete their meaning. These subsections are designated by a modifying phrase indicating the necessary user input.

A concise listing of all Optional and user selectable features together with a suggested usage guideline is included as Section 5 — Summary of Optional Features.

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**SECTION 1 — GENERAL DESIGN REQUIREMENTS**

1. PURPOSE

It is the purpose of Section 1 of these specifications to set forth minimum design and functional requirements for all types of controllers included in the entire specification.

2. ELECTRICAL REQUIREMENT

2.1 Power

2.11 Nominal Voltage and Current — The controller shall be designed to operate from a nominal 120 volt alternating current, 60 Hz, power source.

2.12 Voltage and Current Ranges — The controller shall operate satisfactorily within a voltage range of 105 to 135 volts alternating current and a frequency range of 57 to 63 Hz.

2.13 Optional Special Power Requirement — The controller shall be designed to operate from a special power source as follows: (Purchaser shall insert here special power requirements.)

2.2 Controller Connections

2.21 Minimum Requirements — The controller shall contain a connector enabling outgoing and incoming electrical circuits to be connected or disconnected easily without the necessity of installing or removing individual wires leading thereto.

This may be accomplished by means of a multiple pin jack, a spring connected mounting or approved equivalent mounting. (If specific connector type is desired, purchaser shall specify type in this space.)

2.22 Optional NEMA Connection Requirement — The controller shall contain a circular twist lock — type connector meeting the requirements of the latest NEMA Traffic Control Systems Standard TS1.

2.3 Overcurrent Protection — The controller shall contain a front panel mounted AC power input overcurrent protection device of suitable size to provide adequate overcurrent protection.

2.4 Automatic Reorientation — In the event of a power interruption, the controller shall be capable of automatic reorientation upon power resumption and shall require no manual initiation or switching.

3. CONSTANCY OF INTERVALS

3.1 Minimum Requirements — The length of any interval or timing setting shall not change by more than ±5% of the setting or 1/2 second, whichever is greater, so long as the voltage and frequency of the power source and the ambient temperature inside the controller cabinet remain within the tolerances specified in these specifications.

3.2 Optional Requirements — The length of any interval or timing setting shall not change by more than ±100 milliseconds of its set value so long as the voltage and frequency of the power source and the ambient temperature inside the controller cabinet remain within the tolerances specified in these specifications.

4. INTERVAL SEQUENCE

4.1 General — The controller shall provide the proper intervals and interval sequence as required by the purchaser in the following section of these specifications.

4.2 Required Interval Sequence — The phase and interval sequence shall be: (The desired interval sequence is to be as inserted here or later attached by the purchaser. The following sequence chart is a suggested interval sequence form which the purchaser may use or adapt.)

4.3 Interval Sequence Chart

(See Figure 1)

4.4 Skipping of Actuated Phases — If, at the end of the green interval of the terminating phase, neither vehicle nor pedestrian memory indicates a need for the next traffic phase, the intervals which comprise that phase shall be omitted from the interval sequence.

This does not, however, preclude the use of recall switches which, when in the “on” position, shall cause the phase to be displayed even though no detector actuations have been received.

5. BASIC INTERVAL SETTING AND FUNCTIONS

5.1 Provisions for Setting — The controller shall provide for the
Table of signal heads:

**Intersection Sketch**

<table>
<thead>
<tr>
<th>Display Size</th>
<th>Size/Mounting</th>
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<tbody>
<tr>
<td>R</td>
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**Vehicle Movements**

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<tr>
<th>Signal Head Number</th>
<th>P₁</th>
<th>P₂</th>
<th>P₃</th>
<th>P₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flashing Operation</td>
<td></td>
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</table>

**Phase Interval**

<table>
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<th>Display Sequence</th>
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<tr>
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<td>26</td>
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<td>27</td>
</tr>
</tbody>
</table>

**Legend**

- R = Red
- Y = Yellow
- G = Green
- W = Walk
- DW = Don't Walk
- FPW = Flashing Don't Walk

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Figure 1. Interval Sequence Chart (all phases)
setting of each interval, portion of interval, or function by means of a positive setting on a calibrated control. The control shall be calibrated in seconds and fractions thereof when applicable, and shall give a clear visual indication of the value of each interval or function. Setting of timing and function values shall be accomplished without the use of special tools or wiring changes.

5.2 Location of Controls —
The interval and function controls shall be located on the front of the controller and shall be properly designated as to the function each control performs.

5.3 Basic Required Intervals/Functions and Ranges —
The basic required intervals, portions of intervals, and functions for each phase of operation are listed in Table 1.

5.4 Interval and Function Indication

5.4.1 Minimum Indication —
Means shall be provided on/within the controller to facilitate the determination of operation and termination of intervals and functions contained therein.

5.4.2 Optional Indication —
Indication shall be provided and appropriately labeled on the controller to facilitate the determination of operation and termination of the intervals and functions contained therein. Indication shall include but not necessarily be limited to the following:
- Phase(s) next
- Phase(s) in service
- Status indicators
- Initial interval
- Vehicle interval
- Yellow change interval
- Red clearance interval
- Maximum/gap termination

5.4.3 Call Indication —
Indication shall be provided on the controller to display presence of a detector actuation.

5.5 Vehicle Recall Switch(es) —
A recall switch shall be provided for each actuated vehicle phase which, when asserted, shall cause the automatic return of the right-of-way to that phase in accordance with the specified interval sequence.

5.5.1 Optional Maximum Recall Switch(es) —
The recall switch(es) shall provide a maximum recall position which, when asserted for a phase, shall cause the automatic return of the right-of-way to that phase for the duration of the Maximum green interval in accordance with the specified interval sequence.

5.7 Optional Vehicle Detector Non-Lock Memory Switch(es) —
A switch shall be provided for each actuated vehicle phase which, when placed in the non-lock position, shall cause the vehicle detector memory circuit for that phase to be disabled.

6. OPTIONAL INTERVAL SETTING AND FUNCTIONS

6.1 General —
The following subsection describes Optional intervals, portions of intervals and functions which may be specified in addition to the Basic Intervals and Functions described in the previous subsection.

6.2 Provisions for Setting —
The controller shall provide for the setting of Optional intervals, portions of intervals, and functions as hereinafter described by means of positive settings on calibrated controls. Controls shall be calibrated in seconds or other appropriate designation and shall give a clear visual indication of the value of each interval or function.

Setting of control values shall be accomplished without the use of special tools or wiring changes.

6.3 Location of Controls —
The interval and function controls shall be located on the front of the controller and shall be designated as to the function each control performs.

6.4 Optional Intervals/Functions and Ranges —
Optional intervals, portions of intervals, and functions may be selected by the purchaser from Table 2.

6.5 Interval and Function Indication

6.5.1 Minimum Indication —
Means shall be provided on the controller to facilitate the determination of operation and termination of intervals and functions contained therein.

6.5.2 Optional Indication —
Indication shall be provided and appropriately labeled on the controller to facilitate the determination of operation and termination of the optional intervals and functions contained therein. Indication shall include but not necessarily be limited to the following:
- Status indicators
- Red clearance interval
- Walk interval
- Pedestrian clearance interval
- Rest state

6.5.3 Call Indication —
Indication shall be provided on the controller to display presence of vehicle call including memory and detector actuations and presence of a pedestrian call when pedestrian timing functions are included.

6.6 Pedestrian Recall Switch(es) —
A recall switch shall be provided for each actuated phase that includes pedestrian interval timing functions, which when asserted, shall cause the automatic return of the controller to that phase and related pedestrian interval(s).

6.7 Flashing of Pedestrian Clearance Interval Functions —
Means shall be provided to control the flashing of pedestrian signals during the pedestrian clearance interval(s).

6.8 Optional Flashing of WALK Interval Functions —
When specified, means shall be provided to select and control the flashing of pedestrian signals during the WALK interval(s).

7. SIGNAL CIRCUITS

7.1 General —
The controller shall be provided with suitable load

---

Table 1.

<table>
<thead>
<tr>
<th>Interval (Function)</th>
<th>Approximate Minimum Range</th>
<th>Optional Minimum Range</th>
<th>Increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Green*</td>
<td>10 sec–90 sec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>2 sec–12 sec</td>
<td>1 sec–30 sec/1 sec</td>
<td></td>
</tr>
<tr>
<td>Extension (Passage)</td>
<td>2 sec–12 sec</td>
<td>0 sec–9 sec/½ sec</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>10 sec–60 sec</td>
<td>10 sec–99 sec/1 sec</td>
<td></td>
</tr>
<tr>
<td>Yellow Change</td>
<td>1 sec–10 sec</td>
<td>0 sec–7 sec/¼ sec</td>
<td></td>
</tr>
<tr>
<td>Red Clearance</td>
<td>0 sec–7 sec</td>
<td>0 sec–7 sec/½ sec</td>
<td></td>
</tr>
<tr>
<td>(Purchaser shall select choice of minimum range or optional minimum range and increment.)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*To be provided on non-actuated phases only (semi-actuated controllers) in lieu of Initial, Extension and Maximum functions.
switches, either internal or external to the controller, for closing and opening signal light circuits. Such switches shall be sufficient in quantity to provide the interval sequence as described in Subsection 4, Section 1 of this specification. Solid-state load switches may be required for solid-state controllers.

7.2 Closing and Opening of Circuits/Minimum Capacity —
The closing or opening of signal circuits shall be positive without objectionable dark intervals, flickering of lights or conflicting signal indications. Each switch shall have a capacity of not less than 10 amperes of incandescent lamp load at 120 volts AC.

7.3 Optional External Load Switch(es) — The load switches shall be external to the controller and shall be jack-mounted within the associated cabinet, signal circuits shall be accommodated within each jack-mounted switch unit.

(Purchaser shall insert required number of circuits to be included in each switch unit.)

7.4 Optional NEMA Triple Signal Load Switch(es) — External jack-mounted load switches shall be provided in accordance with "Solid-State Load Switches," of the latest NEMA Traffic Control Systems Standard T51.

8. CONFLICT MONITOR

8.1 Minimum Requirements —
For actuated controllers of solid-state design and construction or actuated controllers utilizing solid-state load switches, a separate, external signal monitoring device shall be provided to monitor the occurrence of conflicting Green or Walk indications and shall cause the signals to go into flashing operation should such conflicts be sensed.

8.2 Optional Requirements
8.21 Mandatory Conflict Monitor —
A separate, external signal monitoring device shall be provided with each actuated controller which shall monitor the occurrence of conflicting Green or Walk indications and shall cause the signals to go into flashing operation should such conflicts be sensed.

8.22 Occurrence of Conflict —
Conflicting Green or WALK is defined as occurring when 25 volts rms or more, at 60Hz, appears for 500 milliseconds or more on any Green or WALK circuit that is in conflict with the

<table>
<thead>
<tr>
<th>Table 2. Optional Intervals/Functions and Ranges.</th>
<th>Optional Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval (Function)</td>
<td>Range or Function Value</td>
</tr>
<tr>
<td>Walk</td>
<td>Approximate Minimum Range or Function Value</td>
</tr>
<tr>
<td></td>
<td>Approximate Values</td>
</tr>
<tr>
<td>Pedestrian Clearance</td>
<td>2 sec-30 sec</td>
</tr>
<tr>
<td>Maximum</td>
<td>1 sec-30 sec/1 sec</td>
</tr>
<tr>
<td></td>
<td>10 sec-60 sec</td>
</tr>
<tr>
<td></td>
<td>1 sec-30 sec/1 sec</td>
</tr>
<tr>
<td></td>
<td>10 sec-99 sec/1 sec</td>
</tr>
</tbody>
</table>

| MODE A                                          | Variable Initial Functions |
| Added Initial                                   | (Select Mode A, B, C, or D) |
| Minimum Initial                                 | 2 sec-12 sec         |
| Added Initial Per Actuation Before Added Initial| 0 sec-2 sec          |
| Maximum                                        | 2 veh-60 veh         |

| MODE B                                          | 2 sec-12 sec |
| Computed Initial                                | 1 sec-30 sec/1 sec |
| Minimum Initial                                | 2 sec-30 sec |
| Maximum Initial                                | 0 sec-30 sec/1 sec |
| Actuations to Reach Maximum Initial            | 5 veh-89 veh |

| MODE C                                          | 2 sec-12 sec |
| Extensible Initial                             | 1 sec-30 sec/1 sec |
| Maximum Initial                                | 2 sec-30 sec/1 sec |
| Added Initial Per Actuation                    | 0 sec-2.25 sec/1 sec |

| MODE D                                          | 2 sec-12 sec |
| Added Initial/Green                             | 1 sec-30 sec |
| Minimum Green                                  | 0 sec-3 sec |
| Added Initial                                  | 0 sec-3 sec/1 sec |

| Time Waiting Gap Reduction Functions            | 0 sec-9 sec/4 sec |
| Minimum Gap                                     | 2 sec-12 sec |
| Time Before Reduction                           | 0 sec-10 sec |

| MODE A                                          | 2 sec-12 sec |
| Time to Reduce to Maximum Gap                   | 10 sec-99 sec |

| MODE B                                          | 0.25 sec-1.7 sec |
| Reduce Gap By                                   | 0.25 sec-1.7 sec/1 sec |
| Reduce Gap Every Second By                      | 0.25 sec-7.75 sec |
| Reduce Gap Every Second By                      | 0.25 sec-7.75 sec/1 sec |

| MODE C                                          | 0.01 sec-0.99 sec |
| Reduce Gap Every Second By                      | 0.01 sec-0.99 sec/4 sec |

| MODE D                                          | 1 sec-60 sec |
| Time to Reduce                                   | 1 sec-60 sec/1 sec |

(Purchaser shall designate Optional intervals/functions required for each phase and shall select choice of minimum range or Optional minimum range and increment)

1. Minimum Initial can be provided by use of initial time setting control under "Basic Intervals."
2. Passage time can be provided by use of Unit Extension setting control under "Basic Intervals."
Green or WALK circuit in effect in a normally functioning controller.

8.23 Release from Flashing — Once a conflict has been sensed and flashing operation has been initiated, release from flashing shall be accomplished only by manual operation of a reset switch provided on the monitoring device.

8.3 Optional NEMA Conflict Monitor — A separate, external signal monitoring device shall be provided in accordance with the latest NEMA Traffic Control Systems Standard TS1. (Such monitors shall detect the occurrence of conflicting Green or Walk indications as well as the absence of a required Red indication.)

9. FLAShING OF SIGNALS

9.1 Minimum Requirements — Means external to the controller shall be provided to permit the substitution of flashing signal indications for the normal specified interval sequence.

The indications to be flashed shall be as specified here or in the included interval sequence chart (Purchaser shall insert the desired flashing operation).

9.12 Flashing Rate — Flashing shall be at the rate of not less than 50 nor more than 60 flashes per minute with approximately 50% on and 50% off periods so long as the power source remains within the specified limits.

9.13 Capacity — The operation of the flashing circuit shall be accomplished in such a manner as to avoid undue pitting or burning or other damage to load switches at 10 amperes of tungsten lamp load at 120 volts, 60 Hz AC for 50 million times.

9.14 Flashing of Vehicular Signals — Flashing of vehicular signal indications shall be obtained from one or more flashers, each of which is a self-contained device designed to plug into a panel in the controller cabinet. If the flashing is provided by two flashers, they shall be wired to assure that the flashing of all indicators on the same approach is simultaneous.

9.15 Flashing of Pedestrian Signals (Pedestrian Clearance) — When pedestrian interval timing functions are included, means shall be provided to permit flashing of the DONT WALK pedestrian signals during the pedestrian clearance interval.

9.2 Optional Requirements

9.21 Flashing of Pedestrian Signals (WALK) — When specified, means shall be provided to permit flashing of the WALK pedestrian signals during the WALK interval.

9.22 Solid-State Flasher — A solid-state flasher with no contact points or moving parts shall be provided. The solid-state flasher shall utilize zero-point switching.

10. MANUAL CONTROL

10.1 Optional Manual Operation — For use under special conditions, controllers shall be provided with means for substituting manual operation of interval timing for normal automatic controller interval timing. Manual operation of interval timing shall provide the same interval sequence as when the controller is operating automatically. When specified, the controller shall provide manual operation in response to commands from external devices.

10.2 Optional Manual Control Enable — When specified, manual commands shall place vehicle calls and pedestrian calls (when pedestrian timing is included in the controller's sequence of operation) on all phases, stop controller timing in all intervals except vehicle change and clearances, and inhibit the operation of interval advance during vehicle change and clearances.

10.21 Operation Without Pedestrian Timing — When concurrent pedestrian timing is not provided, one actuation of the interval advance input shall advance the controller to Green rest, from which it will immediately select a phase next and advance to the Yellow Vehicle change, subject to the constraints of concurrent timing.

10.22 Operation with Pedestrian Timing — When concurrent pedestrian service is provided, two sequential activations of the interval advance input shall be required to advance through a Green interval, the first actuation shall terminate the WALK interval, and the second shall terminate the Green interval and the Pedestrian Clearance Interval.

10.23 Automatic Timing of Vehicle Change/Clearance Intervals — All Vehicle Change/Clearance Intervals shall be timed internally by the controller. Actuations of the interval advance input during Vehicle Change/Clearance Intervals shall have no effect on the controller.

11. AUXILIARY FUNCTIONS

11.1 General — When specified, the controller shall accommodate auxiliary functions and/or devices in order to perform functions previously required in this specification or as hereafter described.

11.2 Stop Timing — Suitable input from auxiliary equipment or other external sources, shall cause cessation of controller timing during assertion of such input. Upon removal of such input assertion, the interrupted interval which was timing shall resume normal timing.

11.3 Optional Accumulation of Vehicle Actuations — During stop timing, vehicle actuations on non-Green phases shall be accumulated, and actuations received for phases timing a Green interval shall cause the passage timer to be reset.

11.4 Optional Auxiliary Functions — Auxiliary functions and/or devices may include, but not be limited to, the following:

11.41 Pedestrian Interval Timer — Adds WALK and Pedestrian Clearance timing to any phase of an actuated controller.

11.42 Advance Green Timer — Adds special advance green or left turn interval at beginning of any phase of an actuated controller.

11.43 Red Clearance Timer — Adds red clearance interval at end of any phase of an actuated controller.

11.44 Double Clearance Timer — Adds special double clearance interval at end of any phase of an actuated controller.

11.45 Minor Movement Controller — Adds actuated phase to the normal operation of an actuated controller. (Purchaser shall select these or other auxiliary functions as required to perform the specified controller operation.)

12. PREEMPTION

12.1 General — Controllers shall be equipped to provide special preemption sequences when specified by the purchaser and described in the signal sequence chart in Subsection 4. Section 1 of these specifications, from railroad track circuits, emergency vehicle preemption, mass transit equipment, or similar devices which may connect through a master controller or directly to the controller.

12.2 Operational Setting of Intervals and Functions — Means shall be provided for the setting of each preemption interval and/or function by means of a positive setting on a calibrated control. Timing controls shall be calibrated in seconds and a
clear visual indication of the value of each interval or function shall be given.

12.3 Optional Constancy of Intervals — Constancy of intervals shall be in accordance with the tolerances specified for the controller in Subsection 3, Section 1 of these specifications.

12.4 Optional Indicator Lights — Indicator lights shall be provided and appropriately labeled to facilitate the determination of operation and termination of the intervals and functions of the preemtator.

12.5 Optional Continuation of Preemption Sequence — Once the preemption sequence is begun, it shall continue through the entire preemption cycle regardless of the condition of the preemption circuit or switch.

12.6 Optional Return to Normal Controller Operation — When the preemption cycle has been terminated and the controller has returned to its normal condition, the controller shall go through its normal interval sequence (as indicated by the sequence chart in Subsection A, Section 1 of this specification) as it calls had been received and remembered on all phases.

12.7 Optional Preemption Test Switch — A momentary contact switch shall be installed in the preemption actuation circuit to provide a means to test the preemtator operation.

12.8 Optional Method of Furnishing — The preemtator shall be an integral unit of the controller or a separate unit built on a chassis which is connected into the controller through an appropriate connector.

12.9 Optional Circuit Design — The preemtator shall consist of solid-state components when used with solid-state controllers and may consist of electromechanical components when used with electromechanical controllers.

13. COORDINATION

13.1 Minimum Requirements — Means shall be provided within the controller to permit its interconnection into a coordinated traffic signal system when coordinating devices are added. As a minimum, this should include the provision of Yield circuit or Hold circuit, accessible to interruption by commands external to the controller.

13.2 Optional Requirements

13.21 Hold Feature — The controller shall contain a Hold feature which when asserted 1: a particular phase shall hold that phase in a rest condition. Upon release from Hold, the phase shall immediately advance into the appropriate change or clearance interval or other unexpired portion of the green, provided there is an actuation on an opposing phase.

13.22 Force-Off Feature — The controller shall contain a Force-off feature which, when asserted shall cause termination of the current phase provided that phase is in the extension portion. In no case shall assertion of force-off cause termination in a change or clearance interval or during a minimum green for vehicles or pedestrians.

13.3 Optional NEMA Coordination Requirements — In addition to the minimum coordination requirements specified above, the controller shall contain the coordination features for the applicable configuration included in the latest NEMA Traffic Control Systems Standard TS1.

14. ENVIRONMENTAL AND TESTING

14.1 Minimum Requirements

14.1.1 General — The controller shall maintain all of its programmed functions and timing intervals when the temperature and humidity ambients are within the specified limits of this specification.

14.12 Ambient Temperature — The operating ambient temperature range shall be from —30°F to +150°F.

14.13 Cooling/Heating Devices — Suitable heating and/or cooling devices shall be furnished if required for reliable controller operation within the required temperature tolerances.

14.14 Optional Ambient Temperature — The operating ambient temperature range shall be from —30°F to +156°F.

14.15 Optional Cooling/Heating Devices — No heating or cooling devices other than standard vent fan(s) shall be required for proper operation of the controller.

14.16 Optional Humidity — The controller shall be designed to operate properly within a relative humidity range of 0 to 95% up to 110°F.

14.17 Optional Heater — A thermostatically controlled heater shall be provided to maintain the ambient temperature in the cabinet within the operating temperature range of the controller.

14.2 Optional NEMA Requirements

14.21 Environmental and Operating Requirements — The controller shall fulfill the environmental and operating requirements as described in the latest NEMA Standards.

14.22 Testing — The controller shall fulfill the testing requirements as described in the latest NEMA Traffic Control Systems Standard TS1.

15. CABINET

15.1 Basic Construction — The controller and all associated equipment shall be provided in weatherproof cabinet of clean-cut design and appearance.

15.11 Construction Material — The cabinet shall be constructed of sheet steel, sheet or cast aluminum, or other specified material (Purchaser shall here select construction material desired).

15.12 Door — A hinged door shall be provided permitting complete access to the interior of cabinet. When closed, the door shall fit closely to gasketing material, making the cabinet weather and dust resistant. The door shall be provided with a strong lock and key.

(Purchaser shall here insert special lock and key requirements.)

15.13 Auxiliary Door — A small, hinged and gasketed "door-in-door" shall be included on the outside of the main cabinet door. The auxiliary door shall not allow access to the controller, its associated equipment, or exposed electrical terminals but shall allow access to a small switch panel and compartment containing a signal shutdown switch, a flash control switch, and other specified functions.

(Purchaser shall insert list of required additional functions).

The auxiliary door shall be equipped with a strong lock utilizing keys of a different design from those provided for the main cabinet door.

(Purchaser shall here insert special lock and key requirements).

15.14 Optional Door Stop — The controller cabinet door shall be provided with a stop and catch arrangement to hold the door open at angles of both 90 degrees and 180 degrees, ± 10 degrees or at other angles if so required.

(Purchaser shall here insert other door stop angles if desired).
15.15 Mounting Shelves —
The cabinet shall contain strong mounting tables(s) or sliding way(s) to accommodate mounting of the controller and all included auxiliary equipment. The mounting facilities shall permit the controller to be withdrawn from the cabinet for inspection or maintenance without breaking any electrical connections or interrupting operation of the controller.

15.16 Mounting Screws — Screws used for mounting shelves or other mounting purposes shall not protrude beyond the outside wall of the cabinet.

15.2 Size, Type and Mounting

15.21 Size — The cabinet shall be of such size to adequately house the controller, all associated electrical devices and hardware, and other auxiliary equipment herein specified.

15.22 Optional Size — The cabinet shall be of the following minimum dimensions: Height _____, width _____, depth _____.

(Purchaser shall specify minimum cabinet size dimensions.)

15.23 Mounting — The cabinet shall be arranged and equipped for mounting as follows:
- Steel pole mounting
- Wood pole mounting
- Post top (pedestal) mounting
- Base mounting on concrete foundation

Sufficient galvanized anchor bolts, clamps, nuts, hardware, etc. as required for the specified mounting type shall be furnished with each cabinet.

(Purchaser shall specify type mounting desired.)

15.3 Ventilation

15.31 Vents — The cabinet shall contain a suitably designed raintight vent or vents equipped with screens or filters. The vent(s) shall allow the release of excessive heat and/or any explosive gases which might enter the cabinet.

When filters are utilized, positive retention shall be provided on all sides to prevent warpage and entry of foreign matter around the edges.

15.32 Optional Vent Fan — A thermostatically controlled vent fan shall be furnished to provide air circulation within the cabinet. The thermostat controlling the fan shall be manually adjustable to turn on between 90°F and 150°F with a differential of not more than 10°F between automatic turn-on and turn-off.

The fan shall be located with respect to the vent holes so as to direct the bulk of the air flow over the controller and included auxiliary equipment.

15.4 Connecting Cables, Wiring, and Panels

15.41 Connecting Cables — Electrical connections from the controller (and auxiliary devices when included) to outgoing and incoming circuits shall be made in such a manner that the controller (or auxiliary device) can be replaced with a similar unit, without the necessity of disconnecting and reconnecting the individual wires leading therefrom. This can be accomplished by means of a multiple plug, a spring-connected mounting or approved equivalent arrangement. Correlation shall be made with connecting cable plug and controller jack as described in Subsection 2.2, Section 1 of this specification.

15.42 Panels and Wiring — Each cabinet shall be furnished with suitable, easily accessible wiring panel(s). All panel wiring shall be neatly arranged and firm.

15.421 Wiring Terminals — terminals shall be provided, as a minimum, for the following:
- Terminal with N.E.C. cartridge fuse receptacle, fuse, power line switch, or magnetic circuit breaker, with integral power line switch for the incoming power line.
- Terminal, unfused, for the neutral side of the incoming power line.
- Terminals, and bases for signal load switches, if required, and outgoing signal field circuits.
- Terminals and bases for signal flasher and outgoing signal field circuits.
- Terminals for detector cables.
- Terminals for all required auxiliary equipment.
- Additional terminal for special circuits specified.

(Purchaser shall specify here additional terminals required.)

15.422 Clearance Between Terminals — Adequate electrical clearance shall be provided between terminals. The controller, auxiliary equipment, panel(s), terminals and other accessories shall be so arranged within the cabinet that they will facilitate the entrance and connection of incoming conductors.

15.423 Signal Circuit Polarity — The outgoing signal circuits shall be of the same polarity as the line side of the power service; the common return of the same polarity as the grounded side of the power service.

15.424 Grounding Conductor Bus — An equipment grounding conductor bus shall be provided in each cabinet. The bus shall be grounded to the cabinet in an approved manner.

15.5 Fusing and Surge Protection

15.51 Incoming AC Line — Suitable overcurrent protection, utilizing one of the methods described in Subsection 15.421, Section 1 shall be provided.

15.52 Optional Surge Protection — High energy transient surge protection shall be provided on incoming lines in order to minimize potential controller damage. The incoming circuits to be protected include the following:

(Purchaser will insert here desired circuits to be protected.)

15.6 Optional Painting — The cabinet and all mounting attachments shall be finished with two coats of high grade enamel paint.

(Purchaser will insert here the color paint to be used.)

16. GUARANTEE

16.1 Minimum Warranty — Each manufacturer shall include in his proposal all warranties and/or guarantees with respect to materials, parts, workmanship, or performance which are included for equipment covered by this specification.

16.2 Optional Warranty — The equipment furnished shall be new, of the latest model, fabricated in a first-class workmanlike manner from good quality material. The manufacturer shall replace free of charge to the purchaser any part that fails in any manner by reason of defective material or workmanship within a period of eighteen months from the date of shipment from the supplier's factory, but not to exceed one year from the date that the equipment was placed in operation after installation.

SECTION 2 — TWO-PHASE TRAFFIC-ACTUATED CONTROLLERS

1. PURPOSE

It is the purpose of this section of the specifications to set forth minimum design and operating requirements for two-phase traffic-actuated traffic signal controllers.
2. GENERAL DESIGN REQUIREMENTS

The General Design Requirements in Section 1 of this specification shall apply in addition to certain operating and functional requirements hereinafter described.

3. OPERATIONAL REQUIREMENTS

3.1 Mode of Operation — The basic controller shall provide for two phases of operation and shall be fully actuated with means for receiving traffic actuations on both phases.

The controller shall also permit a nonactuated mode of operation on either of its phases by assertion of the vehicle recall function (or pedestrian recall function when such function is present) on the desired phase.

3.2 Optional Mode of Operation (Semi-Actuated Mode) — The basic controller shall provide for two phases of operation and shall be semi-actuated with means for receiving traffic actuations from one of the phases.

3.3 Operation with Auxiliary Functions/Devices — The controller shall be capable of having its basic operation expanded or augmented by the addition of auxiliary functions or devices as described in Section 1 of these specifications.

3.4 Minimum Green

3.41 Actuated Phase — The minimum green shall consist of an initial portion and one Unit Extension portion except that when volume density functions are provided, the minimum green may consist of an initial portion or a separately set Minimum Green function.

If pedestrian timing functions are provided and a pedestrian actuation is received, the minimum green shall consist of a WALK interval plus a Pedestrian Clearance interval or a WALK interval plus a Pedestrian Clearance interval plus one Unit Extension portion.

3.42 Optional Actuated Phase — The minimum green shall consist of an initial portion only or a separately set Minimum Green function. If pedestrian functions are provided and a pedestrian actuation is received, the minimum green shall consist of a WALK interval plus a Pedestrian Clearance interval.

3.43 Non-Actuated Phase (Semi-Actuated Mode) — In the non-actuated or semi-actuated mode of operation, the minimum green shall be equal to the values described for Actuated Phases in the preceding paragraphs or shall be equal to a separately set Minimum Green function.

3.5Unit Extension — The actuation of a vehicle detector during the extendible portion of an actuated traffic phase having the right-of-way shall cause the retention of right-of-way by that traffic phase for one Unit Extension portion from the end of the actuation but subject to the Maximum (extension limit).

3.6 Maximum (Extension Limit) — The timing of the Maximum or extension limit shall determine the maximum duration of time the right-of-way can be extended for a phase having successive detector actuations spaced less than a Unit Extension portion apart.

3.7 Initiation of Maximum (Extension Limit) — The timing of the Maximum or extension limit shall commence (1) with the first actuation or other demand for right-of-way on the traffic phase not having the right-of-way or (2) at the beginning of the Green interval if an actuation or other demand for right-of-way has been previously registered on the traffic phase not having the right-of-way or, alternatively, the Maximum may commence at the end of the initial portion of the Green interval if an actuation or other demand has been previously registered on a traffic phase not having the right-of-way.

3.8 Transfer of Right-of-Way — The actuation of any detector on a traffic phase not having the right-of-way shall cause the transfer of the right-of-way to traffic phases immediately following the expiration of one Unit Extension portion during which there was no actuation on the other phase or upon expiration of the Maximum (extension limit) timing on the other phase.

3.9 Change/Clearance Interval(s) Prior to Transfer — The transfer of right-of-way to any conflicting phase shall occur only after the display of the appropriate change/clearance interval(s).

3.10 Rest in Absence of Actuation

3.101 Minimum Rest — In the absence of detector actuation or assertion of recall switch(es), the right-of-way indication shall remain (rest) on the traffic phase on which the last actuation occurred.

3.102 Optional Rest in All-Red — In the absence of detector actuation or assertion of recall switch(es), the controller, after the display of the appropriate clearance interval(s) on the last phase having the right-of-way, shall rest in red (and associated Pedestrian DONT WALK indications) on all phases until detector actuations are received.

3.11 Memory Feature — Unless precluded by the operation of a nonmemory feature, the following memory retention shall be provided in the controller.

3.111 Memory During Change or Clearance Interval(s) — An actuation received during a change or clearance interval for a traffic phase shall cause the right-of-way to return to that phase at the next opportunity in the normal phase sequence.

3.112 Memory if Phase Terminated by Maximum (Extension Limit) — If the right-of-way is transferred by the operation of the Maximum or extension limit, the traffic phase losing the right-of-way shall again receive it without further actuation at the next opportunity in the normal phase sequence.

3.113 Optional Memory If Phase Terminated by Unexpired Unit Extension — If the right-of-way is transferred at a time less than one Unit Extension after a vehicle actuation, the traffic phase losing the right-of-way shall again receive it without further actuation at the next opportunity in the normal phase sequence.

3.12 Pedestrian Timing Operation — When pedestrian timing functions are specified in the General Design Requirements, Section 1 of this specification, the following pedestrian function operation shall be provided.

3.121 Pedestrian Timing and Non-Actuated Phase-Semi-Actuated Mode — In the non-actuated or semi-actuated mode of operation, a WALK interval shall be provided simultaneously with the associated Minimum Green interval. A flashing DONT WALK Pedestrian Clearance interval shall follow the WALK interval, during which the Green traffic phase continues to be displayed.

3.122 Pedestrian Timing with Actuated Phase — When pedestrian actuation is received, a WALK interval shall be provided concurrently with the associated Green traffic phase interval. A flashing DONT WALK Pedestrian
Clearance interval shall follow the WALK interval, during which the Green traffic phase continues to be displayed.

3.1221 Condition in Absence of Pedestrian Call — In absence of pedestrian actuation or assertion of pedestrian recall functions, pedestrian signals shall remain in a DONT WALK condition.

3.1222 Recycle of Pedestrian Functions — In the absence of opposing phase demand, it shall be possible to recycle the pedestrian interval functions to succeeding pedestrian actuations without change in vehicle indications.

3.1223 Pedestrian Actuation Memory — Pedestrian actuations received by a phase during steady or flashing DONT WALK indications of that phase shall be remembered and shall cause the controller to provide pedestrian timing functions for that phase at the next opportunity in the normal phase sequence.

3.1224 Non-extension of Pedestrian Intervals — Successive pedestrian actuations shall not cause extension of the pedestrian intervals.

3.13 Advanced Operational Features — When certain advanced operational features are specified in the General Design Requirements, Section 1 of this specification, the controller shall provide the following operation.

13.11 Volume Density Operation

13.111 Variable Initial Timing — Utilizing the specified mode selected to provide this function, the controller shall enable an increase in timing of the Initial portion of the Green interval of a phase based upon the number of traffic actuations stored on that phase during its Red or Yellow interval.

3.1312 Time Waiting Gap Reduction — Utilizing the functions specified, the controller shall enable a reduction in the Extension portion of the Green interval of the phase having the right-of-way in proportion to the time elapsed from the registration of an actuation on an opposing phase or from the beginning of the Green interval, whichever occurs later.

3.132 Dual Maximum (Extension Limit) Operation — Assertion by external command for the operation of a Maximum II function for a phase shall cause the controller to provide the timing value for that function in lieu of the normal Maximum value.

3.14 Optional Operational Features — (The purchaser shall here insert requirements for special operational features not otherwise described in this specification).

4. FUNCTIONAL REQUIREMENTS

Functional requirements for the two-phase traffic-actuated controller shall be as specified in the General Design Requirements, Section 1 of this specification.

SECTION 3 — THREE-PHASE TRAFFIC-ACTUATED CONTROLLERS

1. PURPOSE

It is the purpose of this section of the specifications to set forth minimum design and operating requirements for three-phase traffic-actuated traffic signal controllers.

2. GENERAL DESIGN REQUIREMENTS

The General Design Requirements in Section 1 of this specification shall apply in addition to certain operating and functional requirements hereinafter described.

3. OPERATIONAL REQUIREMENTS

3.1 Mode of Operation — The basic controller shall provide for three phases of operation and shall be fully actuated with means for receiving actuations on all phases.

The controller shall also permit a non-actuated mode of operation on any of its phases by assertion of the vehicle recall function (or Pedestrian recall function when such function is present) on the desired phase.

3.2 Operation with Auxiliary Functions/Devices — The controller shall be capable of having its basic operation expanded or augmented by the addition of auxiliary functions or devices as described in Section 1 of these specifications.

3.3 Minimum Green

3.31 Actuated Phase — The minimum green shall consist of an Initial portion and one Unit Extension portion except that when volume density functions are provided, the minimum green may consist of an Initial portion or a separately set Minimum Green Function.

If pedestrian timing functions are provided and a pedestrian actuation is received, the minimum green shall consist of a WALK interval plus a Pedestrian Clearance interval plus one Unit Extension portion.

3.32 Optional Actuated Phase — The minimum green shall consist of an Initial portion only or a separately set Minimum Green function. If pedestrian functions are provided and a pedestrian actuation is received, the minimum green shall consist of a WALK interval plus a Pedestrian Clearance interval.

3.33 Non-Actuated Phase — In the non-actuated mode of operation, the minimum green on the non-actuated phase shall be equal to the values described for Actuated Phases in the preceding paragraphs or shall be equal to a separately set Minimum Green function.

3.4 Unit Extension — The actuation of a vehicle detector during the extendible portion of an actuated traffic phase having the right-of-way shall cause the retention of right-of-way by that traffic phase for Unit Extension portion from the end of the actuation but subject to the Maximum (extension limit).

3.5 Maximum (Extension Limit) — The Maximum or extension limit shall determine the maximum duration of time the right-of-way can be extended for a phase having successive detector actuations spaced less than a Unit Extension portion apart.

3.6 Initiation of Maximum (Extension Limit) — The timing of the Maximum or extension limit shall commence (1) with the first actuation or other demand for right-of-way on a traffic phase not having the right-of-way or (2) at the beginning of the Green interval if an actuation or other demand for right-of-way has been previously registered on a traffic phase not having the right-of-way or, alternatively, the Maximum may commence at the end of the initial portion of the Green interval if an actuation or other demand has been previously registered on a traffic phase not having the right-of-way.

3.7 Transfer of Right-of-Way — The actuation of any detector on a traffic phase not having the right-of-way shall cause the transfer of the right-of-way to that traffic phase at the next opportunity in the normal phase sequence provided that there has been an expiration of a Unit Extension portion with no continuing actuation or an expiration of the Maximum (extension limit) timing on
the preceding phase having the right-of-way.

3.8 Change/Clearance Interval(s) Prior to Transfer — The transfer of right-of-way to any conflicting phase shall occur only after the display of the appropriate change/clearance interval(s).

3.9 Rest in Absence of Actuation

3.9.1 Minimum Rest — In the absence of detector actuation or assertion of recall switch(es), the right-of-way indication shall remain (rest) on the traffic phase on which the last actuation occurred.

3.9.2 Optional Rest in All-Red — In the absence of detector actuation or assertion of recall switch(es), the controller, after display of the appropriate clearance interval(s) on the last phase having the right-of-way, shall rest in Red (and associated Pedestrian DONT WALK indications) on all phases until detector actuations are received.

3.10 Memory Feature — Unless precluded by the operation of a non-memory feature, the following memory retention shall be provided in the controller.

3.10.1 Memory During Change or Clearance Interval(s) — An actuation received during a change or clearance interval for a traffic phase shall cause the right-of-way to return to that phase at the next opportunity in the normal phase sequence.

3.10.2 Memory if Phase Terminated by Maximum (Extension Limit) — If the right-of-way is transferred by the operation of the Maximum or extension limit, the traffic phase losing the right-of-way shall again receive it without further actuation at the next opportunity in the normal phase sequence.

3.10.3 Optional Memory if Phase Terminated by Unexpired Unit Extension — If the right-of-way is transferred at a time less than one Unit Extension after a vehicle actuation, the traffic phase losing the right-of-way shall again receive it without further actuation at the next opportunity in the normal phase sequence.

3.11 Pedestrian Timing Operation — When pedestrian timing functions are specified in the General Design Requirements, Section 1 of this specification, the following pedestrian function operation shall be provided.

3.11.1 Pedestrian Timing with Non-Actuated Phase — In the non-actuated mode of operation, a WALK interval shall be provided simultaneously with the associated Minimum Green interval of the nonactuated phase. A flashing DONT WALK Pedestrian Clearance interval shall follow the WALK interval, during which the Green traffic phase continues to be displayed.

3.11.2 Pedestrian Timing with Actuated Phase — When pedestrian actuation is received, a WALK interval shall be provided concurrently with the associated Green traffic phase interval. A flashing DONT WALK Pedestrian Clearance interval shall follow the WALK interval during which the Green traffic phase continues to be displayed.

3.11.2.1 Condition in Absence of Pedestrian Call — In absence of pedestrian actuation or assertion of pedestrian recall function, pedestrian signals shall remain in a DONT WALK condition.

3.11.2.2 Recycle of Pedestrian Functions — In the absence of opposing phase demand, it shall be possible to recycle the pedestrian interval functions to succeeding pedestrian actuations without change in vehicle indications.

3.11.3 Pedestrian Actuation Memory — Pedestrian actuations received by a phase during steady or flashing DONT WALK indications of that phase shall be remembered and shall cause the controller to provide pedestrian timing functions for that phase at the next opportunity in the normal phase sequence.

3.11.4 Non-Extension of Pedestrian Intervals — Successive pedestrian actuations shall not cause extension of the pedestrian intervals.

3.12 Advanced Operational Features — When certain advanced operational features are specified in the General Design Requirements, Section 1 of this specification, the controller shall provide the following operation.

3.12.1 Volume Density Operation

3.12.1.1 Variable Initial Timing — Utilizing the specified mode selected to provide this function, the controller shall enable an increase in timing of the initial portion of the Green interval of a phase based upon the number of traffic actuations stored on that phase during its Red and Yellow intervals.

3.12.2 Time Waiting Gap Reduction — Utilizing the functions specified, the controller shall enable a reduction in the Extension portion of the Green interval of the phase having the right-of-way in proportion to the time elapsed from the registration of an actuation on an opposing phase or from the beginning of the Green interval, whichever occurs later.

3.12.2.1 Dual Maximum (Extension Limit) Operation — Assertion by external command for the operation of a Maximum II function for a phase shall cause the controller to provide the timing value for that function in lieu of the normal Maximum value.

3.13 Optional Operational Features (The purchaser shall here insert requirements for special operational features not otherwise described in this specification).

4. FUNCTIONAL REQUIREMENTS

4.1 Basic Functions — Functional requirements for the three phase traffic actuated controller shall be as specified in the General Design Requirements, Section 1 of these specifications.

4.2 Overlaps — When required by the interval sequence chart in the General Design Requirements, Section 1 of these specifications, overlap(s) shall be provided by the controller and may be implemented via internal or external logic.

4.3 Optional Overlaps — The controller shall be furnished to provide a minimum of three (3) overlaps which shall be designated as follows:

- Overlap A — Phase 2 + Phase 3
- Overlap B — Phase 1 + Phase 3
- Overlap C — Phase 1 + Phase 2

4.4 Optional Method of Providing Overlaps — All required overlaps shall be generated within the controller via internal logic.

SECTION 4 — MULTI-PHASE TRAFFIC ACTUATED CONTROLLERS

1. PURPOSE

It is the purpose of this section of the specification to set forth minimum design and operating requirements for multi-phase (two through eight phase) traffic-actuated traffic signal controllers. (Purchaser will here insert phase requirements).

2. GENERAL DESIGN REQUIREMENTS

The General Design Requirements in...
Section 1 of this specification shall apply in addition to certain design, operations, and functional requirements hereinafter described.

2.1 Optional NEMA Design Requirements — The controller shall be designed in accordance with the applicable requirements included in the latest NEMA Traffic Control Systems Standard TS.1.

2.2 Optional Controller Interchangeability — Interchangeability of controllers furnished under this specification shall be achieved by connector plug interchangeability as designated in the latest NEMA Traffic Control Systems Standard TS.1.

2.3 Optional Controller Expansibility — The controller shall be provided to perform the phasing and interval sequence requirements specified in Section 1 of this specification. In addition, provisions for expansion of the controller to a maximum of phases without replacement of the chassis shall be included.

(Purchaser will insert here the maximum number of phases required for future expansion).

2.4 Optional Cabinet Expansibility — The cabinet shall be designed to accommodate the maximum controller expansibility required in Subsection 2.3 above. This shall include cabinet space, connecting cables, wiring terminals, and load switch bases to facilitate the operation of the maximum controller expansion.

(Purchaser will insert here any additional expansion features required in cabinet).

3. OPERATIONAL REQUIREMENTS

3.1 Mode of Operation — The controller shall provide the multi-phase operation described in Subsections 1 and 2 of this section of the specification and shall be fully actuated with means for receiving actuations on all phases.

The controller shall also permit a nonactuated mode of operation on any of its phases by assertion of the vehicle recall function (or pedestrian recall function when such function is present) on the desired phase.

3.2 Optional Call to Non-Actuated Mode — The controller shall feature an input which, when asserted, shall permit the selection of nonactuated mode of operation on any of its phases.

3.3 Operation with Auxiliary Functions/Devices — The controller shall be capable of having its basic operation expanded or augmented by the addition of auxiliary functions or devices as described in Section 1 of these specifications.

3.4 Minimum Green

3.4.1 Actuated Phase — The minimum green shall consist of an initial portion and one Unit Extension portion except that when volume density functions are provided, the minimum green may consist of an initial portion or a separately set Minimum Green function.

If pedestrian timing functions are provided and a pedestrian actuation is received, the minimum green shall consist of a WALK interval plus a Pedestrian Clearance interval or a WALK interval plus a Pedestrian Clearance interval plus one Unit Extension portion.

3.4.2 Optional Actuated Phase — The minimum green shall consist of an initial portion only or a separately set Minimum Green function. If pedestrian functions are provided and a pedestrian actuation is received, the minimum green shall consist of a WALK interval plus a Pedestrian Clearance interval.

3.4.3 Non-Actuated Phase — In the nonactuated mode of operation, the minimum green on the non-actuated phase shall be equal to the values described for Actuated Phases in the preceding paragraphs or shall be equal to a separately set Minimum Green function.

3.5 Unit Extension — The actuation of a vehicle detector during the extendible portion of an actuated traffic phase having the right-of-way shall cause the retention of right-of-way by that traffic phase for one Unit Extension portion from the end of the actuation but subject to the Maximum (extension limit).

3.6 Maximum (Extension Limit) — The Maximum or extension limit shall determine the maximum duration of time the right-of-way can be extended for a phase having successive detector actuations spaced less than a Unit Extension portion apart.

3.7 Initialization of Maximum (Extension Limit) — The timing of the Maximum or extension limit shall commence (1) with the first actuation or other demand for right-of-way on a traffic phase not having the right-of-way or (2) at the beginning of the Green interval if an actuation or other demand for right-of-way has been previously registered on a traffic phase not the right-of-way or, alternatively, the Maximum may commence at the end of the initial portion of the Green interval if an actuation or other demand has been previously registered on a traffic phase not having the right-of-way.

3.8 Transfer of Right-Way — The actuation of any detector on a traffic phase not having the right-of-way shall cause the transfer of the right-of-way to that traffic phase at the next opportunity in the normal phase sequence provided that there has been an expiration of a Unit Extension portion with no continuing actuation or an expiration of the Maximum (extension limit) timing on the preceding phase having the right-of-way.

3.9 Change Clearance Interval(s) Prior to Transfer — The transfer of right-of-way to any conflicting phase shall occur only after the display of the appropriate change clearance interval(s).

3.10 Rest in Absence of Actuation

3.10.1 Minimum Rest — In the absence of detector actuation or assertion of recall switch(es), the right-of-way indication shall remain (rest) on the traffic phase on which the last actuation occurred.

3.10.2 Optional Rest in All-Red — In the absence of detector actuation or assertion of recall switch(es), the controller, after display of the appropriate clearance interval(s) on the last phase having the right-of-way, shall rest in Red (and associated Pedestrian DONT WALK indications) on all phases until detector actuations are received.

3.11 Memory Feature — Unless precluded by the operation on non-memory feature, the following memory retention shall be provided in the controller.

3.11.1 Memory During Change or Clearance Interval(s) — An actuation received during a change or clearance interval for a traffic phase shall cause the right-of-way to return to that phase at the next opportunity in the normal phase sequence.

3.11.2 Memory if Phase Terminated by Maximum (Extension Limit) — If the right of way is transferred by the operation of the Maximum or extension
limit, the traffic phase losing the right-of-way shall again receive it without further actuation at the next opportunity in the normal phase sequence.

3.113 Optional Memory if Phase Terminated by Unexpired Unit Extension — If the right-of-way is transferred at a time less than one Unit Extension after a vehicle actuation, the traffic phase losing the right-of-way shall again receive it without further actuation at the next opportunity in the normal phase sequence.

3.12 Pedestrian Timing Operation — When pedestrian timing functions are specified in the General Design Requirements, Section 1 of this specification, the following pedestrian function operation shall be provided.

3.121 Pedestrian Timing with Non-Actuated Phase — In the non-actuated mode of operation, a WALK interval shall be provided simultaneously with the associated Minimum Green interval of the non-actuated phase. A flashing DONT WALK Pedestrian Clearance interval shall follow the WALK interval, during which the Green traffic phase continues to be displayed.

3.122 Pedestrian Timing with Actuated Phase — When pedestrian actuation is received, a WALK interval shall be provided concurrently with the associated Green traffic phase interval. A flashing DONT WALK Pedestrian Clearance interval shall follow the WALK interval during which the Green traffic phase continues to be displayed.

3.1221 Condition in Absence of Pedestrian Call — In absence of pedestrian actuation or assertion of pedestrian recall function, pedestrian signals shall remain in a DONT WALK condition.

3.1222 Recycle of Pedestrian Functions — In the absence of opposing phase demand, it shall be possible to recycle the pedestrian interval functions to succeeding pedestrian actuations without change in vehicle indications.

3.1223 Pedestrian Actuation Memory — Pedestrian actuations received by a phase during steady or flashing DONT WALK indications of that phase shall be remembered and shall cause the controller to provide pedestrian timing functions for that phase at the next opportunity in the normal phase sequence.

3.1224 Non-Extension of Pedestrian Intervals — Successive pedestrian actuations shall not cause extension of the pedestrian intervals.

3.13 Advanced Operational Features — When certain advanced operational features are specified in the General Design Requirements, Section 1 of this specification, the controller shall provide the following operation.

3.131 Volume Density Operation

3.1311 Variable Initial Timing — Utilizing the specified mode selected to provide this function, the controller shall enable an increase in timing of the initial portion of the Green interval of a phase based upon the number of traffic actuations stored on that phase during its Red and Yellow intervals.

3.1312 Time Waiting Gap Reduction — Utilizing the functions specified, the controller shall enable a reduction in the Extension portion of the Green interval of the phase having the right-of-way in proportion to the time elapsed from the registration of an actuation on an opposing phase or from the beginning of the Green interval, whichever occurs later.

3.132 Dual Maximum (Extension Limit) Operation — Assertion by external command for the operation of a Maximum II function for a phase shall cause the controller to provide the timing value for that function in lieu of the normal maximum value.

3.14 Optional Operational Features

3.15 Optional NEMA Operational Requirements — In addition to the basic operational requirements specified above, the controller shall provide the operational features for the applicable configuration included in the latest NEMA Traffic Control Systems Standard TS1.

4. FUNCTIONAL REQUIREMENTS

4.1 Basic Functional Requirements — Functional requirements for the multiphase traffic actuated controller shall be as specified in the General Design Requirements in Section 1 of these specifications.

4.2 Optional NEMA Functional Requirements — In addition to the basic functional requirements specified above, the controller shall provide the functional features for the applicable configuration, included in the latest NEMA Traffic Control Systems Standard TS1.

(Purchaser will select desired options from this standard where alternative functions are available).

4.3 Overlaps — When required by the interval sequence chart in the General Design Requirements, Section 1 of these specifications, overlap(s) shall be provided by the controller and may be implemented via internal or external logic.

4.4 Optional Method of Providing Overlaps — All required overlaps shall be generated within the controller via internal logic.

4.5 Optional Overlays — The controller shall be furnished to provide a minimum of ______ overlaps as described below.

(Purchaser will here insert the desired number of overlaps and describe overlap designations required).

SECTION 5 — SUMMARY OF OPTIONAL FEATURES

1. PURPOSE

The purpose of this section is to provide a convenient tabulation of OPTIONAL features which may be included in the specifications if desired and a tabulation of user selectable requirements which may be selected at the appropriate place in the specifications.

2. LIST OF OPTIONS AND USER SELECTABLE REQUIREMENTS

A complete tabulation of all OPTIONS and user selectable requirements in the entire standard together with a brief suggested usage guideline is provided in the following tables. OPTIONAL features are prefixed by the designation (O); user selectable requirements are prefixed with a (U).
**LIST OF OPTIONS AND USER SELECTABLE REQUIREMENTS**

**SECTION 1 — GENERAL DESIGN REQUIREMENTS**

<table>
<thead>
<tr>
<th>Location/Subsection</th>
<th>Description</th>
<th>Suggested Usage Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 2.13</td>
<td>(O) Special Power Requirement</td>
<td>If selected, should be used in place of subsections 2.11 and 2.12</td>
</tr>
<tr>
<td>(2) 2.21</td>
<td>(U) Controller Connections, Minimum Requirements</td>
<td>User specifies special connector if desired</td>
</tr>
<tr>
<td>(3) 2.22</td>
<td>(O) NEMA Connection Requirement</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(4) 3.2</td>
<td>(O) Constancy of Intervals</td>
<td>If selected, should be used in place of Subsection 3.1</td>
</tr>
<tr>
<td>(5) 4.2</td>
<td>(U) Required Interval Sequence</td>
<td>User shall specify desired interval sequence</td>
</tr>
<tr>
<td>(6) 4.3</td>
<td>(U) Interval Sequence Chart</td>
<td>User may select sequence chart provided or may insert another chart</td>
</tr>
<tr>
<td>(7) 5.3</td>
<td>(O, U) Basic Required Intervals, Functions and Ranges</td>
<td>User shall specify minimum range or OPTIONAL minimum range</td>
</tr>
<tr>
<td>(8) 5.42</td>
<td>(O) Interval and Function Indication</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(9) 5.6</td>
<td>(O) Maximum Recall Switch(es)</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(10) 5.7</td>
<td>(O) Vehicle Detector Non-Lock Switch(es)</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(11) 6.</td>
<td>(O) Interval Setting and Functions</td>
<td>May be selected to provide additional features</td>
</tr>
<tr>
<td>(12) 6.4</td>
<td>(O, U) Intervals, Functions, and Range</td>
<td>User shall specify OPTIONAL functions and ranges desired for each phase</td>
</tr>
<tr>
<td>(13) 6.52</td>
<td>(O) Interval and Function Indication</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(14) 6.8</td>
<td>(O) Flashing of WALK Interval Functions</td>
<td>May be selected as additional feature</td>
</tr>
<tr>
<td>(15) 7.3</td>
<td>(O, U) External Load Switch(es)</td>
<td>If selected, Subsection 7.1 should be modified to permit only external load switches. User shall specify circuits required for each switch.</td>
</tr>
<tr>
<td>(16) 7.4</td>
<td>(O) NEMA Triple Signal Load Switch(es)</td>
<td>If selected, should be used in place of Subsection 7.3 and Subsection 7.1; should be modified to permit only external load switches.</td>
</tr>
<tr>
<td>(17) 8.21</td>
<td>(O) Mandatory Conflict Monitor</td>
<td>If selected, should be used in place of Subsection 8.1</td>
</tr>
<tr>
<td>(18) 8.22</td>
<td>(O) Occurrence of Conflict</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(19) 8.23</td>
<td>(O) Release from Flashing</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(20) 8.3</td>
<td>(O) NEMA Conflict Monitor</td>
<td>If Selected, should be used in place of Section 8.2</td>
</tr>
<tr>
<td>(21) 9.1</td>
<td>(U) Flashing of Signal — Minimum Requirements</td>
<td>User shall specify here or on sequence chart (Subsections 4.2, 4.3) the desired flashing sequence</td>
</tr>
<tr>
<td>(22) 9.21</td>
<td>(O) Flashing of Pedestrian Signals (WALK)</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(23) 9.22</td>
<td>(O) Solid State Flasher</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(24) 10.1</td>
<td>(O) Manual Operation</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(25) 10.2</td>
<td>(O) Manual Control Enable</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(26) 11.3</td>
<td>(O) Accumulation of Vehicle Actuations</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(27) 11.4</td>
<td>(O, U) Auxiliary Functions</td>
<td>May be selected to provide additional features; user shall specify desired features</td>
</tr>
<tr>
<td>(28) 12.2</td>
<td>(O) Preemption — Setting of Intervals and Functions</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(29) 12.3</td>
<td>(O) Preemption — Constancy of Intervals</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(30) 12.4</td>
<td>(O) Preemption — Indicator Lights</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(31) 12.5</td>
<td>(O) Continuation of Preemption Sequence</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(32) 12.6</td>
<td>(O) Return to Normal Controller Operations</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(33) 12.7</td>
<td>(O) Preemption Test Switch</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(34) 12.8</td>
<td>(O) Preemption — Method of Providing</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(35) 12.9</td>
<td>(O) Preemption — Circuit Design</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(36) 13.21</td>
<td>(O) Hold feature</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(37) 13.22</td>
<td>(O) Forc-Off Feature</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(38) 13.3</td>
<td>(O) NEMA Coordination Requirements</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(39) 14.14</td>
<td>(O) Environmental-Ambient Temperature</td>
<td>If selected, should be used in place of Subsection 14.12</td>
</tr>
<tr>
<td>(40) 14.15</td>
<td>(O) Cooling/Heating devices</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(41) 14.16</td>
<td>(O) Humidity</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(42) 14.17</td>
<td>(O) Heater</td>
<td>May be selected as an additional feature</td>
</tr>
<tr>
<td>(43) 14.2</td>
<td>(O) Environmental — NEMA Requirements</td>
<td>May be selected to provide additional features</td>
</tr>
<tr>
<td>(44) 15.11</td>
<td>(U) Cabinet — Const. Material</td>
<td>User shall specify const. material desired</td>
</tr>
<tr>
<td>(45) 15.12</td>
<td>(U) Cabinet — Door</td>
<td>User shall specify special lock and key requirements</td>
</tr>
<tr>
<td>(46) 15.13</td>
<td>(U) Cabinet — Auxiliary Door</td>
<td>User shall specify additional functions desired and special lock and key requirements</td>
</tr>
<tr>
<td>(47) 15.14</td>
<td>(O, U) Cabinet — Door Stop</td>
<td>May be selected as an additional feature; user may select other door stop angles when desired</td>
</tr>
<tr>
<td>(48) 15.22</td>
<td>(O, U) Cabinet — Size</td>
<td>May be selected as an additional feature; user shall specify dimensions</td>
</tr>
</tbody>
</table>
SECTION 2 — TWO-PHASE TRAFFIC-ACTUATED CONTROLLERS

1. 3.2  (O) Mode of Operation (Semi-Actuated)
    If selected, should be used in place of Subsection 3.1

2. 3.42 (O) Actuated Phase
    If selected, should be used in place of Subsection 3.41

3. 3.101 (O) Rest in All-Red
    May be selected as an additional feature

4. 3.113 (O) Memory if Phase Terminated by Unexpired Unit Extension
    May be selected as an additional feature

5. 3.14 (O, U) Operational Features
    User shall specify special operational features if desired

SECTION 3 — THREE-PHASE TRAFFIC-ACTUATED CONTROLLERS

1. 3.32 (O) Actuated Phase
    If selected, shall be used in place of Subsection 3.31

2. 3.92 (O) Rest in All-Red
    May be selected as an additional feature

3. 3.103 (O) Memory if Phase Terminated by Unexpired Unit Extension
    May be selected as an additional feature

4. 3.13 (O, U) Operational Features
    User shall specify special operational features if desired

5. 4.3 (O) Overlaps
    May be selected as an additional feature

6. 4.4 (O) Method of Providing Overlaps
    If selected, Subsection 4.2 should be modified to permit use of internal logic only

SECTION 4 — MULTI-PHASE TRAFFIC-ACTUATED CONTROLLERS

1. 1. (U) Purpose (Phases Required)
    User shall specify phase requirements

2. 2.1 (O) NEMA Design Requirements
    May be selected as an additional feature

3. 2.2 (O) Controller Interchangeability
    May be selected as an additional feature

4. 2.3 (O, U) Controllers Expansibility
    May be selected as an additional feature; user shall specify maximum number of phases for future expansion

5. 2.4 (O, U) Cabinet Expansibility
    May be selected as an additional feature; user shall specify additional expansion features required in cabinet

6. 3.2 (O) Call to Non-Actuated Mode
    May be selected as an additional feature

7. 3.42 (O) Actuated Phase
    If selected, shall be used in place of Subsection 3.41

8. 3.102 (O) Rest in All-Red
    May be selected as an additional feature

9. 3.113 (O) Memory if Phase Terminated by Unexpired Unit Extension
    May be selected as an additional feature

10. 3.14 (O, U) Operational Features
    User shall specify special operational features if desired

11. 3.15 (O, U) NEMA Operational Requirements
    May be selected to provide additional features; user shall specify desired options where alternative methods are available

12. 4.2 (O, U) NEMA Functional Requirements
    May be selected to provide additional features; user shall specify desired options where alternative methods are available

13. 4.4 (O) Method of Providing Overlaps
    If selected, Subsection 4.2 should be modified to permit use of internal logic only

14. 4.5 (O, U) Overlaps
    May be selected as an additional feature; user shall specify the required number of overlaps and overlap designations
Controller Cabinets

This was approved as an Equipment Standard of the Institute of Transportation Engineers in January 1990. It supersedes the Proposed Equipment Standard published in ITE Journal in July 1988.

This Equipment Standard was developed and approved in accordance with formally adopted Institute procedures, which are designed to help ensure that all interested parties are given opportunities to provide input. All input received has been considered in order that this standard would represent the best consensus obtainable on the state of the art at the time of approval.

Members of Technical Council Committees TSC-5 responsible for the development of this standard are Harold A. Garfield, P.E., (OM), chairperson; George M. Brown, P.E., (OM); Gary S. Creager, P.E., (F); Roy H. Fielding (FL); James F. Hahn, Jr., P.E. (OM); Arthur E. Haynes (OM); W. Larel L. Kent (A); Michael C. Meyers, P.E., (A); Phillip B. Nicholes (OM); Crawley A. Parris (OM); Brent E. Remsberg, P.E., (OM); and Richard S. Weeks, Jr., P.E. At the time this equipment standard was being developed, Department 2 Equipment Standards, was chaired by Frank L. Dulan, P.E., (OM). George L. Butzer, P.E., (OM), served as assistant department chairperson. At the time this equipment standard was approved, George L. Butzer, P.E., (OM), chaired Department 7; E. Marshall Elston, Jr., P.E., (F), served as assistant department chairperson.

The purpose of this standard is to provide a guide for the preparation of specifications for cabinets to house traffic signal control equipment. A traffic signal control cabinet provides protection and support for the controller unit and auxiliary devices in an outdoor environment.

This standard represents the requirement for the equipment described herein and is not intended to impose restrictions upon design or materials that conform to the purpose and intent of this standard.

Definitions

The definitions of terms used in this section can be found in NEMA Standards Publication No. TSC-5633. Traffic Control Systems.


EIA—Electronics Industry Association.

ETL—Electrical Testing Laboratories, Inc.

NEMA—National Electrical Manufacturers Association.

UL—Underwriters Laboratories, Inc.

Wherever a reference is made to a NEMA Standard, it shall mean the NEMA Standard for Traffic Control Systems on which the order is awarded or the contract bids are opened.

Other NEMA Standards referenced in this document are NEMA Standards Publication 250-1988, Enclosures for Electrical Equipment (1,000 volts, maximum), and NEMA Standards Publication WD-1983, Wiring Devices—Dimensional Requirements.

1.0 Materials

Cabinets shall be furnished of either a ferrous material or an aluminum alloy.

1.1 Cabinets of Ferrous Material

Cabinets shall be fabricated of carbon steel having a minimum thickness of 0.073 inches (in.). The material shall have either a minimum of 0.125-in. at right angles to the face of the cabinet. All external seams for cold-rolled steel cabinets and doors shall be continuously welded. All exterior welds shall be ground smooth. All overlapping seams for steel cabinets shall meet the requirements for Type 4 enclosures according to NEMA Standards Publication 250.

1.2 Cabinets of Aluminum Alloy

Cabinets shall be fabricated of either sheet aluminum or cast aluminum.

1.2.1 Sheet Aluminum

Cabinets shall be fabricated from a minimum thickness of 0.125-in. aluminum alloy sheet meeting the requirements in ASTM Specification No. 5052-83 or equivalent. All overlapping seams for aluminum cabinets shall meet the requirements for Type 4 enclosures according to NEMA Standards Publication 250.

1.2.2 Cast Aluminum

Cabinets shall be fabricated from aluminum alloy meeting the requirements in ASTM Specification No. 5052-83 or equivalent. Cast surface exceeding 12 in. in both directions shall have a minimum thickness of 0.25 in. Flat cast surfaces not exceeding 12 in. in both directions shall have a thickness of 0.125 in.

1.3 Cabinet Dimensions

The outline dimensions of cabinets shall be as shown in Table 1. These are outside dimensions exclusive of hinges, handle, overhang(s), vent, and adapters. Cabinet doors are measured to the lowest point of the top outer edge of the cabinet.

1.4 Top Surface Construction

The cabinet shall be manufactured so as to prevent the accumulation of water on its top surface.

1.5 Doors

1.5.1 Main Cabinet Door

The cabinet shall have a hinged main door that permits access to all equipment within the cabinet, and visible inspection of all indicators and controls. Doors shall be hinged on the right side of the cabinet as viewed from the outside facing the cabinet door opening.

1.5.2 Hinges

Door hinges, pins, and bolts shall be made of stainless steel. Hinges on aluminum cabinets, however, may be aluminum with stainless steel hinge pins. The hinge pins and bolts shall be tamperproof.

1.5.3 Door Stop

Cabinets size and larger shall have a cabinet door stop that holds the door open at the 90-degree (±10 degrees) and 180-degree (±10 degrees) positions. A means shall be provided to maintain the accidental release of the door stop. The stop-and-catch arrangement shall be capable of holding the door open at 90 degrees (±10 degrees) with a load of 15 pounds per square foot (0.3 kg) applied uniformly over the face of the door.

1.5.4 Latches and Locking Mechanism

1.5.4.1 Latching

A three-point latch is required on cabinets size 3 and larger. The latch shall be operable without the use of tools.

1.5.4.2 Rotation of Handle

The handle shall rotate inward from the locked position such that the handle does not extend beyond the perimeter of the door at any time. The operation of the handle shall not interfere with the key or door, or any other cabinet mechanism or projection.

1.5.4.3 Locks

All cabinets shall be provided with a main door lock, Corbin No. 15481RS or equivalent, constructed of brass or stainless steel, which shall operate with a traffic industry conventional No. 2 key. Corbin No. 186300 or equivalent. Two keys shall be furnished with each cabinet. When in the locked position, the lock shall prevent the movement of the latch mechanism.

1.5.4.4 Provisions for Padlock

Cabinets with three-point latches shall be provided with a means of externally padlocking the latching mechanism. A lock with a 1½-in. diameter shackle shall be accommodated.

1.5.5 Door Opening

The main door opening of all cabinets shall be at least 80 percent as large as the area of the side of the cabinet on which the door closes, ex-

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Table 1. Outline Dimensions

<table>
<thead>
<tr>
<th>Size</th>
<th>Width (in.)</th>
<th>Height (in.)</th>
<th>Depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
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<td>3</td>
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<td>44</td>
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<td>24</td>
</tr>
<tr>
<td>7</td>
<td>44</td>
<td>72</td>
<td>24</td>
</tr>
</tbody>
</table>

---
clusive of the area taken up by plenums (vents at the top of the cabinet).

1.5.6 Gasketing. Gasketing shall be provided on all door openings and shall be dust-tight. Gaskets shall be attached with a permanent adhesive bond. The surface with which the gasket mates shall be covered with a silicone lubricant to prevent the gasket from sticking to that surface.

1.5.7 Police Compartment (Optional).

1.5.7.1 Door. A hinged police compartment door shall be provided on the outside face of the main cabinet door. The door shall permit access to a switch panel, but shall not allow access to exposed electrical terminals or other equipment within the cabinet.

1.5.7.2 Locks. Police compartment doors shall be provided with a lock that can be operated by a police key. Corbin Type Blank No. 04266 or equivalent. Two keys shall be furnished with each cabinet.

1.5.7.3 Compartment Size. To allow for the switch controls and the storage of the manual control cord, the volume of the police panel compartment with the door closed shall be a minimum of 70 cubic in.

1.6 Shelves

The cabinet shall be provided with sufficient number and sizes of substantial metal shelves or brackets to support the controller unit and auxiliary equipment. The equipment and shelves shall be arranged so that it is possible to remove any piece of auxiliary equipment from the cabinet without removing any other piece of auxiliary equipment.

1.6.1 Positioning. Cabinets sizes 3, 4, and 5 shall have provisions for positioning shelves to within 12 in. of the bottom of the cabinet and to within 8 in. of the top of the cabinet in increments of not more than 2 in. Cabinets sizes 6 and 7 shall have provisions for positioning shelves within 24 in. of the bottom of the cabinet and to within 8 in. of the top of the cabinet in increments of not more than 2 in. Shelves shall be designed or positioned to allow air flow around the controller unit and auxiliary equipment.

1.7 Finish and Surface Preparation

1.7.1 Steel Cabinets.

1.7.1.1 Preparation. The surface of the cabinet shall be suitably prepared prior to painting. If the surface is damaged, the affected area shall be repaired prior to painting.

1.7.2 Aluminum Cabinets.

1.7.2.1 Preparation—Painted Cabinets. The surfaces of the cabinet shall be suitably prepared prior to painting. If the surface is damaged, the affected area shall be repaired prior to painting.

1.7.2.2 Prime Coat. If a primer paint is used, at least one application of a suitable primer paint shall be applied to the interior and exterior surfaces of the cabinet. If the primer surface is scratched or damaged, the affected area shall be repaired prior to the application of the finish coat.

1.7.2.3 Interior Surfaces (Optional). At least one application of a suitable exterior-grade paint shall be applied to the interior surfaces of the cabinet. (Purchaser to specify color.)

1.7.2.4 Exterior Surfaces (Optional). At least one application of a suitable exterior-grade paint shall be applied to the exterior surfaces of the cabinet. (Purchaser to specify color.)

1.7.3 Inner Pure Wood Cabinets

1.7.3.1 Preparation—Painted Cabinets. The surfaces of the cabinet shall be suitably prepared prior to painting. If the surface is damaged, the affected area shall be repaired prior to painting.

1.7.3.2 Prime Coat. If a primer paint is used, at least one application of a suitable primer paint shall be applied to the surfaces to be painted. If the primed surface is scratched or damaged, the affected area shall be repaired prior to the application of the finish coat.

1.7.3.3 Interior Surfaces (Optional). Interior surfaces shall be unpainted.

1.7.3.4 Exterior Surfaces (Optional). At least one application of a suitable exterior-grade paint shall be applied to the exterior surfaces of the cabinet. (Purchaser to specify color.)

1.7.3.5 Unprinted Aluminum Cabinets (Optional). Unprinted aluminum cabinets shall be fabricated from mill-finish material and shall be cleaned using appropriate methods that will remove oil film, weld black, and mill ink marks and render the surface clean, bright, smooth, and non-sticky to the touch.

2.0 Cabinet Mounting

2.1 Pole-Mounted Cabinets

Cabinets intended for side-of-pole mounting shall be provided with an adaptor (exclusive of lag bolts or banding) necessary to permit mounting to a 4.5-in. diameter or larger pole. The adaptor shall accommodate lag bolts up to 3/8-in. diameter and steel banding up to 1 in. wide. Mounting points shall be provided at or near the top and bottom of the cabinet.

2.2 Pedestal-Mounted Cabinets

Cabinets intended for pedestal mounting shall be provided with the hardware necessary to permit post-top mounting on a 4.5-in. outside diameter pedestal pole.

2.3 Base-Mounted Cabinets

2.3.1 Sizes 3, 4, and 5. When a size 3, 4, or 5 cabinet is to be base mounted, either the cabinet or its base adapter shall be constructed so that it can be mounted on the foundation shown in Figure 1.

2.3.2 Sizes 6 and 7. Size 6 and 7 cabinets shall be so constructed that they can be mounted on the foundation shown in Figure 2.

2.3.3 Anchor Bolts. Anchor bolts for base-mounted cabinets shall be 3/4 in. in diameter and 16 in. long, with a 90-degree bend with a 2-in. leg (overall length of 18 in.). The end opposite the leg shall be threaded for at least 3 in. with a 3/4 UNC-10 thread. Anchor bolts shall be steel with hot-dipped galvanized or zinc plate surface treatment. Each anchor bolt shall be furnished with two 3/4-10 plated steel nuts and one 3/4-in. plated flat washer.

Two anchor bolts shall be provided for each size 3, 4, or 5 cabinet intended for base mounting. Four anchor bolts shall be provided for each size 6 or 7 cabinet.

3.0 Cabinet Ventilation

3.1 Fan or Cooling System Design

Each cabinet shall be provided with a fan rated at a minimum of 100 cubic feet per minute.

3.2 Fan or Cooling System Operation

The fan or cooling system shall be capable of operating continuously for a minimum of 6,000 hours in a 50-degree Celsius (°C) environment, without the need for after-installation maintenance, excluding filter cleaning or replacement.

3.3 Fan or Cooling System Controls

Each cabinet shall be provided with a thermostat to control the operation of the fan or cooling system. The thermostat turn-on
point shall be manually adjustable from 33° C and 45° C, with a differential of not more than 5° C between automatic turn-on and turn-off. The thermostat shall be located on the inside of the top portion of the cabinet not lower than 6 in. from the top of the cabinet.

3.4 Filter
Each cabinet shall be provided with a device to filter incoming air. Cabinets size 5 or larger shall have a replaceable filter with the following dimensions: width—16 in., height—12 in., thickness—1 in. Size 4 and smaller cabinets shall have a replaceable filter.

4.0 Cabinet Wiring
4.1 Requirements

Wiring within controller cabinets shall be neatly arranged and laced, enclosed in plastic tubing or raceway, or secured with plastic cable ties.

4.2 Flat Cable (Optional)
Flat cable may be used for low-voltage circuits (less than 25 volts) in lieu of individual conductors. Cable shall be constructed of No. 28 or larger conductors. Conductor insulation shall be rated at 300 volts and shall be rated for use at 105° C. Cables shall be provided with strain relief.

4.3 Loop Detector Lead-In (Optional)
The loop detector lead-in, from the field terminals in the cabinet to the sensor unit, shall conform to one of the following:

(a) A twisted pair of No. 22, or larger, conductors or
(b) A cable containing two No. 22, or larger, conductors with each conductor insulated with either a minimum of 10 mils of polyvinyl chloride and 2 mils of nylon, or a minimum of 14 mils of polyethylene or polypropylene. The conductors shall be twisted, and the twisted pair shall be protected with a shield.

The shield or a stranded tinned copper drain wire shall be grounded at only one end of the cable. The cable shall be provided with a polyethylene or polyvinyl chloride outer jacket with a minimum thickness of 20 mils, or with a chrome vinyl outer jacket with a minimum thickness of 25 mils.

4.4 Ungrounded AC Conductors (Optional)
Ungrounded alternating current (AC) conductors to external light relays and solid-state switching devices shall be No. 14 or larger. The signal light grounded conductor feeding the grounded AC bus within the cabinet shall have the same ampacity as the cabinet main breaker. Ungrounded conductors in signal light circuits between the switching device and the field terminal shall be No. 14 or larger.
5.0 Cabinet Accessories and Auxiliary Equipment

5.1 Component Identification
Component identification shall meet the requirements of NEMA Standards Publication No. TS 1-1983, Traffic Control Systems, Section 10, "Terminals and Facilities."

5.2 Auxiliary Panels
5.2.1 Control Panel Assembly (Optional). A control panel assembly shall be provided inside the cabinet. It shall be readily accessible when the door is open. The control panel assembly shall consist of:

(a) (Optional.) A switch that shall be wired to energize the controller unit timing circuits while the signal lights are off or are being operated by flasher. The switch shall be labeled and rated for load current.

(b) (Optional.) A convenience receptacle.

(c) (Optional.) A "Signal Flash" switch that when placed in the "Flash" position shall provide flashing operation. When switch is placed in the "Signal" position, the controller unit shall resume control.

(d) (Optional.) A "Stop Time/Off" switch that when placed in the "Stop Time" position will cause the controller unit to stop time when the "Flash-Automatic" switch on the police panel is placed in the "Flash" position. When in the "Off" position, the controller unit shall not stop time when the police panel switch is placed in the "Flash" position.

(e) (Optional.) Momentary contact test switches shall be provided to place calls on each vehicle and pedestrian phase. Switches shall be enclosed and shall be designed for the voltage and current to be switched.

(f) (Optional.) Momentary contact test switches shall provide tactile feedback.

5.2.2 Panel Assembly (Optional). A panel assembly, located behind the auxiliary door, shall be provided. The panel assembly shall consist of the following:

(a) A "Flash/Automatic" switch that when placed in the "Flash" position shall cause the controller assembly to go into the flashing mode and remove power from the signal bus. When placed in the "Automatic" position, it shall cause the controller assembly to resume operation.

(b) A "Lights/Off" switch that when placed in the "Off" position shall extinguish the signal indications.

(c) A removable, rigid metal cover on the back of the police panel to cover switch terminals.

5.3 Conflict Monitor (Solid-State Controller)
A conflict monitoring device shall be installed externally to and electrically independent of each solid-state controller unit. The conflict monitor shall meet the requirements of NEMA Standards Publication No. TS 1-1983, Traffic Control Systems, Section 6, "Conflict Monitors."

5.3.1 Conflict Monitor (Electro-Mechanical Controller) (Optional). A conflict monitoring device shall be installed externally to and electrically independent of each electro-mechanical controller unit. The conflict monitor shall meet the requirements of NEMA Standards Publication No. TS 1-1983, Traffic Control Systems, Section 6, "Conflict Monitors."

5.4 Solid-State Load Switches
Solid-state load switch circuits shall be controlled externally to each solid-state controller unit by solid-state load switches. The solid-state load switches shall meet the requirements of NEMA Standards Publication No. TS 1-1983, Traffic Control Systems, Section 5, "Solid-State Load Switches."

5.5 Solid-State Logic (Optional)
Solid-state logic or timing circuits, external to a controller unit, shall be built on edge-connected plug-in, printed circuit boards. Logic circuits shall be built up by plugging logic circuit boards into wired connectors.

5.6 Special Timers (Optional)
Each special timer shall have a range from 0 to 30 seconds. Timing of the interval shall be adjustable in 1-second maximum intervals. Timing accuracy shall conform to the requirements in Section 2 of the NEMA Standards. Each special timer shall be a plug-connected, solid-state digital device with an indicator light to show when the timer is operating.

5.7 Time Switch (Optional)
Time switches to control specified functions shall be solid-state digital devices, shall be equipped with a seven-day setting feature, and shall provide for at least three openings and three closings per 24-hour period. Any one day or combination of days shall be omittable. The time switch shall be setable to time within a 15-minute period. The switch shall be capable of being turned off and on within 30 minutes.

The switch shall be wired in a manner that transfers from flashing operation to stop-and-go operation or from stop-and-go operation to flashing operation will only provide signal displays and sequencing permitted by the Manual on Uniform Traffic Control Devices.

5.8 Convenience Receptacle (Optional)
Convenience receptacle shall be duplex, three-prong, NEMA Type 5-15R grounding outlet according to NEMA WD-6, with ground-fault circuit interruption as defined by the Code.

5.8.1 Mounting—Convenience Receptacle (Optional). In lieu of mounting the convenience receptacle on the control panel assembly, the receptacle may be mounted in a readily accessible location inside the cabinet on either the left or right wall.

5.9 Flashers
Flashers shall meet the requirements of NEMA Standards Publication No. TS 1-1983, Traffic Control Systems, Section 8, "Solid-State Flashers."

5.10 Heavy-Duty Relays
5.10.1 Continuous Duty. Heavy-duty relays shall be designed for continuous duty. Each relay shall operate in the 8-pin Jones-type socket.

5.10.2 Contacts. Relays shall be provided with double-pole, double-throw contacts. Contact points shall be of fine silver, silver-alloy, or superior alternative material. Contact points and contact arms shall be capable of operation for 30,000 cycles with 10 amperes of tungsten load per contact at 120 volts, 60 Hz AC.

5.10.3 Coils. Coils shall have a power consumption of 10 volts-ampere or less and shall be designed for continuous duty on 120 volts, AC.

5.10.4 Enclosure. Heavy-duty relays shall be enclosed with a removable, clear plastic cover.

5.11 Light-Duty Relays (Optional)
Light-duty relays shall be enclosed with a
removable, clear plastic cover and shall be permanently marked with the coil voltage.

5.11.1 Coils Rated at 120 Volts. Relays with coils rated at 120 volts or more shall be the three-pole, double-throw type, with a contact rating of two amperes at 120 volts, AC. Relays shall be provided with a plug for mounting in a standard 11-pin octal socket.

5.11.2 Coils Rated at 24 Volts. Relays with coils rated at 24 volts or less shall be the two-pole, double-throw type, with a contact rating of two amperes at 120 volts, AC. Relays shall be provided with a plug for mounting in a standard 8-pin octal socket.

5.11.3 Contacts. Relays used to switch logic voltages shall have contact designed for the voltage and current to be switched.

5.12 Toggle Switches (Optional) Toggle switches shall have poles as required and shall be rated at 200 percent of circuit current for circuits of 10 amperes or less and 125 percent of circuit current for circuits over 10 amperes.

Circuit breakers used as toggle switches shall be adequate for the application and shall be UL or ETL listed for switching operation.

5.13 Indicator Lights (Optional) 5.13.1 Lamp Life. Indicator lights shall be incandescent type with a minimum rated operating life (at rated voltage) of 5,000 hours, or shall be light-emitting diode type with a minimum rated operating life of 100,000 hours.

5.13.2 Off Switch. Means shall be provided to turn off incandescent indicator lights.

5.14 Lighting Fixtures (Optional) 5.14.1 Fluorescent Fixtures (Optional). Each cabinet shall be provided with a fluorescent lighting fixture mounted on the inside top of the cabinet near the front edge. Fixture shall be provided with an F18T8 cool-white lamp operated from a normal power factor UL or ETL listed ballast.

5.14.2 Incandescent Lamp Receptacle (Optional). Each cabinet shall be provided with an incandescent lamp receptacle mounted on the inside top of the cabinet near the front edge. Receptacle shall be rated to accommodate a 100-watt medium base lamp.

5.14.3 On/Off Switch (Optional). The "On/Off" switch for the lighting fixture shall be one of the following:
(a) A toggle switch mounted on the inside control panel.
(b) A door-actuated switch that turns the light on when the door is open and off when the door is closed.

5.15 Connectors
Connectors used for interconnecting various portions of circuits together shall be designed to provide positive connection of all circuits and easy insertion and removal of mating contacts. Connectors shall be permanently keyed to prevent improper connection of circuits. Connectors, or devices plugging into connectors, shall be provided with positive means to prevent any individual circuit from being broken due to vibration, pull on connecting cable, or similar disruptive force.

5.16 Terminal Blocks
Terminal blocks shall meet the requirements of NEMA Standards Publication No. TS 1-1985, Traffic Control Systems, Section 10, "Terminals and Facilities."

5.17 Surge Arrestor
The surge arrestor shall reduce the effects of power line voltage transients and shall have ratings as follows:
- Recurrent peak voltage—184 volts.
- Energy rating, maximum—20 joules.
- Power dissipation, average—0.85 watts.
- Peak current for pulses less than 7 microseconds—1,250 amperes.

5.18 Radio Interference Suppressors
Radio interference suppressors shall provide a minimum attenuation of 50 decibels over a frequency range of 200 kilohertz to 75 megahertz when used in connection with normal installations. The interference suppressor shall be hermetically sealed in a substantial metal case filled with a suitable insulating compound. Terminals shall be nickel-plated, 10–24 brass studs of sufficient external length to provide space for connecting two No. 8 conductors and shall be so mounted that the terminals cannot be turned in the case. Ungrounded terminals shall be properly insulated from each other and shall maintain a surface leakage distance of not less than ¼ in. between any exposed current conductor and any other metallic part, with an insulation factor of 100 to 200 megohms dependent on external circuit conditions. Suppressors shall be designed for 125 percent of the total connected load, and in no event less than 25 amperes on 120 volts, 60 hertz, single-wire circuits, and shall meet standards of the UL or ETL and the EIA.
DEFINITIONS

Lane-Use Traffic Control Signal. A special overhead signal having indications used to permit or prohibit the use of specific lanes of a street or highway or to indicate the impending prohibition of use.

Traffic Control Signal. Any device, whether electrically or mechanically operated, by which traffic is warned or directed to take some specific action.

Signal Head. An assembly containing one or more signal faces which may be designated accordingly as one-way, two-way, etc.

Signal Indication. The illumination of a traffic signal lens or equivalent device or a combination of several lenses or equivalent devices at the same time.

Signal Face. That part of a signal head provided for controlling traffic in a single direction. Turning indications may be included in a signal face.

Green Indication. Vehicular traffic may travel in any lane over which a green signal is shown.

Steady Yellow Indication. Vehicular traffic is thereby warned that a lane control change is being made.

Flashing Yellow Indication. Vehicular traffic may use the lane only for the purpose of approaching and making a left turn.

Steady Red Indication. Vehicular traffic shall not enter or travel in any lane over which a red signal is shown.

POSITION OF SIGNAL INDICATIONS

Lane-use control signal units shall be located approximately over the center of the lane controlled.

If the area to be controlled is more than ¼ mile in length, or if the vertical or horizontal alignment is curved, intermediate lane-use control signal indications shall be placed over each controlled lane at frequent intervals. This placement shall be such that a motorist will at all times be able to see at least one indication, and preferably two (due to the possibility of a burnout of a single indication), along the roadway and will have a definite indication of the lanes specifically reserved for his use.

All lane-use control indications shall be located in a straight line across the roadway at right angles to the roadway alignment.

The bottom of any lane-use control signal unit shall be not less than 15 feet nor more than 19 feet above the pavement grade.

On roadways having intersections controlled by traffic signals, the lane-use control indication shall be placed sufficiently far in advance of or beyond such traffic signals to prevent them from being misconstrued as intersection traffic control signals.

HOUSING, DOORS, ETC.

Housing. The housing shall be made of a cast or fabricated corrosion-resistant material.

All cast metal parts shall have a tensile strength of not less than 17,000 pounds per square inch. All parts must be clean, smooth, and free from flaws, cracks, blowholes and other imperfections.

Parts made of aluminum alloy shall have one of the following compositions:

1. Die casting shall be alloy S-12A, S-12B, SC-84A, SC-84B, SG-100A or SG-100B or ASTM specification B85-60 or the latest revision thereof.

2. Sand castings shall be of alloy S-5A or alloy CS-72A or ASTM specification B-20-60T or the latest revision thereof.

3. Permanent mold castings shall be of alloy S-5A or alloy CS-72A of ASTM specification B108-60T or the latest revision thereof.

4. Fabricated cases shall be of alloy 3003 H14, minimum of .100 gauge aluminum.

The housing shall be securely fastened together into one weathertight signal face or assembly.

The lane control signal shall have an opening(s) to accommodate standard pipe brackets. The lane control signal shall be designed for mounting on standard 1½-inch signal brackets as a single unit or as a double unit.

When required, the successful bidder shall furnish evidence satisfactory to the purchaser that materials comply with all of the foregoing requirements.

Doors. The housing door shall be made of a cast or fabricated one-piece corrosion-resistant material identical to the housing (or compatible with the housing). It shall be hinged and gasketed to form a tightly sealed connection to prevent entry of dust and moisture. The door shall have an integrally cast collar not less than 3/16 inch high around the lens opening; the visor shall be designed to fit tightly against the collar and door and shall not permit any perceptible filtration of light between the door and the visor.

All exterior hardware such as hinge pins, lens clips, locking devices, etc. shall be stainless steel.

Adequate gasketing shall be provided between the body of the housing and the doors and between

This report was approved as a Standard of the Institute by the ITE Board of Direction on April 15, 1980 in concurrence with a recommendation of the Institute's Technical Council.

The Standard was developed by Committee 4K-S.

Members of Committee 4K-S were: Robert A. Fosnaugh (M); E. E. Guinup (AF); Irwin Hart (AF); Dennis Kyrk (F); Alva Williams Jr. (F); James B. Rudden (F); and Dave Wigglesworth.

William G. McKinley (M)
Chairman
the lenses and reflectors to exclude dust and moisture.

Where the fabrication of a case does not require a door, then each optical assembly shall use adequate gasketing to exclude dust and moisture.

The lens opening in the door shall be designed to provide a minimum area of 121 square inches with a minimum dimension of 10 inches. Greater surface areas are recommended for improved visibility and recognition at greater distances.

VISORS

Each lane-use control signal section shall have a visor. The visor shall encompass the entire top and sides of the lens opening and shall be a minimum of 9 inches in length.

The visor shall be of corrosion-resistant non-ferrous material and shall be mounted with twist-on slots and stainless steel screws positioned for either vertical or horizontal mounting of the signal.

TRUNNIONS, BRACKETS AND SUSPENSIONS. All trunnions, brackets and suspensions used for assembling and mounting traffic control signal faces shall be entirely watertight.

All tubular parts shall be 1½ inches I.P.S. pipe. When hollow cast brackets or trunnions are used, they shall be of sufficient strength to support the maximum load imposed by the signal heads under all normal wind conditions.

Wire raceway areas within hollow cast brackets, trunnions and suspensions shall be of adequate size to carry all necessary wires without crowding; raceway surfaces shall be free of sharp edges or protrusions which might damage insulation on wires. Suspensions for mast arms or span wire mounting shall include a device to permit adjustment for proper vertical alignment of the signal head.

EXTERIOR FINISH. All exterior metal parts of the signal heads, excepting the lenses and parts specified in the next paragraph but including the mountings and assemblies, shall be finished of the best quality synthetic resin enamel of the color specified by the purchaser (either highway yellow or dark green is recommended).

The insides of visors, and the entire surface of louvers or fins used in front of lane-use control signal lenses, shall be painted a dull black.

COLOR DEFINITIONS FOR LANE-USE CONTROL SIGNAL LENSES

The purpose of this section is to define the minimum values or relative luminous transmittance for lane-use control signal lenses and the limits of chromaticity for lane-use control signal colors by combinations of illuminant and redirecting cover lens material or illuminant and standard limit glass.

The specification covers the so-called red, yellow and green colors used in lane-use control signals.

Basis of Chromaticity Requirements. The values given in the specifications were derived from spectrophotometric data obtained by the Colorimetry Section, National Bureau of Standards, with defining glasses selected by a technical committee of the Institute of Transportation Engineers. These values were computed on the following basis:


2. Illuminant: C.I.E. Illuminant A. Planckian Radiator at 2856 K for values of x, y and z transmittance.

3. Angular distribution of illumination: Approximately at right angles to the surface of the glass.

4. Angle of view: Approximately at right angles to the surface of the glass.

The conditions above specified shall be used in testing lens materials for conformity to this section and the following section of this specification, except that to test a lens for conformity to this section, a photometric procedure must be used similar to that indicated in the section concerning Materials and Performance of Lane-Use Control Signal Lenses.

Explanation of Chromaticity. Any color can, in general, be adequately specified in terms of three colorimetric quantities. In the case of the signal colors, the three quantities adequate for the purpose are two numbers defining the chromaticity of the color: i.e., its hue and saturation, and one number defining the luminous transmission of the lens material. Since no two observers would, in general, get the same numbers by direct observation (because of difference in luminosity function and chromatic vision), it is desirable to express such numbers in terms of a hypothetical average normal observer. Such an observer was defined by resolutions adopted at the 1931 meeting of the International Commission on Illumination at Cambridge.

The chromaticity of a color expressed in terms of this 1931 I.C.I. standard observer is given by number x, y, z (called trichromatic coefficients or trilinear coordinates), which may be considered as expressing roughly the respective red, green and blue contents of the color. Since the sum of x, y and z always equals unity, the chromaticity is adequately specified by giving x and y only.

The chromaticity of all colors may, therefore, be represented graphically on a "mixture diagram" with values of y plotted against values of x, as seen in Figure 1. Permissible values of chromaticity for the signal colors are represented by certain areas on this diagram; the boundaries of these areas may be expressed as functions of x and y. These boundaries are placed so as to include the chromaticity obtained from the standard limit glasses when used with illuminants from 2856 K to 2866 K.

Tolerances on Transmittance and Chromaticity Coordinates. Red lane-use control signal color: The value of y shall not be greater than 0.306 nor less than 0.306-x.

Yellow lane-use control signal color: The value of y shall not be less than 0.411 nor less than 0.995-x nor greater than 0.452.

Green lane-use control signal color: The value of y shall not be less than 0.506-0.519x nor less than 0.150 + 1.068x nor more than 0.730-x.

The minimum relative luminous transmittance of lane-use control signal lenses with illuminant at 2856 K shall be: red, 0.095; yellow, 0.440; green, 0.190.

CERTIFIED DUPLICATE LIMIT GLASSES

The purpose of this section of this specification is to define the maximum deviations from the standard limit glasses, both in transmission and in chromaticity, to be permitted in glasses certified as duplicates of the standard limit glasses.
Transmittance of Limit Glasses. The luminous transmittance of certified duplicate limit glasses shall be within the limits shown in Table 1, the illuminant being C.I.E. Illuminant A (2854°K).

Chromaticity of Limit Glasses. All certified duplicate limit glasses shall pass the previous section of this specification with respect to the trichromatic coefficients of \( x \) and \( y \). They must also pass the additional specifications of Table 1. Table 1 gives the values of \( x \) and \( y \) for the standard limit glasses with the specified illuminant, followed by the range of values which is permitted in the certified duplicate glasses.

Marking of Certified Limit Glasses. Each certified limit glass (2 inches square) shall be permanently engraved with the serial number by the maker and further permanently engraved by the National Bureau of Standards with the serial number, the designation, the value of transmittance and the N.B.S. test number. Note: in all cases, the engraving may be verified and additional information regarding the certified limit glasses obtained from the...
Table 1. C.I.E. Coordinates of Primary Standards at National Bureau of Standards and Accuracy to Be Observed in Preparing Certified Duplicates C.I.E. Illuminant A, 2856 K.

<table>
<thead>
<tr>
<th>Name of Standard and N.B.S. Serial No.</th>
<th>Chromacity of Standard</th>
<th>Transmittance Range for Duplicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red, Yellow Limit #75</td>
<td>0.6927</td>
<td>0.1800 to 0.2100</td>
</tr>
<tr>
<td></td>
<td>±0.0009</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+0.0005</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.0012</td>
<td></td>
</tr>
<tr>
<td>Red, Transmittance Standard #154</td>
<td>0.7132</td>
<td>0.085 to 0.115</td>
</tr>
<tr>
<td></td>
<td>±0.0008</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+0.0008</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.0007</td>
<td></td>
</tr>
<tr>
<td>Yellow, Pale and Green Limit #339</td>
<td>0.5432</td>
<td>0.677 to 0.763</td>
</tr>
<tr>
<td></td>
<td>±0.0020</td>
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</tr>
<tr>
<td></td>
<td>+0.0020</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.0020</td>
<td></td>
</tr>
<tr>
<td>Yellow, Red Limit #199</td>
<td>0.5762</td>
<td>0.570 to 0.655</td>
</tr>
<tr>
<td></td>
<td>±0.0026</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+0.0026</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.0020</td>
<td></td>
</tr>
<tr>
<td>Green, Pale Limit #134</td>
<td>0.2448</td>
<td>0.252 to 0.285</td>
</tr>
<tr>
<td></td>
<td>±0.0024</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+0.0016</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.0024</td>
<td></td>
</tr>
<tr>
<td>Green, Blue Limit #87</td>
<td>0.2884</td>
<td>0.188 to 0.213</td>
</tr>
<tr>
<td></td>
<td>±0.0012</td>
<td></td>
</tr>
</tbody>
</table>

N.B.S. certificates for the glasses, which shall be made available to the purchaser by the seller.

**MATERIALS AND PERFORMANCE OF LANE-USE CONTROL SIGNAL LENSES**

The purpose of this section of this specification is to provide for approved colored lenses for vehicle lane-use control signals, to describe the materials and specify the appliances and apparatus necessary to make the required tests and inspection to determine whether the lens materials will be satisfactory for their intended use.

**Materials.** Lenses shall be made of either glass or plastic, the quality and processing of which shall be the best for the purpose. The composition must be durable on prolonged exposure to weather; all lenses shall be uniformly colored throughout the body of the material true to size and form and free from any streaks, wrinkles, chips or bubbles that in any way detract from their efficiency or use. The plastic material shall conform to the ASTM Specifications D788-88 Grade 8 or D702-64T Grade 3 or D2473-86 or the latest revision thereof. The index of refraction shall be between 1.48 and 1.59.

**Performance.** Each colored lens shall be so designed and manufactured that, when it is installed in a standard lane-use control signal (equipped with an approved lamp and reflector properly operated and focused), the resultant appearance, candle-power distribution and intensity, when compensated for absorption due to the color, will at least equal the light distribution required under "Candlepower Distribution" in the latest "Standards for Adjustable Face Vehicular Traffic Control Signal Heads." Each colored lens shall have chromaticity characteristics within the ranges provided for in "Color Definitions for Lane-Use Control Signal Lenses" of this specification with illuminant ranging between 2856 K and 2366 K.

**Equipment for Photometric Testing**

**Certified Limit Glasses.** Certified light and dark limit glasses calibrated by the National Bureau of Standards shall be made available by the manufacturer for use of the purchaser while conducting tests of lane-use control signal lenses at the manufacturer's plant. These certified glasses shall serve to define both the proper luminous transmission of the lenses to be tested and the proper chromaticities of the resulting signal colors as hereinafter provided.

**Photometer.** A suitable photometer shall be made available at the lens manufacturer's plant by the seller for use of the purchaser while conducting tests. The illuminant used for measurements shall have a color temperature between 2366 K and 2856 K, and with no samples in the beams the two halves of the photometric field shall have the same chromaticity. Note: Vacuum lamps or gas-filled lamps with opal bulbs should give the specified color temperature and produce a uniform color and brightness over a uniform area.

**Spectroradiometer.** A suitable spectroradiometer may be used in lieu of the photometer and be made available at the lens manufacturer's plant by the seller to measure the chromaticity of light from a lane-use control signal.

A spectrophotometer may be used to measure the chromaticity of flat test plaques.

**Tests and Inspections**

**Relative Luminous Transmittance.**

The minimum values of relative luminous transmittance for any lane-use control signal lens of a given color shall be as shown in Table 2.

No lens or test plaque of the proper thickness made from the lens material shall fail below the transmittance of Table 2 even after two years of outdoor exposure mounted at an angle of 45° to the vertical facing south in Florida.

**Chromaticity Test.** The chromaticity of each lens shall be compared with that of the respective certified limit glasses, using for this purpose the above specified photometer and illuminant. The comparisons shall be made with brightnesses matched. A lens shall not be acceptable if its chromaticity fails to meet either of the following requirements:

1. The hue shall not be outside the hue limits given by the respective certified light limit glasses, except that for red lenses only the yellow limit need be tested.
2. The saturation shall not be less than that given by the respective certified limit glasses.

Table 2. Minimum Values of Relative Luminous Transmittance for Any Lane-Use Control Signal Lens of a Given Color.

<table>
<thead>
<tr>
<th>Color</th>
<th>Luminous Transmittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>0.095</td>
</tr>
<tr>
<td>Yellow</td>
<td>0.440</td>
</tr>
<tr>
<td>Green</td>
<td>(0.220) 0.190</td>
</tr>
</tbody>
</table>
3. Lenses or test plaques shall meet the chromaticity requirements of this specification after the Florida exposure noted under "Tests and Inspections" above.

**Labeling.** The lens manufacturer shall place on each lens a label which shall indicate that the lens meets the requirements of this specification.

If required by the purchaser, certification as to conformance to these specifications shall be furnished by the manufacturer based on results of tests made by a neutral testing laboratory.

**Marking on Lens.** Each lens shall have pressed on its flange the word "TOP" to indicate the proper positioning of the lens in the door for obtaining the light distribution required, together with the dimensions and other descriptions including the name or trademark of the manufacturer needed for proper application and help in purchasing replacements.

**Lens Sizes and Tolerance.** There shall be no specific sizes for lenses but 12 inches square is the minimum. The lens size shall be based on the conditions of its use.

**Arrow and "X" Lenses**

For use in directing traffic moving in a certain direction during a specific interval, this specification provides for arrow and "X" indication of the types shown in Figure 2. Those shown in the figure are intended to serve as a minimum guide to what the arrow and X should look like. Lane-use control arrows should look like arrows in the Institute of Transportation Engineers' specification for adjustable face vehicular traffic control signal heads. The stem of the arrow may extend all the way to the head. The size of the arrow should vary accordingly with the size of the lens. The center portion of the X should be blocked out, however, continuous X liner may be used. The size of the X should also vary according to the size of the lens.

**Design.** All lenses shall be prismatic diffusing or equal thereof.

**Color.** The lens shall be of approved color conforming to previous section of those standards for the particular function of the lens.

**Backing.** All lenses shall be covered, except for the arrow and X, with a dull or dark gray opaque material of a thickness sufficient to totally hide the light from a 200-watt lamp placed behind it operating at rated voltage. The opaque material shall be hard and durable and shall be bonded so that it will not peel or flake when subject to the heat of a signal lamp when the lens is in use or when the lens is washed. The arrow and X shall be the only illuminated portion of the lens.

**Shape.** Arrow and X lenses may be rectangular in the sizes described in "Lens Sizes and Tolerances."

**Reflectors**

Reflectors may be either silvered glass or specular Alzak finished aluminum.

Reflectors shall be mounted in a cast aluminum reflector support attached to the housing, or shall be an integral reflector and support of formed sheet aluminum.

The reflector assembly shall be pivoted to the housing and shall be designed so that it can be swung out or easily removed without the use of any tools.

The method of mounting and fastening reflectors shall be sufficiently rigid to secure proper alignment between the lens and reflector when the door is closed.

The construction of the signal head and its components shall be such that the fit between the reflector and the lens will eliminate all possibility of false indications.

Reflectors shall have an opening in the back for the lamp socket.

**Glass Reflectors.** Glass reflectors shall be of alloy, a coat of metallic copper, best quality clear glass reasonably free from bubbles or ripples, with its back surface silvered by chemical deposition to such a thickness that the filament of a lighted 200-watt incandescent lane-use control signal lamp is invisible through the silver layer before application of the copper or paint backing.

The reflector backing shall consist of a homogeneous coating of metallic silver, evenly applied. It shall be so applied that no foreign substance remains between it and the glass, and it shall adhere so closely to the glass that the admission of any foreign substance (solid, liquid or gas) shall be prevented.

Over the reflector backing there shall be applied electrolytically a coat of metallic copper at least 0.0005 inch thick at the minimum point to reinforce the strength of the reflector.
and protect the silver from the admission of vapors or oxidizing agents prevalent in the atmosphere. 

The copper shall extend over the edge of the mirror at least one-fourth of the thickness of the glass.

There shall be placed over the backing one or more coats of paint or enamel of such quality as to provide the greatest resistance possible to the admission of moisture or gases which might injure the copper or silver backing.

Tests and Inspection

1. The reflector shall meet the following test: The reflector shall first be immersed for 24 hours at room temperature in a solution composed of tap water and 20 percent by weight of salt. It shall then be removed from the salt solution and rinsed in clear water, after which it shall be placed in clear water at room temperature. This bath with the reflector shall then be gradually heated to a temperature of 85°C and maintained at that temperature for four hours. After that heating, the reflector shall be removed from the water and placed in dry air at 85°C for four hours.

2. After the above test, the glass, silver and backing on the reflector shall show no chipping, cracking or softening of the coatings and shall show no separation of the backing into layers or from the mirror surface of the glass, and no appreciable change in the color of the glass, backing or the silver reflecting surface.

3. If required by the purchaser, certification as to conformance to these specifications shall be furnished by the manufacturer based on the results of tests made by a neutral testing laboratory.

Alzak Aluminum Reflectors.

Aluminum reflectors shall be made of specular Alzak aluminum, the thickness of the anodic coating to be a minimum of 0.0001 inch, or its equivalent, spun or drawn from metal not less than 0.025 inch thick equipped with a bead or flange on the outer edge to stiffen the reflector and insure its being held true to shape.

The reflecting surface shall be totally free of flaws, scratches, defacements or mechanical distortion.

Lighting. The lighted signal shall appear to be illuminated without shadows when viewed from the usual angles encountered in service.

Spurious Indications

Sun Phantom. The optical unit, including lens, reflector, lamp and visor shall be designed as a whole so as to minimize the return of the outside light rays entering the unit from above to produce the phenomenon known as sun phantom.

Light Seal. The optical unit shall be so designed and assembled that no light can escape from one indication to another.

Separate Illumination. The optical unit shall be so designed that each lens will be illuminated separately. Lamps

Wattage and Output Standards. Lamps to be used in lane-use control signal heads shall conform to the standards set forth in the Institute's latest Standard for Traffic Signal Lamps.

Electrical Components

Lamp Receptacle. The lamp receptacle shall be heat resisting material designed to properly position a medium screw base lane-use control signal lamp with means to accommodate a lamp having light center 2 7/16 inches in length for the 60-watt and 100-watt series, 3 inches in length for the 150-watt series. The receptacle shall be provided with a lamp grip to prevent the lamp from working loose due to vibration.

Provision shall be made on either the lamp receptacle or the reflector holder to permit rotation of the lamp so that the lead wires are up and a secure fastening for the retention of the lamp in that position, but shall not permit any change in position of the socket with respect to the optical center of the reflector. The metal portion of the lamp receptacle shall be compatible with brass or copper.

Wiring. Each lamp receptacle shall be provided with two coded No. 18 or larger lead wires, type TEW, 600-volt, AWM fixture with 2/64 inches, 105°C rating thermoplastic insulation, securely fastened to the socket and with sufficient length to reach the terminal block with the reflector fully open. The thermoplastic insulation shall at –32°C be capable of being bent six times around a 1-inch mandrel without damage to its insulating properties at rated voltage. A suitable terminal block for connection of the wires from the socket and the incoming wires to the lane-use control signal head shall be provided in the signal housing.

OTHER TYPES

If other types of lenses, reflectors and light sources are used, they should be so constructed and appear to the driver's eye similar to those types covered in this specification.
A Model Performance Specification for the Purchase of Pavement Marking Paints and Powders

Chapter I—General

1. INTENT OF SPECIFICATION

It is the intent of this specification to describe the general and specific requirements for reflective pavement marking paints or powders to be used by the (city or state)* in its pavement marking program as well as to provide for the submission of samples and to describe the laboratory and service test procedure which will be used to rate the materials submitted for test. It is intended that samples will be received under this specification from any individual, company or corporation desirous of furnishing traffic marking paints or powders to the (city or state), that such samples will be subjected to appropriate laboratory and field service tests, and that the (city or state) will request competitive bids for the (city’s or state’s) requirements on such materials as prove satisfactory. Depending upon the materials tested, it is expected that a field service test will require from six months to three years for completion.

2. TYPES OF MATERIALS

This specification covers those reflective pavement marking materials, paints and powders whose description and physical properties are given in Chapter II of this specification. The procedures given in Chapter III of this specification may be used to test any pavement marking materials against other types of materials.

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3. METHOD OF TESTING

The methods of sampling and testing all paints and powders covered by this specification shall be in accordance with the latest standards of the American Society for Testing Materials, the American Association of State Highway and Transportation Officials, the Federal Government or of other recognized standardizing agencies as indicated for each material.

Chapter II—Properties, Application and Packaging of Paints and Powders

1. PAINTS

A. Type of Paint.

This section covers ready mixed paint products of spraying consistency suitable for use as reflecting pavement markings on portland cement concrete or bituminous pavements.

1. The paint types relative to drying times hereinafter shall be referred to as follows:
   a) Conventional paint—over 3 minutes (requiring line protection devices).
   b) Rapid dry paint—1 to 3 minutes drying time.
   c) Quick dry paint—less than 60 seconds drying time.

The rapid dry and quick dry paints are heated during application to achieve uniform sprayable viscosity. The beads are applied on quick dry paint by a pressurized bead system.

2. The paint types relative to glass bead application methods hereinafter shall be referred to as follows:
   a) Premix type beads—a type in which the glass spheres are mixed in the paint during manufacture.
   b) Drop-on type beads—a type in which the glass spheres are dropped or sprayed into the wet paints as it is applied to the pavement.
   c) Combination type beads—a type
that combines the premix and drop-on type beads using some of each type.

B. General Properties.

1. Condition and Stability. The paint shall be homogeneous, shall be well ground to a uniform and smooth consistency and shall not skin or settle badly, nor cake, liver, thicken, curdle or gel in the container. The paint shall be capable of being broken up and mixed without difficulty by use of a paddle and shall show the desired characteristics at any time within a period of six months from the date of delivery. The paint shall be tested in accordance with ASTM designation D-869 and D-1309 and a paint rated below (6) shall be considered unsatisfactory.

2. Foreign Matter. The paint shall be free from skins, dirt and other foreign matter and shall not contain more than 1 percent water. The paint shall be tested in accordance with methods 4081, 4091 and 4092 of Federal Test Method No. 141.

3. Suitability to Application. The paint shall be suited to application by means of spray-type pavement marking equipment used by the (city or state) and when used with such equipment shall be capable of producing a solid, full-width line of the required thickness.

4. No Tracking Time. The paint, when applied with glass spheres to dry concrete or bituminous pavement surface under normal field conditions at the required application rates with pavement temperature between 35 and 45° Fahrenheit and under all humidity conditions suitable for applying paint, shall dry to a no-tracking condition in the following times:

   Conventional—45 minutes.
   Rapid dry—60 seconds.
   Quick dry—20 seconds.

The no-tracking time shall be determined by passing over the line in a simulated passing maneuver with a passenger ear at approximately 30 m.p.h. after the expiration of above time. A line showing no visual paint deposition to the pavement surface when viewed from a distance of 50 feet shall be considered as showing no-tracking and conforming to the requirements for field drying conditions. The paint may also be tested in accordance with ASTM Designation D-711 and when so tested, shall dry to no pickup in the following maximum times:

   Conventional—30 minutes.
   Rapid dry—8 minutes.
   Quick dry—6 minutes.

5. Viscosity. The paint, as received, shall have a consistency determined on the Stormer Viscosimeter and expressed as Krebs Units at 77° as follows:

   Conventional—70-90 K.U.
   Rapid dry—90-110 K.U.
   Quick dry—100-125 K.U.

Any paint which changes consistency within six months after receipt so that the consistency falls outside the viscosity limits stated above shall be considered to have failed this requirement.

Note: A viscosity range of 70 to 80 Krebs Units at 77° F is recommended for drop-on type bead application in conventional paint and a range of 80 to 90 Krebs Units at 77° F is recommended for premix or combination bead application in conventional paint.

6. Color. The paint shall visually match the Federal Highway Administration color tolerance chart for standard highway yellow, or standard highway white, as required by the order. The color determination shall be made after the paint has dried for 24 hours on premix as received and on combination and drop-on types after the beads have been dropped in. The paint shall not discolor in sunlight.

Note: If a light shade of yellow is desired, a standard to green tolerance should be shown. If an orange-yellow shade is desired, a standard to red tolerance should be shown.

7. Bleeding. When tested and evaluated on both and asphalt substrates in accordance with the Method of Laboratory Test for Degree of Resistance of Traffic Paint to Bleeding, ASTM designation D-969, and the Method of Evaluating Degree of Resistance of Traffic Paint to Bleeding, ASTM designation D-868, the numerical rating of degree of bleeding for both white and yellow paints shall not be less than (6). Paints will be tested for bleeding with the prescribed quantity of glass spheres in or on the paint.

8. Hiding Power. The pigment binder, when tested in accordance with Method 4121 of Federal Test Method No. 141, "Dry Opacity," and when applied at the rate of 10 mils wet film thickness over a Moist Black and White Hiding Power Chart, Form 03-B, shall show complete hiding or give a contrast ratio of not less than 0.98

C. Application

In road service tests and in routine use, the paint shall be applied at the rate recommended by the manufacturer within plus or minus 10 percent as determined by quantitative measurements made of the area of line applied per unit volume of material. If no rate is specified by the manufacturer, the paint will be applied at the rate of 16.5 gallons per mile of 4-inch continuous stripe (wet film thickness of 15 mils), and glass spheres shall be applied at the rate of six pounds per gallon of paint of the drop-on type and three pounds of glass spheres per gallon of paint of the combination type.

D. Equipment

1. Conventional Paint. The equipment required for the application of conventional paints may range from simple hand or self-propelled strippers to relatively large truck mounted equipment. Paint heating equipment is not normally required for the application of this type material.

2. Rapid Dry Paint. The application equipment for rapid dry paint is normally truck-mounted due to the paint heating equipment required. Rapid dry paints require heating from 110° to 170° F at the spray nozzle as recommended by the manufacturer. The paint heating is usually accomplished by circulating hot water taken from the truck or compressor radiator through a heat exchanger and jacketed tubes adjacent to the paint lines. A 180° F thermostat used in the radiator will normally produce enough water heat for the system.

3. Quick Dry Paint. Quick dry paint must be applied at 180°-195° F nozzle temperature. Therefore, more heating capability must be available than for rapid dry paint as described earlier. This additional heating is usually in the form of a diesel fuel fired heat exchanger through which the paint is circulated after leaving the tank. A temperature of 230° F in the heat exchanger should be available. Paint lines between the heat exchanger and spray guns must be heated and jacketed to obtain the desired paint temperature at the nozzle.

E. Packaging

The packaging of paint for road service test samples and for laboratory tests is described in Chapter III of this specification. Unless otherwise specified, paint purchased under this specification for regular use by the (city or state) shall be shipped in clean, open-headed drums of ___ gallons capacity, sealed, vapor proof, and meeting current Interstate Commerce Commission requirements. Each container shall be plainly marked, both on the head and side, with a durable, weather resistant ink or paint, showing the name and address of the manufacturer or vendor, description of material, purchase order number, batch number and volume and weight of contents.

Note: The capacity of paint containers desired by the (City or State) should be inserted in the blank space left. Pails or drums with a capacity of 5, 30 or 55 gallons are common.
F. Special Handling or Use Instructions

Any special handling, storage or use instructions made necessary by the use of unusually flammable solvents shall be provided by the manufacturer.

2. PROPERTIES OF GLASS SPHERES FOR REFLECTORIZATION

A. General Requirements

1. Types of Glass Spheres. Glass spheres for use with traffic paint shall be clear and colorless of the following two types:
   a) Standard Glass Spheres (may be moisture proof).
   b) Flotation Glass Spheres. These glass spheres differ from the standard glass spheres in that when applied to traffic paint, they are hemispherically embedded to provide approximately 50 percent sphere embedment and equivalent sphere for reflectance.

2. Crushing Resistance. The crushing resistance of glass spheres shall be determined in accordance with ASTM designation D-1213. A 40-pound dead weight for 20 to 50 mesh spheres should be the average resistance of the spheres tested.

3. Roundness. The roundness of glass spheres shall be determined by ASTM designation D-1155. A typical requirement is that more than 20 to 30 percent shall contain irregular or fused spherical particles.

4. Index of Refraction. The liquid immersion method at 25 percent C. shall be used to determine the refractive index of glass spheres. A refractive index of 1.50 to 1.60 is usually required for glass spheres used with traffic marking materials.

5. Gradation. A sieve analysis of glass spheres shall be made in accordance with ASTM designation D-1214. Typical gradations required for various types of pavement marking materials are as follows:
   (1) For premix and combination type paints:
      0 to 20 percent passing #40; retained on #60 sieve.
      30 to 70 percent passing #60; retained on #100 sieve.
      25 to 50 percent passing #100; retained on #200 sieve.
      0 to 5 percent passing #200 sieve.

   (2) For drop-on type paints:
      5 to 20 percent passing #20; retained on #30 sieve.
      30 to 75 percent passing #30; retained on #50 sieve.
      9 to 22 percent passing #50; retained on #80 sieve.
      0 to 10 percent passing #80 sieve.

6. Chemical Resistance. The glass sphere shall withstand immersion in water and acids without undergoing noticeable corrosion or etching and shall not be darkened or otherwise noticeably decomposed by sulfides. The tests for chemical resistance shall consist of one hour immersion in water and in solutions of corrosive agents followed by microscopic inspection. A 3 to 5 gram sample shall be placed in each of three Pyrex glass beakers or porcelain dishes; one sample shall be covered with distilled water, one with a 3N solution of sulfuric acid and the other with a 50 percent solution of sodium sulfide. After one hour of immersion, the glass spheres of each sample shall be examined microscopically for evidence of darkening and frosting.

   Note: The tests described in United States Federal Specifications TT-F-85b, items 4.4:13; 4.4:14; 4.4:15; and 4.4:16 may be substituted for the test described above.

7. Flotation. A minimum of 90 percent of the flotation glass spheres shall float on xylol (aromatic solvent) and a minimum of 75 percent shall float on heptane (aliphatic solvent) when tested as follows:
   A single layer of spheres shall be spread on the flat center of a clean inverted pint tin can lid. Solvent shall be slowly introduced with a syringe or dropper into the circular groove at the edge of the lid until it overflows into the center. The percentage of spheres floating on the solvent surface shall be estimated visually.

8. Flow Properties. The glass spheres shall flow freely through the dispensing equipment in any weather suitable for striping.

   Note: For areas experiencing relatively high humidity during the striping season, the use of additives or special treatments in the production of the spheres may be required to insure adequate moisture-proof qualities. If such additives or silicone treatments are required, either of the following tests shall be used to insure that the spheres will flow freely, even in high humidity.
   (1) Beaker Test: One hundred (100) grams of glass spheres are placed in a 600 milliliter beaker and an equivalent volume of distilled water shall be flowed into the beaker on top of the glass spheres. The beaker shall then be permitted to stand for a period of five minutes, at the end of which time the water shall be poured off, the spheres transferred to a clean, dry beaker and permitted to stand for five minutes. At the end of this time, the spheres shall be introduced into a standard 125 millimeter diameter glass funnel having a stem 125 millimeters in length. The spheres shall flow through the funnel stem without stoppage. Slight initial agitation to start the flow through the funnel at the beginning of the test will be permissible.
   (2) Bag Test. A 2-pound sample of spheres is placed in a cotton bag and immersed in a container of water for 30 seconds or until water completely covers the spheres, whichever is longer. The bag shall then be removed and excess water forced from the sample by squeezing the bag. The bag shall then be suspended and allowed to drain for two hours at 70-72° F, after which the sample shall be thoroughly mixed by vigorously shaking the bag. The entire sample shall then be slowly transferred to a clean, dry glass funnel having a stem 4 inches in length, a ¾ inch inside diameter stem opening and an exit opening of ½ inch. The entire sample shall flow freely through the funnel without stoppage. If the spheres clog the funnel when first introduced, it is permissible to lightly tap the funnel to start the flow of spheres.

   In addition to complying with the above test requirements, the glass spheres shall remain in a free-flowing condition for a period of at least 12 months when stored indoors.

9. Color. The glass spheres shall be colorless to the extent that they impart no off-color day or night-time hue to the paint binder when applied at normal application rates.

B. Packaging

Packaging requirements for glass spheres used for road service tests or laboratory tests may vary depending upon the quantities required for the various materials listed in Chapter III of this specification. Glass spheres for routine applications in conjunction with drop-on or combination paints shall be shipped in bags or drums that are strong enough to permit normal handling during shipment and transportation on the job without loss of spheres and shall be sufficiently water resistant so that the spheres will not become wet or caked in transit.

Flotation glass spheres shall be specifically marked on each package or bag as "Flotation Type Spheres.

Note: Multiply paper bags or bulk bags with a polyethylene liner having a capacity of 50 pounds of spheres are normally used.

3. PROPERTIES OF STRIPING POWDERS

A. Type of Powder

This section covers ready mixed powder paints for use in the production consistency suitable for use as reflecting pavement markings on portland cement.
concrete or bituminous pavement with or without liquid road surface conditioner.

B. General Properties

1. Description. The striping powder shall be a free-flowing plastic type pavement marking material which is premixed with glass spheres for reflectorization. When flame-sprayed to clean portland cement concrete and bituminous pavement road surfaces by a suitable mechanical striping, the striping powder shall produce an instant dry to no pickup, adherent, reflectorized stripe capable of resisting deformation by traffic. A liquid may be desired for application to some road surfaces before application of the marking powder; if so, it shall be so stated on the request for bid.

2. Suitability to Application

a) The powder shall be suited to application by means of flame-spray gun type pavement marking equipment used by (purchasing agency) and when used with such equipment shall be capable of producing a solid, full-width lane of the required thickness.

b) The liquid road surface conditioner shall be suited to application by spray gun system or by conventional paint roller.

3. Physical Characteristics of Striping Powder. The striping powder shall be a dry mixture capable of freely flowing through the flame-spray marking equipment at the rate of 14 to 18 ounces per 30 seconds even when exposed to combined conditions of high humidity (90 percent R.H.) and high ambient air temperature (100° F). The striping powder shall require no thinning, mixing or heating prior to use and shall be satisfactorily usable at minimum road surface temperatures of 50° F and minimum ambient air temperature of 60° F.

4. Color. The striping powder shall match the Federal Highway Administration color tolerance chart for standard highway yellow or standard highway white as required by the order. Color determinations shall be made on casts of samples melted at 200° F and poured into aluminum foil weighing dishes of the following dimensions:

Rim diameter—58 mm.
Height—18 mm.

5. Particle Size. The finished powder as supplied shall have the following grading:

<table>
<thead>
<tr>
<th>U.S. Sieve No.</th>
<th>Weight Retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0-2</td>
</tr>
<tr>
<td>230</td>
<td>93-100</td>
</tr>
<tr>
<td>Pan</td>
<td>0-5</td>
</tr>
</tbody>
</table>

6. Softening Point. Tested in accordance with "ring and ball softening point determination" ASTM Test No. E28-67, the softening point shall be from 215° to 225° F.

7. Liquid Road Surface Conditioner. The liquid, when specified, shall require no thinning, be easily applied and compatible with road surfaces and the marking powder supplied.

8. Glass Spheres. The finished powder shall contain intermixed glass spheres.

Figure 1

CERTIFICATE OF COMPLIANCE
AND STATEMENT OF CHARACTERISTICS
Paints and Powders

<table>
<thead>
<tr>
<th>1. Weight (Paint Only)</th>
<th>16/gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Viscosity (Paint Only)</td>
<td>K.J.</td>
</tr>
<tr>
<td>3. Vehicle (Paint Only)</td>
<td>%</td>
</tr>
<tr>
<td>4. Percent Pigment</td>
<td>%</td>
</tr>
<tr>
<td>5. Type of Pigment</td>
<td></td>
</tr>
<tr>
<td>6. Drying Time Maximum at</td>
<td>°F</td>
</tr>
<tr>
<td>7. Plastic Solids (Powders Only)</td>
<td>%</td>
</tr>
</tbody>
</table>

Glass Spheres

<table>
<thead>
<tr>
<th>1. Refractive Index</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Crushing Resistance</td>
<td></td>
</tr>
<tr>
<td>3. Imperfections</td>
<td></td>
</tr>
<tr>
<td>4. Gradation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pre-Mix</th>
<th>Drop-In</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Standard Sieve</td>
<td>% Passing</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

(Signature and Title)

Mail to:

b) Percent of weight of glass spheres: 30 percent minimum; 35 percent maximum.

1) Method of Determination of Percent by Weight of Glass Spheres:

a) Equipment:

(1) Laboratory triple beam balance.

(2) U.S. standard screen (270 mesh).

(3) 400 ml glass beaker.

(4) Oven at 200° F.

b) Procedure:

(1) Weight 100 grams of finished powder into 400 ml beaker.

(2) Add 200 ml of suitable sol-
vent (alcohol, aromatic solvent or Ketone).

(3) Stir until finished powder is dissolved.

(4) Pour solution on 270 mesh screen (flush beaker with solvent to remove all the beads).

(5) Wash the beads on the screen with solvent until they are clear.

(6) Dry in oven at 200°F and weigh the amount of beads recovered.

(7) Calculate percent of beads recovered.

\[
\text{Wt. of Beads} \times 100\% = \% \text{ of beads.}
\]

C. Grading of Glass Sphere:

\[
\text{Percent by Weight Retained:}
\]

<table>
<thead>
<tr>
<th>U.S. Sieve No.</th>
<th>Weight Retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>0-5</td>
</tr>
<tr>
<td>70</td>
<td>15-60</td>
</tr>
<tr>
<td>230</td>
<td>35-85</td>
</tr>
<tr>
<td>Pan</td>
<td>0-15</td>
</tr>
</tbody>
</table>

2) The properties of crushing resistance, roundness, index of refraction and chemical resistance shall be as required in Chapter II of this specification.

D. Equipment

Striping powder is designed for application by a relatively small light weight hand propelled striper. The powder is fed through a propane fired application gun. A small external compressor capable of delivering 18 cfm at 70 PSI is required for the system.

E. Packaging

The finished powder shall be delivered ready for use and shall be packaged in 25-pound cartons or other acceptable containers clearly identified as to manufacturer, color, contents and quantity and shall be free of clumps, foreign particles or other matter. Cartons employed for packaging shall withstand normal handling and shall have a suitable protective interliner to resist moisture absorption. The powder, as supplied, may be stored at temperatures not to exceed 90°F for up to one year, without adversely affecting the physical properties stated in this specification. The liquid road surface conditioner, if required, shall be delivered ready for use in one-gallon containers meeting current Interstate Commerce Commission requirements.

F. Properties of Applied Powder Line

Dispensed and properly applied by flame-oil or gas type striper, the finished line shall be reflective and shall adhere so as to form a smooth continuous film on both portland cement and asphaltic concrete road surfaces. Minor temporary line discoloration, due to surface soot, shall be permissible on adjacent overlapping lines. Lines exhibiting surface soot shall regain full color with traffic wear. A properly applied striping powder line shall not exhibit bleeding when applied on cured asphalt surfaces. An applied line shall have the following specific properties:

1) Dry to no pickup (10 mils application). Tested in accordance with ASTM Test No. D-711-67. Determination shall be made by averaging a minimum of three no pickup readings at each pavement temperature tested.

- Pavement temperature between 50 and 90°F—10 seconds or less.
- Pavement temperature between 90 and 140°F—25 seconds or less.

Liquid road surface conditioner shall be easily applied by pressure spray gun or conventional paint roller with a solvent resistant sleeve with ¾-inch nap.

a) Allow to dry on the pavement surface for approximately 5 minutes prior to applying marking powder.

Chapter III—Road Service Tests

1. INTENT OF SPECIFICATION

It is the intent of this portion of the specification to describe a procedure to be followed by manufacturers and others in submitting samples for this test, and the procedure which will be followed by the (city or state) in testing the pavement marking materials submitted to determine the most economical material for the (city or state) to purchase. Only materials submitted for performance tests under the specification and thereby found to be acceptable will be considered when bids are taken. It is therefore the responsibility of the manufacturer to submit for tests samples of all types and colors of materials upon which he later may wish to submit bids.

2. SAMPLES REQUIRED

A. An invitation to submit samples may be issued several months or, for relatively long-life materials, two or three years in advance of the invitation to submit bids in order to permit evaluation of the service test results. All samples shall be properly identified with the manufacturer's code number, which shall be different for each type and color submitted. The manufacturer's name, address, type of material and code number for each sample shall be submitted separately.

B. Each sample shall consist of the following amounts of each material which the manufacturer proposes to furnish:

1) For premix type paints:
   a) Two (2) one-gallon cans of the finished product.
   b) Three (3) one-quart cans of the finished product.
   c) Two (2) one-quart cans of the paint without beads.
   d) Ten (10) pounds of beads.

Note: One (1) five-gallon can of the finished product may be substituted for the above items.

2) For drop-on type paints:
   a) Two (2) one-gallon cans of the finished product.
   b) Three (3) one-quart cans of the finished product.
   c) Twenty-five (25) pounds of beads.

Note: One (1) five-gallon can of the finished product and 30 pounds of beads may be substituted for the above items.

3) For combination type paints:
   a) Two (2) one-gallon cans of the finished product.
   b) Three (3) one-quart cans of the finished product.
   c) Two (2) one-quart cans of the paint without beads.
   d) Ten (10) pounds of premix type beads.
   e) Twenty-five (25) pounds of drop-on beads.

Note: One (1) five-gallon can of the finished product and sufficient drop-on beads may be substituted for the above items.

A one-gallon paint sample is for the road service test; the one-quart samples are for the laboratory tests, including can stability; the other one-gallon sample is for the (city's or state's) use to determine if the paints will perform satisfactorily in its regular marking equipment and it will therefore be applied under normal operating conditions at prescribed application rates.

Each sample of striping powder shall consist of the following amounts of each material which the manufacturer proposes to furnish:

1) One (1) twenty-five (25) pound container of the finished product.

2) One (1) gallon of liquid road surface conditioner (if requested by purchasing agency).

The 25 pound powder samples are for the road service test and for the (purchasing agency's) use to determine if the material will perform satisfactorily in the marking equipment.

The number of samples of each type of material that will be accepted from each manufacturer can be reduced if the city or state does not desire to accept the number of samples permitted in the model specification.

C. On each invitation to submit samples, each manufacturer may submit not more than (3) samples of each color material. The (city or state) re-
serves the right to request from manufacturers the submission of only those types and colors of material in which purchases are contemplated.

3. CERTIFICATIONS REQUIRED

A. Certificate of Compliance

The manufacturer shall submit for each sample a Certificate of Compliance on the form (see Figure 1) provided certifying that the sample meets all of the requirements in this specification.

B. Statement of Characteristics

The manufacturer shall submit with each sample a Statement of Characteristics on the form provided giving all of the information requested. This statement shall be for the confidential use of the (city or state), and the information therein will not be revealed by the (city or state), but will serve and assist in identifying and testing materials furnished.

4. Submission of Samples and Certifications

Samples, certificates of compliance and statements of characteristics shall be sent prepaid to the (city or state). Unless the samples and corresponding certificates and statements of characteristics are received by the hour and date fixed in the inquiry for the receiving of such samples, the (city or state) shall not be obligated to include the samples in the test or to consider them for purchase.

Due to time required for the preparation of samples by manufacturers, the inquiry shall allow 45 to 60 days for the submission of samples.

4. SERVICE TESTS

A. Application

The test strips shall be 4 inches in width and applied transversely across the lanes of the road. The application will be made by selected personnel under the supervision of (city or state). The selection of test sites and all aspects of the test line applications shall be in accordance with ASTM designation D713-66T. The material shall be applied to four sections of highway, two of which have a concrete surface and the other two a bituminous surface. The section selected shall be areas where high traffic volumes exist and where it is uniform with full exposure to sun throughout the daylight hours. The test area shall be laid out where traffic is free rolling and with no grades, curves, intersections or access points near enough to cause excessive braking or turning movements.

At least three lines of each sample shall be applied in order that differences due to position and time of day will be compensated for, insofar as it is practical to do so. The material shall be applied at the rate recommended by the manufacturer within plus or minus 10 percent as determined by quantitative measurements made of the area of line applied per unit of volume of material. If no rate is specified by the manufacturer of paint samples, the samples will be applied at the rate of 16.5 gallons per mile of 4-inch continuous stripe (wet film thickness of 15 mils) and glass spheres at the rate of 6 pounds per gallon of paint on drop-on types and 3 pounds per gallon on combination types. If no rate of application is specified by the power manufacturer, the samples shall be applied at a rate of 10 mils dry film thickness or approximately 20-25 square feet per pound.

Note: The number of test lines can be reduced if the city or state does not intend to apply the paint to both portland cement concrete pavements and bituminous pavement. Test lines are needed only on the type of pavement that is to be marked. All samples received for test lines are needed only on the type of pavement that is to be marked.

All samples received for tests will immediately be given a code identification number which shall be recorded and filed with the manufacturer's code number and certifications. All identification other than the said code identification number shall be removed from the sample containers and the code number shall be used for identification of the material for all succeeding operations of testing, application and field rating of the material.

B. Evaluation

The uniformity of application, covering properties and drying time will be determined at the time materials are applied on the road and the comparative results obtained on these properties of the various materials will be taken into consideration in the final evaluation.

Periodic inspections will be made of the test sections in accordance with ASTM designation D-713, D-821 and D-913. Records will be made at each inspection of general daytime appearance (including color), film condition and reflectivity. It is desirable to carry on the inspections for a period of one year or more, depending upon the types of materials under test, or until all of the transverse test lines are more than 50 percent worn off in the wheel tracks.

Representatives on the inspection team may vary as desired; however, it is suggested that the Traffic, Materials and Purchasing Bureau or Departments be represented on the inspection team.

Evaluation of service will be based on appearance, durability and night visibility as defined below. The test lines will be rated numerically from very poor to perfect, using numbers of 0 to 10, with number 10 indicating a perfect condition and 0 complete failure.

D. Definitions

The following definitions shall be applied in evaluating the test lines and in computing the economic aspects of the various lines and materials.

1. Appearance. This is the complete impression conveyed when the marking is viewed at a distance of at least 10 feet before any detailed inspection has been made. The appearance should be rated on a 0-10 scale with 10 representing no change in appearance of the freshly applied marking. It also includes a comparison of color of the line under consideration with the original color, taking into account changes due to yellowing, darkening, fading, dirt collection, mold growth, etc. The determination is to be made with no preliminary washing or other modifications of the surface of the test lines.

2. Durability. The factor used in rating film failure is equal to 1/10 of the percentage of material remaining on the pavement when examined closely by the unaided eye, this determination to be made in each wheel track in an area extending 9 inches each side of the point of greatest wear. Percentage of material remaining on the pavement will be considered as the percentage of the prescribed area of test stripe in which the substrate is not exposed.

3. Night Visibility. Night visibility designates the apparent brightness when examined at night under tungsten illumination from the side of the road, with eye and light source separated by distance which corresponds to a divergence of viewing angle of approximately 1/3°. Night visibility determinations will be made on the same areas as those used for rating durability.

4. Service Factor (R). In evaluating each sample at the end of the test (or at any time prior thereto), a service factor (R) will be determined for each quality: Rₚ for appearance, R₅ for durability and R₄ for night visibility on the basis of the following formula (in which each value of r is the average of the ratings for the specific quality by all [three] observers for all four test sections) at the time (t) in days between successive evaluations. The time tₜ at which the rating of a paint goes below (four), which is R₄ at the time of any inspection, will be determined by interpolation.
R = \frac{r_1 s_1 + r_2 s_2 + r_3 s_3 \ldots r_n s_n}{t_1 + t_2 + t_3 \ldots t_n}

Note: When it is desired to determine the service factor, etc., separately for concrete and bituminous surfaces, a separate set of calculations will have to be made for the ratings of the materials on the two pavement surfaces.

5. Weighted Rating (W). The three qualities of appearance, durability and night visibility are not considered of equal importance in rating a pavement marking material and will be weighed as follows: Appearance—30 percent; durability—30 percent; night visibility—40 percent.

The weighted rating (W) of a material will, therefore, be determined by the formula
\[ W = 0.30R_a + 0.30R_d + 0.40R_n \]
where \( R_a \), \( R_d \), and \( R_n \) are the service factors for appearance, durability and night visibility.

Note: The weighted ratings indicated above are suggestive only. The purchaser may add additional qualities or assign other values to increase or decrease the importance of each quality as he may desire. An example, if the pavement marking is to be applied to a well-illuminated city street, the weight for night visibility could be reduced and the weight of either appearance or durability increased. The three rates must, however, total 100 percent.

D. Final Evaluation

After the test lines have been in service for one year or whenever all materials are rated below (4) in one or more of the service factors, a final evaluation will be made and the weighted rating for each material will be determined. The average of the figures of performance for all four test sections arrived at by all (three) observers will be used to determine the final figure of each performance or weighted rating for each material sample.

Note: the one year shown can be decreased if results must be obtained at an earlier date, but it is desirable to subject the test lines to both summer and winter wear and deterioration.

E. Length of Useful Life (L)

The length of useful life of each sample is the product of the length of the test period and the comparable rating of the line with a perfect line and with one that has reached the end of its useful life (a rating of 4). The length of useful life is determined by the formula:
\[ L = D \times \frac{(10 - E)}{(10 - W)} \]
where \( D \) = days of the period of test, \( E \) = weighted rating of a line at the end of its useful life, \( W \) = weighted rating at the end of the test period.

6. BIDS

All vendors whose samples receive a satisfactory rating will be given an invitation to bid. Each bidder will be required to file an affidavit that the material which he proposes to furnish will be identical with that of the sample submitted for performance tests or within the tolerances allowed. Material will be evaluated by ranking them in ascending order on the basis of (C), the cost (in dollars) per foot per day of useful life, determined by (M), the cost in dollars per foot of materials installed and (L), the length of useful life of the material. The formula for this purpose is as follows:
\[ c = \frac{L}{M} \]

Note No. 1. The cost of paints installed (M) is determined by the formula:
\[ M = \frac{c_0 + c_6 + c_8}{F} \]
where \( c_0 \) = cost of paint per gallon, including any premixed beads,
\( c_6 \) = cost of drop-on beads per gallon of paint,
\( c_8 \) = cost of application of paint per gallon including all labor, administrative, equipment, traffic control costs, etc.,
\( F \) = rate of application in feet of 4-inch line per gallon of paint.

Note No. 2: For drop-on paints, with bead application rates of six pounds per gallon, \( F \) should be 1.2 times the actual binder application rate. For combination types in which three pounds of beads are dropped on each gallon of paint, \( F \) should be 1.1 times the actual binder application rate. The adjustments are necessary to insure equal application rates when using the formula to compare premix type paints with combination and drop-on type paints.

Note No. 3: For stripping powders, the cost of powder installed (M) is determined by the formula:
\[ M = \frac{C_p + C_s}{F} \]

When comparing paints with thermoplastics in the same test, the paint line should be repainted each time their rating (W) reaches 0.4. The formula for paint samples thus repainted should be modified like this:
material is to be inspected at the factory or at the destination. Any material not meeting the specifications shall be replaced with satisfactory material and all handling and transportation charges for such replacement shall be paid by the vendor.

7. ACCEPTANCE AND REJECTION

Materials furnished under the contract shall be identical with the sample submitted for performance tests or within the tolerances allowed and shall comply with the requirements herein set forth. In the event that the material does not comply with this specification or is not identical with the sample submitted or within the tolerances allowed, the vendor will be required to replace all such material at his own expense, including all handling and transportation charges, with materials that do so comply.

Tolerances permitted between the material delivered and the original sample submitted for service tests are:

A. Paints and Powders

1. Weight. Weight per unit quantity of material purchased shall not be less than that specified on the container.

2. Viscosity. While the viscosity of the original test sample of paint may be anywhere within the range stipulated in this specification, the viscosity of all paint purchased on the basis of the performance test for regular use by the (city or state) shall be within plus or minus (5) Krebs Units of that of the original test sample throughout the production of the entire order, with the further requirement that such range in viscosity be entirely within the limits specified in Chapter II.

3. Color. Slight differences in color between material delivered and the original samples will be permitted provided that the change does not detract from the appearance of the material.

4. Vehicle. The percent of nonvolatile paint in the vehicle of the material delivered shall not vary more than (2) percent from the percent of nonvolatile in the original sample submitted.

5. Pigment. The weight of the pigment in the material delivered shall not vary more than (2) percent from the weight of the pigment in the original sample. The purchaser reserves the right to make spectrophotometric analyses to determine if the pigment in the delivered material is comparable to that of the original sample.

6. Drying Time. The drying time of the material delivered shall not be more than the limits specified in Chapter II.

7. Plastic Solids. The percent of free-flowing pigmented plastic solids of the powder delivered shall not be more than 70 percent or less than 65 percent of the combined weight of plastic solids and glass spheres.

B. Glass Spheres

1. The amount of spheres per gallon of premix or combination type paint shall not vary by more than plus or minus (10) percent from the amount contained in the service test sample.

2. The crushing resistance of the glass spheres shall not vary by more than plus or minus (10) percent from the crushing resistance of the service test samples.

3. Roundness and imperfections of the glass spheres shall not vary by more than minus (10) percent from the values obtained for the service test samples.

4. Index of refraction of the glass spheres shall not be less than that of the service test samples.

5. Gradation of the spheres of any sieve size shall not vary by more than plus or minus (10) percent from the gradation of the service test sample. Regardless of these tolerances, all aspects of all materials delivered shall fall within the ranges specified in Chapter II.
This report was approved as an Equipment Standard of the Institute of Transportation Engineers in July 1992. It supersedes the Proposed Standard dated December 1990.

This equipment standard was developed in accordance with formally adopted Institute procedures which are designed to help assure that all interested parties are given opportunities to provide input. All input received has been considered such that the report would represent the best consensus obtainable on the state of the art at the time of approval.

Any requests for revision must be submitted to the Director of Technical Programs; Institute of Transportation Engineers; 525 School St., S.W., Suite 410; Washington, D.C. 20024.

The Technical Council Committee 7S-2A was responsible for the development of this standard. Members of ITE Technical Council Committee 7S-2A were: Douglas E. Hefly (M) (Chairperson), Jose E. Goncalves, P.E. (A), Randall A. Kier, and Martin A. Smith.

Members of the Department 7 Standing Committee at the time of approval of this report were: R. Marshall Elizer, P.E. (F) (Chairperson); T. Darcy Sullivan, P.E. (F) (Assist. Chairperson); James L. Pline, P.E. (F); Herman E. Haenel, P.E. (F); and George L. Buter, P.E. (F). Eugene M. Wilson, P.E. (F) was the Chairperson of Technical Council, and Brian S. Bochner, P.E. (F) was the Assistant Chairperson.

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1.0. Scope

1.1. This specification covers a retroreflective pavement marking material of the type that is applied to the road surface in a molten state by ________________ (select one or more of the following application methods: "screed/extrusion, suspended extrusion or spray") means with a surface application of glass beads at a rate specified by the purchaser. Upon cooling to normal pavement temperature, it produces a retroreflective marking of specified thickness and width capable of resisting deformation by traffic.

2.0. Classification

2.1. The thermoplastic material shall be homogeneously composed of pigment, filler, resins and glass beads.

2.1.1. The thermoplastic material shall be available in white, yellow and black colors.

3.0. Materials

3.1. The vendor shall have the option of formulating the material according to their own specifications; however, the solid resin shall be [insert here either/or the following words in quotes] "a synthetic hydrocarbon" or "maleic-modified glycerol ester resin" (alkyd binder)]. The physical and chemical properties contained in this specification shall apply regardless of the type of formulation used. The material, upon heating to application temperature, shall not exude fumes which are toxic, or injurious to persons or property. The pigment, beads, and filler shall be well dispersed in the resin.

3.2. Glass Beads

3.2.1. Pre-Mix— The pre-mix beads shall be uncoated and conform to AASHTO M247-81 (1985) Type 1.

3.2.2. Drop-on— The drop-on beads shall be moisture resistant coated. A maximum of 5 percent shall pass the 80 percent screen; glass spheres shall have a minimum of 70
4.0. Requirements of the Thermoplastic Mixture

4.1. Specific Gravity—The specific gravity of the thermoplastic material shall not exceed 2.3.

4.2. Composition—The pigment, beads, and filler shall be uniformly dispersed in the resin. The material shall be free from all skins, dirt and foreign objects and shall comply with the requirements in Table 1.

4.3. Physical Characteristics

4.3.1. Color—The thermoplastic material after heating for 4 hours ± 5 min. at 425° ± 3°F (218° ± 2°C) under agitation shall meet the following luminosity and color requirements:

4.3.1.1. Luminosity

White—Daylight reflectance at 45 degrees, 0 degrees-75% minimum.

Yellow—Daylight reflectance at 45 degrees, 0 degrees-45% minimum.

4.3.1.2. Color

(a) For highway use, the colors shall match Federal Highway Administration yellow and white color specifications.

(b) For airport use, the color shall comply with the requirements established by the Federal Aviation Administration.

4.3.2. Set time—When applied at a temperature range of 412.5° ± 12.5°F (211° ± 7°C) and thickness of 60 mils to 185 mils (1.5mm to 4.7mm) the material shall set to bear traffic in not more than two minutes when the air and road surface temperature is approximately 50° ±3°F (10° ± 2°C) and not more than ten minutes when the air and road surface temperature is approximately 90° ± 3°F (32° ± 2°C).

4.3.3. Bond Strength—After heating the thermoplastic material for 4 hours ± 5 min. at 425°F (218°C), the bond strength to portland cement concrete shall exceed 180psi (1.24MPa), (Method—ASTM D4796-88).

4.3.4. Cracking Resistance at Low Temperature—After heating the thermoplastic material for 4 hours ± 5 min. at 425° ± 3°F (218° ± 2°C), applying to concrete blocks, and cooling 15° ± 3°F (9.4° ± 1.7°C), the material shall show no cracks when observed from a distance exceeding 12 inches (30cm).

4.3.5. Impact Resistance—After heating the thermoplastic material for 4 hours ± 5 min. at 425° ± 3°F (218° ± 2°C) and forming test specimens, the impact resistance shall be a minimum of 10 inch pounds (1.13J).

4.3.6. Softening Point—After heating the thermoplastic material for 4 hours ± 5 min. at 425° ± 3°F (218° ± 2°C) and testing in accordance with ASTM D36 the materials shall have a softening point of 215° ± 15°F (102.5° ± 9.5°C).

4.3.7. Flowability—After heating the thermoplastic material for 4 hours ± 5 min. at 425° ± 3°F (218° ± 2°C) and testing for flowability, the white thermoplastic shall have a maximum percent residue of 18 and the yellow thermoplastic shall have a maximum residue of 21 percent.

4.3.8. Yellowness Index—The white thermoplastic material shall not exceed a yellowness index of 0.15.

4.3.9. Flowability—Extended Heating—After heating and stirring the thermoplastic material for 8.5 hours at 425° ± 3°F (218° ± 2°C) and testing for flowability, the thermoplastic shall have a maximum residue of 28 percent.

4.3.10. Flash Point—The thermoplastic material shall have a flash point not less than 475°F (246°C) when tested in accordance with ASTM D92 “Flash and Fire Points by Cleveland Open Cup.”

4.4. Storage Life—The material shall meet the requirements of this specification for a period of 1 year. The thermoplastic must also melt uniformly with no evidence of skins or unmelted particles for this 1 year period. Any material not meeting the above requirements shall be replaced by the manufacturer.

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Table 1. Composition (Percentage By Weight)

<table>
<thead>
<tr>
<th>Component</th>
<th>White</th>
<th>Yellow</th>
<th>Black</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder, See Note (a)</td>
<td>18.0 min.</td>
<td>18.0 min.</td>
<td>18.0 min.</td>
</tr>
<tr>
<td>Glass Beads</td>
<td>30-40</td>
<td>30-40</td>
<td>0.0 max.</td>
</tr>
<tr>
<td>Titanium Dioxide</td>
<td>10.0 min.</td>
<td>–</td>
<td>0.0 max.</td>
</tr>
<tr>
<td>Calcium Carbonate &amp; Inert Fillers</td>
<td>42.0 max.</td>
<td>50.0 max.</td>
<td>82.0 max.</td>
</tr>
<tr>
<td>Yellow Pigment, See Note (c)</td>
<td>0.0 max.</td>
<td>2.0 min.</td>
<td>0.0 max.</td>
</tr>
<tr>
<td>Black Pigment</td>
<td>0.0 max.</td>
<td>0.0 max.</td>
<td>See Note (b)</td>
</tr>
</tbody>
</table>

Note (a): If alkyd, binder shall consist of a mixture of synthetic resins, at least one of which is solid at room temperature, and high boiling point plasticizers. At least one-third of the binder composition shall be solid maleic-modified glycerol ester resin and shall be not less than 8 percent by weight of the entire formulation. The alkyd binder shall not contain petroleum based hydrocarbon resins.

Note (b): Amount of black pigments, calcium carbonate and inert fillers shall be at the option of the manufacturer, providing all other requirements of this specification are met.

Note (c): The percentage of yellow pigment can be reduced if lead pigments are eliminated from the formulation.
4.5. Primer Sealer—Primer sealers for use on portland cement concrete or hot mix asphaltic concrete surfaces prior to application of the thermoplastic material shall be either recommended by the thermoplastic material manufacturer or especially compounded for use with the specified thermoplastic material.

5.0. Application Properties

5.1. The thermoplastic material shall readily apply to the pavement at temperatures of 400°-440°F (204°-226°C) from approved equipment to produce

6.0. Packaging and Markings

6.1. The thermoplastic material shall be packaged in suitable containers which will not adhere to the product during shipment and storage. The container of thermoplastic material shall weigh approximately 50 lbs (23kg). Each container shall designate the color, binder (alkyd or hydrocarbon), spray or extrude, user information, manufacturer name and address, batch number and date of manufacture. Each batch manufactured shall have its own separate number. The label shall warn the user that the material shall be heated in the range of 400°-440°F (204°-226°C).

6.2. The contractor shall assume all costs arising from the use of the patented materials, equipment, devices, or processes used on or incorporated in the work; agrees to indemnify and save harmless the purchaser and its duly authorized representatives from all legal suits or actions of every nature for, or on account of, the use of any patented materials, equipment, devices, or processes.

7.0. Methods of Sampling and Testing

7.1. The minimum batch size of thermoplastic marking material when tested shall not be less than 2000 lbs (907 kg) unless the total order is less than that amount. A small trial batch should be made prior to making the thermoplastic marking material in large quantities to make certain the finished product will comply with all the requirements of this specification.

7.2. The material shall be tested in accordance with AASHTO M249-79 (1986) and T250 with the appropriate method in Federal Test Method Standard No. 141 or ASTM designation.

8.0. Thermoplastic Performance and Application Characteristics

8.1. All thermoplastic material shall not deteriorate by contact with sodium chloride, calcium chloride or other chemicals used to prevent roadway ice. If the thermoplastic has an alkyd binder, it shall also not deteriorate because of the oil content of pavement materials or from oil droppings or other effects of traffic.

8.2. Application—The material shall be applied to the pavement by

8.3. Equipment—The equipment used to install the applied thermoplastic material by contract under this specification shall be constructed to provide continuous uniform heating to temperatures exceeding 400°F (204°C), mixing and agitation of the material. Conveying parts of the equipment between the main material reservoir and the line dispensing device shall prevent accumulation and clogging. All parts of the equipment which come in contact with the material shall be constructed for easy accessibility and exposure for cleaning and maintenance. The equipment shall operate so that all mixing and conveying parts, including the line dispensing device, maintains the material at the plastic temperature. The use of pans, aprons, or similar appliances which the dispenser overruns will not be permitted under this specification. The equipment shall provide
for varying traffic marking application widths.

8.3.1. The application equipment shall be mobile and maneuverable to the extent that straight markings can be followed and normal curves can be made in a true arc.

8.3.2. Glass spheres applied to the surface of the completed marking shall be applied by an automatic bead dispenser attached to the marking machine so that the beads are dispensed closely behind the installed marking. The glass sphere dispenser shall be equipped with an automatic cut-off control synchronized with the cut-off of the thermoplastic material.

8.3.3. A special kettle shall be provided for uniformly melting and heating the thermoplastic material. The kettle must be equipped with an automatic thermostat control device and material thermometer for positive temperature control and to prevent overheating or underheating of the material. The heating kettle and application equipment shall meet the requirements of the National Fire Underwriters and the National Fire Protection Association of the state and local authorities.

8.4. Installation Techniques—The finished markings shall have well defined edges. The contractor (if installation is made by contractor) shall clean off pavement surface dirt, grease, and concrete curing compounds where necessary by standard acceptable practices within the industry.

8.4.1. A primer sealer of the type recommended by the manufacturer of the thermoplastic material shall be applied on all portland concrete pavement surfaces, and if recommended by the manufacturer, on other types of pavement surface, prior to the installation of the thermoplastic material. The primer shall be void of solvent and water prior to the thermoplastic application.

8.4.2. To insure optimum adhesion, the thermoplastic material shall be installed in a melted state at a temperature from 400°F to 440°F (204°C - 226°C). Adhesion of thermoplastic to hot melt asphaltic-concrete pavements shall be frequently verified by cutting and lifting approximately a 6 inch (15 cm) thermoplastic stripe section which should reveal a layer of asphalt clinging to the removed thermoplastic stripe.

8.4.3. Longitudinal markings shall be offset at least 2 inches (5cm) from construction joints of portland cement concrete pavements and joints or shoulder breaks of bluminous concrete pavements.

8.4.4. Thermoplastic pavement marking materials shall not be applied by the sprayed/extrusion method when air and pavement surface temperatures are below 50°F (10°C), by the suspended extrusion method or by the spray method when air and pavement surface temperatures are below 55°F (13°C), or when the surface of the pavement contains any evidence of moisture.

Moisture tests shall be made using aluminum foil, roofing paper, litmus, or clear plastic prior to application of the thermoplastic material.

It is suggested that openings of 6 inch (15 cm) lengths be provided at 20 foot (6 m) intervals on edge lines placed on the inside of super-elevated curves to prevent the possible ponding of water on the pavement surface.

8.5. Warranty (Contract applications only)—The thermoplastic pavement marking material furnished and installed by contract under this specification shall be guaranteed by the contractor against failure due to poor adhesion resulting from defective materials or methods of application.

Warranties may vary depending upon the applied line thickness, the positioning of the line, the traffic density, the use of studded snow tires, and the frequency of snowplow operations.

The following warranties are typical for application thicknesses of 0.125 in (3.175 mm) for crosswalks and stop lines and 0.90 in (2.286 mm) for lane lines, center lines and edge lines. Warranties for thinner lines in these applications or for higher traffic volumes may be reduced commensurately.

8.5.1. For non-defective pavement surfaces carrying volumes less than 50,000 vehicles per day, the contractor shall guarantee to replace or renew without cost to the (city or state) that part of the pavement markings installed which have not remained to perform useful service as follows:

(a) Crosswalks, stop lines, and legends—75 percent of the total of any 1 intersection for 1 year.

(b) Lane lines, edge lines, and center lines—90 percent of a unit for 1 year, 80 percent of a unit for 2 years and 60 percent of a unit for 3 years. (A "unit" is defined as any length of highway having installed thereon 2,000 linear feet (610 m) of line of specified width in any combination or pattern.)

8.5.2. The replacement material installed under this guarantee shall be guaranteed the same as the original material, from the date of the original installation.

8.6. Thickness Measurement—Shall be accomplished by placing black tapes, film or metal plates of known and uniform thickness in the area to be marked. Once the marker has passed, the sample shall be removed by making sharp cuts with a knife. Measurements of the marking plus film shall be made with a micrometer or vernier calipers with a proper correction for the film base. For longitudinal markings, these thickness checks shall be made every one-third mile (536 m), at the judgement of the project engineer. For symbols and intersection markings, the frequency of checking shall be at the option of the project engineer. These thicknesses shall be considered as the average of 2 or more measurements made in a three-foot distance.

The intent is not to extend the original warranty period.
The warranty does not cover those markings that have been removed by such devices as snow-plows chains or studded tires.

8.7. Observation Period— (used by several states that prohibit extended warranties, particularly on Federal-aid projects.) Prior to consideration of final acceptance of all work completed as required herein and shown in the pavement marking plans, there shall be a ____________ (select either 90 day or 180 day) observation period beginning upon the satisfactory completion of all work required by the intermediate completion date included elsewhere in this proposal form.

8.7.1. During the ____________ (select either 90-day or 180-day) observation period the thermoplastic pavement marking material furnished and installed under this contract shall be warranted against failure due to blistering, excessive cracking, bleeding, staining, discoloration, smearing or spreading under heat or gasoline drippings, chipping, spalling, poor adhesion to the pavement materials, loss of retroreflection, vehicular damage, and wear, and if thermoplastic has an alkyd binder, deterioration due to oil content of the pavement materials, contact with grease deposits, oil, or diesel fuel.

8.7.2. The Contractor, at no expense to the Department of Transportation, shall replace any pavement markings that will not perform satisfactory under traffic during the ____________ (select either 90-day or 180-day) observation period due to defective materials and/or application methods. (Failure to comply with any portion of this specification shall be considered as unsatisfactory performance of the thermoplastic pavement marking material.)

8.7.3. Marking replacement shall be performed in accordance with the requirements specified herein for the initial application, including but not limited to surface cleaning, pavement marking removal, seasonal and weather limitations, etc.

8.7.4. Traffic shall be operating on the facility during the ____________ (select either 90 day or 180-day) observation period. Delayed acceptance of up to 180 days has been approved on Federal-aid projects by the Federal Highway Administration pursuant to an October 25, 1977 letter by H. A. Lindberg Number 64847:10/13/771.
A Model Performance Specification for the Purchase of Preformed Plastic Pavement Marking Materials


Comments are being sought on this report to assist in the consideration for adoption as an Equipment Standard of the Institute. Comments should be submitted by December 1, 1993. Comments, questions, and any requests for a public hearing should be directed to the Director of Technical Programs at ITE Headquarters.

Any comments and suggested revisions received will be considered and addressed by the committee before forwarding the report to the ITE Standards Approval Board for a final decision on adoption as an Equipment Standard of the Institute.

The Technical Council Committee 75-2B was responsible for the development of this proposed equipment standard.

Members of ITE Technical Council Committee 75-2B were: Norman K. Kollet (F); James M. Lee, P.E. (F); John G. Rothrock (F); David W. Oplet; and Robert Austin.

Members of the Department 7 Standing Committee at the time of approval of this report were: R. Marshall Elizer, P.E. (F) (chairperson); T. Darcy Sullivan, P.E. (F) (asst. chairperson); James L. Pline, P.E. (F); Herman E. Haenel, P.E. (F); and George L. Butzer, P.E. (F). Eugene M. Wilson, P.E. (F) was the Chairperson of Technical Council, and Brian S. Roche, P.E. (F) was the Assistant Chairperson.

Certain individual volunteer members of the Institute Equipment Standards developing bodies are employed by Federal agencies, other governmental offices, private enterprise, or other organizations. Their participation in these activities does not constitute endorsement by any government agency or other organization of any of the Institute Equipment Standards developing bodies or any institute reports which are developed by such bodies.

1.0 General

1.1 Intent of Specification. It is the intent of this specification to describe the general and specific requirements for reflective pavement markings (cold preformed, excluding epoxy materials) to be used by the (jurisdiction)1 in its pavement marking program as well as to provide for the submission of samples and to describe the laboratory and service test procedure which will be used to rate the materials submitted for test. It is intended that samples will be received under this specification from any individual, company, or corporation desirous of furnishing traffic marking materials to the (jurisdiction), that such samples will be subjected to appropriate laboratory and field service tests, and that the (jurisdiction) will request competitive bids for the (jurisdiction's) requirements on such materials as prove necessary. Depending upon the materials tested, it is expected that the field service test will require from six months to three years for completion.

1.2 Types of Material. This specification covers those reflective pavement marking materials whose description and physical properties are in Chapter II of this specification. The procedures in Chapter III of this specification may be used to test any pavement marking material against other similar materials and to test any type of material against a completely different type.

1.3 Method of Testing. The methods of sampling and testing all materials and products covered by this specification shall be in accordance with the latest standards of ASTM, the federal government or of other recognized standardizing agencies as indicated for each material.

Note 1: The name of the city or state, or the name of the commission, department, or other purchasing authority should be inserted at all points as shown as (jurisdiction). Elsewhere throughout this model specification values in parentheses and italicized, as (40), are suggested values, and other values appropriate to the specific needs or requirements of the particular purchasing authority may be substituted. (This model specification is a performance specification. It should be recognized that pavement marking materials can also be purchased on the basis of general specifications.)
2.0 Properties, Application and Packing of Materials

2.1 Preformed Plastics

2.1.1 Type of Material. This section covers reflectorized plastic materials preformed into rolls or ribbons of various lengths, pliability, and widths suitable for use as reflecting pavement markings on Portland cement concrete or bituminous pavement.

2.1.2 General Characteristics. The preformed marking materials shall consist of white or yellow films with pigments selected and blended to provide the appropriate highway colors for traffic markings. Glass or ceramic beads shall be incorporated to provide immediate and continuing retroreflection. The size, quality, and refractive index of the beads shall be such that the performance requirements of this specification shall be met.

The edges of the preformed material shall be clean cut and true. The preformed plastic material may be supplied complete with a pre-coated, factory applied adhesive for immediate pavement application without the use of heat, solvent, or other types of adhesive operations or it may be furnished with separate adhesives as recommended by the manufacturer.

The affixed material shall be capable of molding itself to the pavement contours by the action of traffic and maintain its original dimensions and placement under normal traffic conditions at the pavement temperatures which could occur within the State. After application, the markings shall be immediately ready for traffic.

2.1.3 Physical Requirements

2.1.3.1. Color. Pigments shall be selected and blended to conform to standard highway colors throughout the expected life of the material. When tested by Federal Test Method Standard 141 Method 4252, the white shall be no darker than Color Number 37778 of Federal Standard Number 595 and the yellow shall conform to Color Number 33538 of Federal Standard Number 595 (Highway Yellow Color PR#1).

2.1.3.2. Retroreflectivity. The retroreflective preformed film shall have a layer of reflective spheres bonded to the top surface. The white and yellow film shall have the following initial minimum retroreflectance values at 0.2° and 0.5° observation angles and 86° entrance angle as measured in accordance with the photometric testing procedures of ASTM-D4061.

Retroreflectance values shall be expressed as specific luminance in milliandreas per square meter per lux.

<table>
<thead>
<tr>
<th>Observation Angle</th>
<th>White</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2° 0.5°</td>
<td>550</td>
<td>380</td>
</tr>
<tr>
<td>0.2° 0.5°</td>
<td>410</td>
<td>250</td>
</tr>
</tbody>
</table>

SL [(mcd-ft-2-ft-1) 550 380 410 250]

The test distance shall be 50 feet and the sample size a 2.0 x 2.5 foot rectangle. The angular aperture of both the photoreceptor and light projector shall be 10 minutes of arc. The reference center of the sample and the reference axis shall be taken perpendicular to the test sample.

2.1.3.3. Bead Retention. When tested with a 2 inch by 6 inch sample bent over a 1/2 inch diameter mandrel with the 2 inch dimension perpendicular to the mandrel axis, microscopic examination of the area on the mandrel shall show no more than 10 percent of the beads are entrapped in the binder less than 40 percent of the surface of the bead.

2.1.3.4. Skid Resistance. The surface of the preformed marking shall provide an initial minimum skid resistance value of 45 BPN when tested according to ASTM E-303-74.

2.1.3.5. Patchability. The material shall be capable of fusing into worn areas of previously applied material of the same type and composition of film following manufacturer's recommended patching procedures.

2.1.4. Application. The preformed plastic material shall be capable of application to non-defective pavement surfaces that are dry and free from dirt or other foreign matter. For normal application, the pavement temperature should be at least 60° F and rising.

Special instructions should be supplied by the vendor for application to be made at pavement temperatures below 60° F. Application shall be according to manufacturer's recommended procedures. Plastic pavement marking materials shall only be applied to surfaces with temperatures within the range specified by the manufacturer for optimum adhesion.

Adhesive, activators or special coatings for various types of pavement surfaces shall be provided with the preformed plastic material. Detailed information must be supplied with the material outlining required application procedures for such adhesives, activators or special coating.

Preformed plastics shall be capable of being applied to new asphaltic pavement immediately prior to the final rolling of the new surface and of being rolled into place with conventional pavement and highway rollers. The plastic material and adhesives used in such applications shall be of the type that water used on the roller to prevent asphalt pickup shall not be harmful to the successful application of the plastic.

Note 2: There are products designed specifically for various uses. That is, for urban or rural long line applications, intersection applications, etc. These products may have different reflectivity levels which may be higher than the table minimums.
Special equipment necessary for the successful installation of any preformed plastic material shall be available from the manufacturer of the plastic material on a lease, loan or purchase basis.

Longitudinal lines shall be offset at least 2 inches from construction joints of Portland cement concrete pavement. When directed by the engineer, openings of 6 inch lengths shall be left at 20 foot intervals in edge lines not inlaid into the pavement surface that are placed on the inside of super elevated curves so as to prevent the ponding of water on the pavement surface.

2.1.5. Packaging. The preformed plastic material shall be supplied in rolls or strips of specified lengths and widths. Material for symbols and word messages may be pre-cut to other widths and lengths for convenience of application.

Each package shall be clearly and adequately marked to indicate the color of the material, specific symbol or word message, the process batch number or other similar manufacturer's identification, the manufacturer's name, address of the plant and the date of manufacture.

3.0 Road Service Tests

3.1 Intent of Specification. It is the intent of this portion of the specification to describe a procedure to be followed by manufacturers and others in submitting samples for this test, and the procedure which will be followed by the (jurisdiction) in testing the pavement marking materials submitted to determine the most economical material for the (jurisdiction) to purchase. Only materials submitted for performance tests under the specification and thereby found to be acceptable will be considered when bids are taken. It is therefore the responsibility of the manufacturer to submit for test samples of all types and colors of materials on which he later may wish to submit bids.

3.2 Samples Required

3.2.1. An invitation to submit samples may be issued several months or, for relatively long life materials, one year in advance of the invitation to submit bids in order to permit evaluation of the service test results. All samples shall be properly identified with the manufacturer's code number, which shall be different for each type and color submitted. The manufacturer's name, address, type of material and code number for each sample shall be submitted separately.

3.2.2 Each sample shall consist of the following amounts of each material which the manufacturer proposes to furnish (for cold (preformed) thermoplastics):
   a. Three (3) 1 foot by 4 inch sections of each color (for laboratory tests).
   b. One (1) quart can of primer or adhesive if the use of such surface preparation material is recommended by the manufacturer.
   c. Ample quantities of 4 inch wide materials (±50 yards) (and primer or adhesive material, if required) for road service test applications, as described in Section C.

3.2.3 On each invitation to submit samples, each manufacturer may submit not more than three (3) samples of each color material to be purchased (unless otherwise called for in the specifications).

3.3. Certifications Required

3.3.1. Certificate of Compliance. The manufacturer shall submit for each sample a Certificate of Compliance on the form provided certifying that the sample meets all of the requirements in this specification.

3.3.2. Statement of Characteristics. The manufacturer shall submit with each sample a Statement of Characteristics on the form provided giving all of the information requested except that which is proprietary. This statement shall be for the confidential use of the (jurisdiction), and the information therein will not be revealed by the (jurisdiction), but will serve and assist in identifying and testing materials furnished.

3.3.3. Submission of Samples and Certification. Samples, certificates of compliance, and statements of characteristics shall be sent prepaid to the (jurisdiction). Unless the samples and corresponding certificates and statement of characteristics are received by the hour and date fixed in the inquiry for such samples, the (jurisdiction) shall not be obligated to include the samples in the test nor to consider them for purchase.\  

3.4. Service Tests

3.4.1. Application. The test stripes shall be 4 inches in width and applied transversely across the lanes of the road. The application will be made by selected personnel under the supervision of the (jurisdiction). The selection of test sites and all aspects of the test line applications shall be in accordance with ASTM designation D-713. The material shall be applied to four sections of highway, two of which have a concrete surface and the other two a bituminous surface. The

Note: Due to the time required for the preparation of samples by manufacturers, the inquiry shall allow 45 to 60 days for the submission of samples.
section selected shall be areas where traffic is heavy and where it is uniform with full exposure to sun throughout the daylight hours. The test area shall be laid out where traffic is free rolling, and no grades, curves, intersections or access points near enough to cause excessive braking or turning movements.

At least three lines of each sample shall be applied at each section of highway in order that differences due to position and time of day when placed will be compensated for, insofar as it is practical to do so.  

All samples received for tests will immediately be given a code identification number which shall be recorded and filed with the manufacturer's code number and certifications. All identification other than the code identification number shall be removed from the sample containers and the code number shall be used for identification of the material for all succeeding operations of testing, application and field rating of the material.

3.4.2. Evaluation. The uniformity of application, covering properties and drying time will be determined at the time materials are applied on the road, and the comparative results obtained on these properties of the various materials will be taken into consideration in the final evaluation.

Periodic inspections will be made of the test sections in accordance with ASTM designations D-713, D-821, D-913, and D-1011. Records will be made at each inspection of general daytime appearance (including color), film condition and reflectivity. It is desirable to carry on the inspections for a period of one year or more depending on the types of materials under test, or until all of the transverse test lines are more than 50 percent worn off in the wheel tracks.

Representatives on the inspection team may be varied as desired; however, it is suggested that the traffic, materials and purchasing bureaus or departments be represented on the inspection team.

Evaluation of service will be based on appearance, durability and night visibility as defined below. The test lines will be rated numerically from very poor to perfect, on a scale from 0 to 10, with 10 indicating perfect conditions and 0 a complete failure.

3.4.3. Definitions. The following definitions shall be applied in evaluating the test lines and in computing the economic aspects of the various lines and materials.

3.4.3.1. Appearance. This is the complete impression conveyed when the marking is viewed at distance of at least 10 feet before any detailed inspection has been made, and is estimated purely in terms of satisfactory or unsatisfactory appeal to the observer. It also includes a comparison of color of the material under consideration with the original color, taking into account changes due to yellowing, darkening, fading, dirt collection, mold growth, etc. The determination is to be made without preliminary washing or other modification of the surface of the test line.

3.4.3.2. Durability. The factor used in rating film failure is equal to 1/10 of the percentage of material remaining on the pavement when examined closely by the unaided eye, this determination to be made in each wheel track in an area extending 9 inches each side of the point of greatest wear. Percentage of material remaining on the pavement will be considered as the percentage of the prescribed area of test stripe in which the substrate is not exposed.

3.4.3.3. Night Visibility. Night visibility designates the apparent brightness when examined at night under tungsten illumination from the side of the road, with eye and light source separated by distance which corresponds to a divergence or viewing angle of approximately 1/3° (one-third degree). The rating is based on a factor of 10 for the highest reading and 0 for complete failure. Night visibility determinations will be made on the same areas as those used for rating durability.

3.4.3.4. Service Factor (R). In evaluating each sample at the end of the test (or at any time prior thereto), a service factor (R) will be determined for each quality (Ra of appearance, Rd for durability, and Rn for night visibility) on the basis of the following formula in which each value of 'r' is the average of the ratings for the specific quality by all three observers for all four test sections) at the time (t) in days between successive evaluations. The time (t) at which the rating of a marking goes below (four), which is rx at the time of any inspection, will be determined by interpolation.

\[
R = \frac{r_{11} + r_{22} + r_{33} + \ldots + r_{xx}}{1 + 2 + 3 + \ldots + tx}
\]

3.4.3.4. Weighted Rating (W). The three qualities of appearance, durability and night visibility are added together, the results are multiplied by 100, and the result is divided by the number of tests, or average rating for the three qualities. The weighted rating is the sum of durability and night visibility and must be greater than 70 for the marking to be considered acceptable.

Note 5: Use of portable reflectometers is also encouraged to obtain quantitative data for comparing reflectivity levels.

Note 6: When it is desired to determine the service factor, etc., separately for concrete and bituminous surfaces, a separate set of calculations will have to be made for the ratings of the materials on the two pavement surfaces.
durability, and night visibility are not considered of equal importance in rating a pavement marking material and will be weighted as follows:

- Appearance - 30 percent
- Durability - 30 percent
- Night Visibility - 40 percent

The weighted rating (W) of a material will, therefore, be determined by the formula:

\[ W = 0.30 \text{Ra} + 0.30 \text{Rd} + 0.40 \text{Rn} \]

in which Ra, Rd, and Rn are the service factors for appearance, durability, and night visibility.

Note: The weighted ratings indicated above are suggestive only. The purchaser may add additional qualities or assign other values to increase or decrease the importance of each quality as desired.

For example, if the pavement marking is to be applied to a well illuminated city street, the weight for night visibility could be reduced and the weight of either appearance or durability increased. The three rates must, however, total 100 percent.

3.4.4 Final Evaluation. After the test lines have been in service for two (2) years, or whenever all materials are rated below four (4) in one or more of the service factors, a final evaluation will be made and the weighted rating for each material will be determined. The average of the figures of performance for all four test sections arrived at by all three observers of the committee will be used to determine the final figure of each performance or weighted rating for each material sample.

3.4.5. Length of Useful Life (L). The length of useful life of each sample is the product of the length of the test period and the comparable rating of the line with a perfect line and with one that has reached the end of its useful life (a rating of 4). The length of useful life is determined by the formula:

\[ L = \frac{D \times (10 - E)}{10 - W} \]

where
- D = days of the period of test,
- E = weighted rating of a line at the end of its useful life (4), and
- W = weighted rating at the end of the test period.

3.4.6. Bids. All vendors whose samples receive a satisfactory rating will be given an invitation to bid. Each bidder will be required to file an affidavit that the material which they propose to furnish will be identical to that of the sample submitted for performance tests or within the tolerances allowed. Materials will be evaluated by ranking them in ascending order on the basis of (C), the cost (in dollars) per foot per day of useful life, determined by (M), the cost in dollars per foot of materials installed and (L), the length of useful life of the material. The formula for this purpose is as follows:

\[ C = \frac{M \times A}{L_1} \]

where M = the average cost for each application, computed as shown above for each application,
A = the number of applications, and
L_1 = the total length of useful life of the several applications.

3.4.7. Sampling and Testing

3.4.7.1. Materials purchased under this specification will be sampled and tested by the jurisdiction using the indicated standards and methods to determine conformance with specification requirements and to equipment, traffic control costs, etc.

F = the rate of application in feet of 4 inch line or square feet of material.

The procedure outlined above can be used with the following modifications for the comparative testing of various thermoplastic pavement marking materials.

1. Tests involving preformed plastic materials should be confined to roads having average daily traffic (ADT) of 25,000 or more, and the test area pavement should be stable and required no surface treatment for at least three years. These restrictions are necessary because thermo-plastic materials are comparatively long life materials and may require a testing period as long as two to three years, depending upon the traffic volumes involved.

2. When comparing the paints with preformed plastics in the same test, the paint line should be repainted each time their rating (W) reaches 0.4. The formula for paint samples thus repainted should be modified as follows:

\[ C = \frac{M \times A}{L} \]

Note 7: The two year shown can be decreased if results must be obtained at an earlier date, but it is desirable to subject the test lines to both summer and winter wear and deterioration.
establish identity with the sample originally submitted for performance tests. An adequate size sample of preformed plastic material shall be extracted at random from each production batch.\textsuperscript{8}

3.4.7.2. The (jurisdiction) reserves the right to inspect and accept the material either at the destination or at the point of manufacture. In either case, the manufacturer shall furnish whatever samples and formulas required to ascertain that the finished material complies with specifications. If factory inspection is required, the inspector shall be afforded all necessary facilities to make the inspection, including shipment of samples to the (jurisdiction). At the time when contracts are awarded, it will be decided, unless otherwise indicated when invitations to bid are extended, whether the material is to be inspected at the factory or at the destination. Any material not meeting the specifications shall be replaced with satisfactory material, and all handling and transportation charges for such replacement shall be paid by the vendor.

3.4.8. Acceptance and Rejection. Materials furnished under the contract shall be identical with the sample submitted for performance tests or within the tolerances allowed and shall comply with the requirements herein set forth. In the event that the material does not comply with this specification or is not identical with the sample submitted or within the tolerances allowed, the vendor will be required to replace all such material at this own expense, including all handling and transportation charges, with materials that do so comply.

\textsuperscript{8} Tolerances permitted between the material delivered and the original sample submitted for service tests for preformed plastic are as follows:

a) Slight differences in color between the plastic delivered and the original sample will be permitted provided that the change does not detract from the appearance of the thermoplastic.

b) The weight of the pigment in the plastic delivered shall not vary more than (2) percent from the weight of the pigment in the original sample.

Note 8: If it is considered desirable to specify the minimum size of the product batch, this amount should be indicated by the jurisdiction.
traffic controls for street & highway construction, maintenance, utility, & emergency operations

chapters 13-14
Purchase Specification for Flashing and Steady Burn Warning Lights

1.0 Purpose

The purpose of this purchase specification is to provide minimum requirements for newly purchased light-emitting warning lights used for warning purposes in roadway work zones.

2.0 Types of Light-Emitting Devices for Work Zones

Types of devices include any devices that emit light, either in a flashing or steady burn mode, using any power source (electrical, solar, etc.). These lights include, among others, incandescent lamps, light emitting diodes (LED), neon, and halogen lamps. Types of warning lights are categorized as:

Type A: low intensity flashing warning lights  
Type B: high intensity flashing warning lights  
Type C: steady burn warning lights  
Type D: 360-degree steady burn warning lights

3.0 General Requirements

3.1. The warning lights shall be internally illuminated by means of a light source behind a lens and, for type A and C devices, shall be externally illuminated by retro-reflective elements built into the lens to enable warning lights to be seen by retro-reflection of the light from the headlights of oncoming vehicles.

3.1.1. The type B device may have a retro-reflective ring of prismatic tape or built in elements that meet the requirements of 10.1.

3.2. When the device is to be operated by battery, the battery must be entirely enclosed in a weatherproof case that is constructed of steel or any other material such as high-impact plastics suitable for use along roadway work zones. The case shall be secured by a locking device.

3.3. When the device is to be operated by a 120-volt, 60Hz power supply, the unit shall be supplied with a separate ground wire and shall be protected with suitable fuses. At no time shall the effective intensity of the light have a value greater than 500 candelas. The connections and equipment used shall be in accordance with the pertinent current standards of the Institute of Electrical and Electronics Engineers, the American Society for Testing Materials, and the National Board of Fire Underwriters. In those areas where there are pertinent local ordinances and requirements, the wiring, material, and installation procedures shall comply with the local requirements.

3.4. When the device is to be operated by battery, the battery may be replaceable or rechargeable using, for example, solar collectors or an ac power source.
4.0 Flash Requirements

4.1. Flash Rate. The light from Type A and Type B devices shall have a flash rate of 65±10 flashes per minute for temperatures between -29°C to 66°C (-20°F to +150°F) regardless of the power source.

4.2. ON-time.

a. Definition. ON-time is defined as the period of the flash where instantaneous intensity is equal to or greater than the effective intensity as specified in Section 5.1.
b. Type A. The light shall have an ON-time of not less than 10 percent of the flash cycle.
c. Type B. The light shall have an ON-time of not less than 8 percent of the flash cycle.
d. Maximum allowable ON-time for either Type A or Type B lights shall be 50 percent.

5.0 Optical Requirements

5.1. Photometry

5.1.1. The light distribution for types A, B and C shall have a minimum lateral width of ±9° and a minimum vertical height of ±5° from the optical axis of the system. Within these confines, minimum candela requirements, as specified in Sections 5.1.1.1 through 5.1.1.3 below shall be met.

5.1.1.1. For Type A the effective luminous intensity shall not drop below 4.0 candelas within the area specified in section 5.1.1, during the first 336 hours of continuous flashing.

5.1.1.2. For Type B the effective luminous intensity shall not drop below 25 candelas within the area specified in section 5.1.1, during the first 168 hours of continuous flashing. During the hours of darkness, the effective intensity may be reduced by a maximum of 50 percent.

5.1.1.3. For Type C the luminous intensity shall not drop below 2.0 candelas within the area specified in section 5.1.1, during the first 168 hours of continuous burning.

5.1.2. The light distribution for Type D shall be 360 degrees in the horizontal plane with a minimum luminous intensity of 1 candela and shall be a minimum of ±5 degrees vertical from the horizontal plane with a minimum luminous intensity of 0.5 candelas. This performance shall be met throughout the first 168 hours of continuous burning. Type D steady burn warning lights shall be visible on a clear night from a distance of 3,000 feet.

5.3. Testing Procedure

5.3.1. The effective intensity of Type A and Type B lights shall be calculated using the "Guide for Calculating the Effective Intensity of Flashing Signal Lights," published in the November 1964 edition of Illuminating Engineering magazine, by the Illuminating Engineering Society of North America, or latest revision.

5.3.2. The intensity of the Type C and Type D lights shall be tested as set forth in the current edition of SAE Standard J575 (Society of Automotive Engineers, Inc., Lighting Equipment and Photometric Tests).

5.3.3. (Reserved for future use)

5.3.4. Retro-reflection shall be tested in accordance with the current edition of SAE Standard J594.

5.3.5. Warning devices furnished under this specification shall be tested in accordance with the current edition of ATSSA Test Procedure T-101 (American Traffic Safety Services Association).

5.3.6. If the device uses a solar collector, the collector shall be disabled by either covering the collector or disconnecting it for the entire test period.

6.0 Lens Requirements

The following section applies to devices that use a lens.

6.1 Size of Lens

6.1.1. Type A, B, and C device lenses shall not be less than 177 mm (7 in) in diameter, including a retro-reflective ring of 12 mm (1/2 in) width around a minimum of 300° of the lens periphery.

6.1.2. A Type D device lens shall be 360 degrees circular in the horizontal plane, with a minimum outside diameter of 75 mm (3 in) and a minimum height of 75 mm (3 in), including mounting flanges.

6.2. Number of Lens

6.2.1. Type A and Type C device lenses shall be either bi-directional or unidirectional.

6.2.2. A Type B device lens shall be unidirectional.

6.2.3. A Type D device shall have a 360 degree dome lens.

6.3. Lens Chromaticity

6.3.1. The chromaticity of the lens colors and retro-reflective colors shall be tested using a light source with a color temperature ranging between 2600K and 2856K. The chromaticity of lenses and the emitted light from both yellow and red warning lights, and of both yellow and red retro-reflectors, shall conform to the chromaticity requirements of Section 8.04 and Figure 1 of the ITE Vehicle Traffic Control Signal Head standard. The wavelength spectral distribution of the light source
shall be within the range of 500 nm to 650 nm.

6.4–Retro-Reflective Performance
The specific intensity of the retro-reflector, when provided, shall meet the requirements as specified in Section 10.1.

6.5–Lens Material
The lens shall be of one-piece construction. The lens shall be manufactured using materials such as plastic capable of meeting the chromaticity requirements of this specification. The lens material shall meet the test requirements set forth in the most recent edition of SAE Standard J576 (Society of Automotive Engineers, Inc., Lighting Equipment and Photometric Test). For the purposes of this purchase specification, the exposure time and conditions of paragraph 3.4.3, SAE Standard J576, shall be for one year (365 calendar days).

7.0 Head and Housing

7.1–Swivel Head
If swivel capabilities as described in this Section are not incorporated in the device used to mount a Type A or Type C light to any channelizing device, barrier, or a sign, the head shall be mounted on the housing in a manner permitting it to be swiveled through a minimum 90° arc in a horizontal plane. If swiveling is to be accomplished by rotating the head, the design of the device head and its construction shall be such that rotating the head will not result in damaging any circuitry or wiring. If the lens assembly rotes around the light source, the photometrics shall meet the requirements of Section 10.0.

7.2–Housing

7.2.1. Definition. Housing is defined as the case containing the battery and may contain the circuitry.

7.2.2. Material. The housing, when constructed of steel, shall be constructed of No. 18 U.S. Standard Gauge Steel. The housing may be made of any other material such as high-impact plastics suitable for use along roadway work zones.

7.3–Painting
The housing and the lens frame, if constructed using corrodable metal, shall be properly cleaned, degreased and pretreated to promote adhesion. It shall be given one or more coats of enamel which, when dry, shall completely obscure the metal substrate. The enamel coating shall be of such quality that when the coated case is struck a light blow with a sharp tool, the paint shall not chip or crack, and if scratched with a knife shall not powder.

7.4–Weatherproofing
The case shall be so constructed and closed as to exclude moisture that would affect the specified operation of the light. The case shall have a weep hole to allow the escape of moisture.

8.0 Photoelectric Controls
Photoelectric controls, when provided, shall keep the device operating whenever the ambient light level falls below 215 lux.

9.0 Testing and Certification, Quality, and Marking

9.1–Testing and Certification of New Warning Lights

9.1.1. Warning lights furnished under this specification shall be statistically represented by units that have been tested and approved as to conformance to these purchase specifications by an independent accredited testing organization.

9.1.2. Certification as to conformance to these specifications shall be provided upon request and will be furnished by the manufacturer as substantiated by testing results from an independent accredited testing laboratory or organization.

9.1.3. Warning lights tested and approved as in Section 9.1.1 or 9.1.2 above shall be retested for compliance and recertification when required or when the supplier makes changes to any aspect of the light-emitting warning devices covered by this purchase specification, for example, whenever any changes are made in the lens, light source, or circuitry.

9.2–Quality
All electrical components, the quality of the materials used, and the workmanship of all warning lights furnished for use and certified as to the conformance to this purchase specification shall be the same as that of models approved under this purchase specification.

9.3–Marking
Each device shall be plainly marked as to type (A, B, C, or D), the manufacturer's or customer's name, model number or name, and label or marking stating it meets this purchase specification. The location of the label or marking may be internal or external to the housing, and may be placed on the outside of the circuit and/or lamp holder assembly.
10.0 Summary Information

<table>
<thead>
<tr>
<th></th>
<th>Type A</th>
<th></th>
<th>Type B</th>
<th></th>
<th>Type C</th>
<th></th>
<th>Type D</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Intensity</td>
<td></td>
<td>High Intensity</td>
<td></td>
<td>Steady Burn</td>
<td></td>
<td>Steady Burn</td>
<td></td>
</tr>
<tr>
<td>Lens Directional Faces</td>
<td>1 or 2</td>
<td></td>
<td>1</td>
<td></td>
<td>1 or 2</td>
<td></td>
<td>360°</td>
<td></td>
</tr>
<tr>
<td>Flash Rate Per Minute</td>
<td>55 to 75</td>
<td></td>
<td>55 to 75</td>
<td></td>
<td>N.A.</td>
<td></td>
<td>N.A.</td>
<td></td>
</tr>
<tr>
<td>Minimum On-Time</td>
<td>10%</td>
<td></td>
<td>8%</td>
<td></td>
<td>N.A.</td>
<td></td>
<td>N.A.</td>
<td></td>
</tr>
<tr>
<td>Minimum Effective Luminous Intensity*</td>
<td>4.0 candelas (Yellow)</td>
<td>35 candelas** (Yellow)</td>
<td>12 candelas** (Red)</td>
<td>N.A.</td>
<td>N.A.</td>
<td>2.0 candelas</td>
<td>1.0 to 0.5 candelas</td>
<td></td>
</tr>
<tr>
<td>Minimum Luminous Intensity*</td>
<td>N.A.</td>
<td></td>
<td>N.A.</td>
<td></td>
<td>2.0 candelas</td>
<td></td>
<td>dusk to dawn</td>
<td>dusk to dawn</td>
</tr>
<tr>
<td>Hours of Required Operation*</td>
<td>dusk to dawn</td>
<td></td>
<td>24 hours/day</td>
<td></td>
<td>dusk to dawn</td>
<td></td>
<td>dusk to dawn</td>
<td></td>
</tr>
</tbody>
</table>

*These values must be maintained within the areas as specified in, section 5.1.1 and 5.1.2.

**During the hours of darkness, the effective intensity may be reduced by a maximum of 50 percent.

10.1 Retro-Reflector Requirements

<table>
<thead>
<tr>
<th>Observation Angle</th>
<th>Entrance Angle</th>
<th>Yellow Luminous Intensity (candelas/lux)</th>
<th>Red Luminous Intensity (candelas/lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2°</td>
<td>20° Left</td>
<td>0.90</td>
<td>0.23</td>
</tr>
<tr>
<td>0.2°</td>
<td>10° Left</td>
<td>1.31</td>
<td>0.33</td>
</tr>
<tr>
<td>0.2°</td>
<td>0° (HV)</td>
<td>1.67</td>
<td>0.42</td>
</tr>
<tr>
<td>0.2°</td>
<td>10° Right</td>
<td>1.31</td>
<td>0.33</td>
</tr>
<tr>
<td>0.2°</td>
<td>20° Right</td>
<td>0.90</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Appendix


ASTM, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959, Ph: 610-832-9585. Committee #DO1, Subcommittee Name: Highway Traffic Control Materials.

ATSSA, 15 Riverside Parkway, Suite 100, Fredericksburg, VA 22406-1022, Ph: 540-368-1701.

ATSSA Test Method for Light-Emitting Warning Devices for Work Zones

Note: The ATSA (now ATSSA) Designation T-101 test method is being revised. The new test method will provide some guidance to testing laboratories. This test method is currently written around incandescent technology. The American Society for Testing and Materials (ASTM) will be revising this test method to include other light sources. ITE anticipates reprinting this purchase specification with the new test method when it is completed by ASTM.
Portable Bulb-Type Changeable Message Signs
for Highway Work Zones

This report was approved as an Equipment Standard on the Institute of transportation Engineers in August 1993. It supersedes the Proposed Equipment Standard dated April 1988.

This Equipment Standard was developed and approved in accordance with formally adopted Institute procedures which are designed to help assure that all interested parties are given opportunities to provide input. All input received has been considered in order that the report would represent the best consensus obtainable on the state-of-the-art at the time of approval.

Any requests for revisions must be submitted to the Director of Technical Programs, 525 School St., SW, Suite 410, Washington, D.C. 20024. Such requests shall contain a statement of concern, appropriate material to support the concern, and other relevant information.

This standard was developed by ITE Technical Council Committee 75-3 Work Zone Traffic Control Standards-Changeable Message Signs.

The committee's initial scope was to develop a performance standard for portable bulb-type changeable message signs. The committee is also in the process of developing a proposed standard for flip-disc changeable message signs. ITE supports other changeable message sign technologies and will develop standards for those as appropriate.

Members of Technical Committee 75-3 were: John J. Logan, P.E. (F) (chairperson); Peter M. Beaudry (M); James A. Bradon, P.E. (M); George A. Dale, P.E. (F); Dwight L. Fox, P.E. (F); Robert M. Garrett (M); Dennis L. Hansen, P.E. (F); Stephen P. Hart (IA); Steven D. Hofener, P.E. (F); Steven Z. Levine, P.E. (A); Russell M. Lewis, P.E. (M); Frank B. Lindh, P.E. (F); Gary C. Price, P.E. (F); Lewis R. Rhodes, P.E. (F); Dwight L. Stevens, P.E. (F); Robert J. Waldorf, P.E. (A); Kurt Weinrich, P.E. (F); and Robert Zimowski.

Members of the Department 7 Standing Committee at the time of approval of this report were: R. Marshall Elizer, P.E. (F) (chairperson); T. Darcy Sullivan, P.E. (F) (asst. chairperson); James L. Pline, P.E. (F); Herman E. Haenel, P.E. (F); and George L. Butzer, P.E. (F). Eugene M. Wilson, P.E. (F) was the Chairperson of Technical Council, and Brian S. Bochner, P.E. (F) was the Vice Chairperson.

Certain individual volunteer members of the Institute Equipment Standards developing bodies are employed by Federal agencies, other governmental offices, private enterprise, or other organizations. Their participation in these activities does not constitute endorsement by any government agency or other organization of any of the Institute Equipment Standards developing bodies or any institute reports which are developed by such bodies.
Introduction

The purpose of this standard is to provide a guide for the preparation of specifications for portable bulb-type changeable message signs. The units discussed in this report are to be used as part of the plan to control traffic through work zones. The standard represents the requirements for equipment described herein and is not intended to impose restrictions on:

1. Design and materials that conform to the purpose and the intent of this standard, or

2. Placement and operation of changeable message signs at the work zone location.

The intent of this standard is to describe portable one-line, two-line, and three-line bulb-type changeable message signs. Each unit shall be self-contained and consist of a message board, controller, power supply, electrical cable, and adjustable height structural support system. The changeable message sign shall be suitable for mounting on either a truck or a two-wheeled trailer. The message displayed from each unit shall be visible from a distance of one-half mile and have an average legibility distance of 850 feet under conditions of normal sunlight.

Section 1 - Message Board

1.1 Legend
The message board shall provide for one, two, or three lines of legend with each line containing a lamp matrix of at least 36 columns with seven rows.

1.2 Dimensions
The minimum overall width of the message board shall be 89 inches. The minimum overall height of the message board shall be 30 inches for one-line units, 50 inches for two-line units, and 70 inches for three-line units. The sign panel assembly including the mounting brackets shall not exceed 96 inches in overall width.

1.3 Distance from Roadway
When in operation, the bottom of the sign panel shall be a minimum of 7 feet above the roadway.

1.4 Lamps
The lamps shall be at the minimum 2-inch diameter rugged, high performance, bayonet or screw base units. The lamps shall be rated at 24 volts, 20 watts, with a life expectancy of at least 8000 hours. The lamps shall have a minimum light output of 800 foot-lamberts and meet the requirements stated of visibility at one-half mile and average legibility of 850 feet.

1.5 Protection
The entire sign panel shall be protected by some form of screen or bulb cylinders for increased legibility and bulb protection. Easy access to the lamps for maintenance of replacement operations shall be designed into the protection.

1.6 Protective Coating
All lamp matrices and lamp driver circuit assemblies shall be coated with a protective coating for weather proofing and shall be provided with absorbers to dampen shock and vibration.

1.7 Intensity
Intensity of the lamps on the sign panel shall be adjustable by an automatic dimming mechanism, as well as by manual control. Three intensity positions shall be provided for selecting high, medium, or low intensity. The intensity switch shall be used to select the lamp intensity to

1) suit the outside ambient light conditions, or
2) dim the light intensity for nighttime operations.

1.8 Display
The unit shall be capable of displaying a minimum of seven-character words with a standard single-stroke character font, seven bulbs high, and four or five bulbs wide. The legend shall be a minimum of 17 inches in height.

All lamps within modules and within a message line shall be equally spaced, both vertically and horizontally.

The sign shall automatically display any group of characters using automatic proportional spacing. Proportional spacing shall be defined as the ability to display any group of characters at the center of a sign, with predefined character-to-character spacing accounted for, on a real-time basis, requiring no operator interaction.

1.9 Display Rate
All messages shall be cycled so that a four-word message is displayed at least two or more times to a driver approaching the sign from 850 feet to the sign location while driving at 55 mph. This is equivalent to a display rate of approximately 1 second per word. The system shall be capable of displaying sequencing messages at various rates and shall include the capability of displaying messages at the rate of 1 second per word.

1.10 End of Message
The sign shall be designed to give the operator the option to display either a set of stars (asterisks) or a blank period to delineate the end of a sequenced message before it cycles through again.

Section 2 - Controller

2.1 Description
The controller shall be a fully self-contained, compact, solid state, modularized unit with standard preprogrammed messages and the additional capability of having either an integral or plug-in type keyboard system for message generation. The controller display shall show a miniaturized version of the message being displayed, or to be displayed, on the sign panel. The controller shall also contain the controls for raising or lowering the sign panel, starting or stopping the generator, and controlling the light intensity of the lamps, as well as readouts for the fuel supply and running time.
2.2 Keyboard
The keyboard shall contain complete alphanumerics and will provide the capability of entering any message as long as the seven-letter capability is not exceeded.

2.3 Light Intensity
The light intensity of the miniaturized message display shall be variable, allowing the lamp intensity to suit the outside ambient light conditions.

2.4 Housing
For truck-mounted units, the controller shall be packaged into a compact form and be capable of being located and mounted in the cab of a truck. For trailer-mounted units, the controller shall be assembled in a sturdy, weather-proof metallic housing hereinafter referred to as the controller cabinet.

2.5 Memory
The controller shall contain a nonvolatile memory to hold the keyboard-created and PROM messages in memory during a non power period of up to six months.

2.6 Security
On controllers with integral keyboards, provisions shall be made to lock out keyboard capability. This will result in a key being needed to electrically connect the keyboard, thereby providing security to keyboard access.

2.7 Minimization of Failures
Each unit shall be designed such that failures are kept to a minimum. The lamp switching electronics shall be rated for 35,000 hours mean time before failure at 80°C. All electronic components shall be rated by the manufacturer for operation from -30°F to 165°F. All printed circuit boards shall be plated minimum 2-ounce copper. All circuit boards shall be uniformly coated.

All lamp sockets shall be nickel plated and shall not rotate about their bases.

All lamps shall be rated a minimum of 8,000 hours at the operating voltages used in the sign.

Section 3-Power Supply

3.1 Description
The power supply shall have a heavy-duty gasoline- or diesel-powered generator capable of supplying continuous power at one-and-a-half times the maximum power draw for sign operation over extended time periods. The fuel supply shall be adequate to permit operation of the unit for at least 72 hours without refueling. An electric start assembly shall be provided.

The power supply unit shall be equipped with a 25-amp UL-approved major circuit breaker to provide protection on the main power supply. A low oil shut-off system shall be provided.

Section 4-Structural Support System

4.1 Support Mechanism
The structural support system shall provide the support mechanism between the sign panel assembly and the power supply cabinet. This will allow the system to be assembled into a unit that is easily mountable on either a trailer or in the bed of a variety of trucks.

4.2 Primary Support
The primary support shall be welded structural steel of a size and type capable of meeting the above specified sign operation while traveling at sustained freeway speeds of 55 mph for the one-line or two-line panels, and 30 mph for the three-line panels. All structural steel shall be protected from weather by galvanization or made of corrosive-resistant material.

4.3 Lifting Mechanism
Each unit shall be supplied with a power-driven hydraulic lifting mechanism to be operated from the control panel for raising or lowering the sign panel. An emergency hand-powered lifting-lowering device shall also be included. In the case of truck-mounted signs, indicators shall be provided to advise the operator of full up and down positions.

4.4 Lifting Mechanism: Truck Mounted Signs
For truck-mounted systems, the raise/lower mechanism shall be of sufficient capacity to raise and lower the sign while the vehicle is underway at 55 mph for one-line or two-line units and 30 mph for three-line units.

Section 5-Inspection

5.1 Delivery
Each unit shall be delivered with the following items at the time of delivery:

1) Operator's manual for the sign-raising mechanism and sign operations.

2) Schematic wiring diagram of the sign, control console, and the control unit.

3) Service manual for the sign, sign-raising mechanism control unit, and the control console.

4) Warranty on the sign-raising mechanism, sign control console, and control unit.

Section 6-Testing

6.1 Purchasing Agency Testing
The purchasing agency reserves the right to test any or all units delivered to the purchasing agency. The purchasing agency shall test the first production model and at least 10% of the units of the purchase order, which will be selected at random from the delivered units.
appendix a

user comments form
We Want Your Comments....

Standards, recommended practices, and informational reports published by the Institute of Transportation Engineers are prepared by committees staffed by transportation engineers and planners who have volunteered their time and effort to the committee's project task.

The committees encourage and welcome your views and opinions on the topics discussed in the reports; your comments, suggestions, and ideas will prove helpful to them as they work on future editions.

Please take a few moments to jot down your thoughts on this report, and then return this form to ITE. Thank you!

Equipment and Material Standards of the Institute of Transportation Engineers

Did you find the report useful? ____________________________________________
If "no," please explain why. ____________________________________________

__________________________________________
__________________________________________

Are there specific subjects or issues that were not covered in the report that should have been?

__________________________________________
__________________________________________

__________________________________________
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Are there any specific subjects or issues that were covered in the report that should not have been?

__________________________________________
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__________________________________________
__________________________________________
Do you have any suggestions for specific changes or corrections to the report? 

__________________________________________________________________________

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Do you have any other suggestions or comments regarding this report? 

__________________________________________________________________________

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__________________________________________________________________________

Do you know of other literature or reference material that should be brought to the committee's attention? 

__________________________________________________________________________

__________________________________________________________________________

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Address __________________________
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appendix b
standard ITE metric conversion
STANDARD METRIC CONVERSION

During the service life of this document, use of the metric system in the United States is expected to expand. The following common factors represent the appropriate magnitude of conversion. This is because the quantities given in U.S. Customary units in the text, tables or figures, represent a precision level that in practice typically does not exceed two significant figures. In making conversions, it is important to not falsely imply a greater accuracy in the product than existed in the original dimension or quantity. However, certain applications such as surveying, structures, curve offset calculations, and so forth, may require great precision. Conversions for such purposes are given in parentheses.

Length
1 inch = 25 mm (millimeters—25.4)
1 inch = 2.5 cm (centimeters—2.54)
1 foot = 0.3 m (meters—0.3048)
1 yard = 0.91 m (0.914)
1 mile = 1.6 km (kilometers—1.61)

Volume
1 cubic inch = 16 cm³ (16.39)
1 cubic foot = 0.028 m³ (0.02831)
1 cubic yard = 0.77 m³ (0.7645)
1 quart = 0.95 L (liter—0.9463)
1 gallon = 3.8 L (3.785)

Speed
foot/sec. = 0.3 m/s (0.3048)
miles/hour = 1.6 km/h (1.609)

Temperature
To convert °F (Fahrenheit) to °C (Celsius), subtract 32 and divide by 1.8.

Area
1 square inch = 6.5 cm² (6.452)
1 square foot = 0.09 m² (0.0929)
1 square yard = 0.84 m² (0.836)
1 acre = 0.4 ha (hectares—0.405)

Mass
1 ounce = 28 gm (gram—28.34)
1 pound = 0.45 kg (kilograms—0.454)
1 ton = 900 kg (907)

Light
1 footcandle = 11 lux (lumens per m²—10.8)
1 footlambert = 3.4 cd/m² (candela per m²—3.426)

For other units refer to the American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA, Standard for Metric Practices E 380.