SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Optical Warning Devices for Authorized Emergency, Maintenance, and Service Vehicles

RATIONALE

2.1.1: Document SAE J1889 is no longer an applicable document since the definition of photometric stability was added to this document. The title of SAE J578 was updated to reflect its current title.

Section 3: Reordered and renumbered definitions to place them in alphabetic order per ANSI guidelines.

3.1 and 3.2: The phrase “to call for the right-of-way“ was added to the definitions to clarify conditions that indicate the need for Class 1 performance and to provide common language with SAE J2498.

3.7: The definition of the term “duty-cycle” was added to clarify its meaning within the document.

3.8: The limitation of “in all modes if the mode of the device is vehicle operator adjustable” was removed from the determination of when multiple EWD lamp assemblies can be considered as a single device because it was determined to be unneeded.

3.9: The definition of the term “emergency warning device photometric stability” was added to clarify its meaning within the document.

3.11: The definition of the term “flash energy” was added to clarify its meaning within the document.

3.14: The definition of the term “on-time” was added to clarify its meaning within the document.

3.17: The definition of the term “peak intensity” was added to clarify its meaning within the document.

3.20: The definition of the term “pulse width modulation” was added to clarify its meaning within the document.

3.23: The definition of the term “Talbot’s law” was added to clarify its meaning within the document.

3.24: The definition of the term “warning mode” was added to clarify its meaning within the document.

Section 4: Added the appending of the letter “M” to the device marking code to indicate devices that contain warning modes of different performance. Added the requirement that selective coverage devices with asymmetric beam patterns must be marked to indicate the front of the device.

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Section 5: Renumbered the section to improve clarity.

5.1.5: This section was re-written to clarify the measurement procedure and match the practices of test laboratories. Methods are provided to determine the photometric performance of un-tested flash patterns by photometric testing of a single flash pattern and determining an adjustment factor that can be applied to the photometric test results of the tested flash pattern.

5.1.5.2: The H-V reference point determinations were changed to reflect laboratory practices currently in use and improve clarity.

5.1.5.3: Added this section to define how pulse width modulation shall be evaluated.

Figure 1: Updated the figure to reflect the elimination of the ±2.5 degree test points.

5.2: Revised the text to clarify incandescent sources may be evaluated while steady burning and that device chromaticity shall be tested at 1 minute and when photometric stability has been reached.

5.4: Revised the flash characteristics that must be measured to the ones needed to determine compliance to the definition of a flash.

Section 6: Renumbered the section to improve clarity.

6.1.5: The minimum angular measurement interval was moved to 5.6 since it is a test parameter.

6.4: References to the definitions of a light pulse and flash were added to the requirements to eliminate ambiguity.

Figures 3, 4, and 5: The 2.5 degree up and down test points were determined to be unnecessary and were removed. Text concerning the device adjustment during photometric testing was revised to make clear that it is a single adjustment and that it applies to both optical power and peak intensity.

Added Section 9 to include the acknowledgement of the IEC for the use of their Talbot's law definition.

1. SCOPE

This document provides design guidelines, test procedure references, and performance requirements for omnidirectional and selective coverage optical warning devices used on authorized emergency, maintenance, and service vehicles. It is intended to apply to, but is not limited to, surface land vehicles.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J575 Test Methods and Equipment for Lighting Devices for Use on Vehicles Less than 2032 mm in Overall Width

SAE J576 Plastic Material or Materials for Use in Optical Parts Such as Lenses and Reflex Reflectors of Motor Vehicle Lighting Devices

SAE J578 Chromaticity Requirements for Ground Vehicle Lamps and Lighting Equipment

SAE J759 Lighting Identification Code

SAE J1330 Photometry Laboratory Accuracy Guidelines

SAE J2139 Tests for Signal and Marking Devices Used on Vehicles 2032 mm or More in Overall Width

SAE J2357 Application Guidelines for Electronically Driven and/or Controlled Exterior Automotive Lighting Equipment

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J387 Terminology - Motor Vehicle Lighting

SAE J595 Directional Flashing Optical Warning Devices for Authorized Emergency, Maintenance, and Service Vehicles

SAE J2498 Minimum Performance of the Warning Light System Used on Emergency Vehicles

3. DEFINITIONS

3.1 CLASS 1A OMNIDIRECTIONAL OPTICAL WARNING DEVICE

A device utilized on authorized vehicles to capture the attention of motorists and pedestrians to call for the right-of-way or warn of a potentially hazardous activity or emergency situation. It provides 360 degrees of visual warning coverage. The device can also consist of an array of individual selective coverage EWD lamp assemblies within a common housing whose coverage angles overlap or adjoin such that 360 degrees of warning coverage results.

3.2 CLASS 1S SELECTIVE COVERAGE OPTICAL WARNING DEVICE

A device utilized on authorized vehicles to capture the attention of motorists and pedestrians to call for the right-of-way or warn of a potentially hazardous activity or emergency situation. A single device of this class will not provide 360 degrees of warning coverage.

3.3 CLASS 2A OMNIDIRECTIONAL OPTICAL WARNING DEVICE

A device utilized on authorized vehicles to capture the attention of motorists and pedestrians and warn of traffic hazards such as a lane blockage or a slow moving vehicle. It provides 360 degrees of visual warning coverage. The device can also consist of an array of individual selective coverage EWD lamp assemblies within a common housing whose coverage angles overlap or adjoin such that 360 degrees of warning coverage results.

3.4 CLASS 2S SELECTIVE COVERAGE OPTICAL WARNING DEVICE

A device utilized on authorized vehicles to capture the attention of motorists and pedestrians and warn of traffic hazards such as a lane blockage or a slow moving vehicle. A single device of this class will not provide 360 degrees of warning coverage.

3.5 CLASS 3A OMNIDIRECTIONAL OPTICAL WARNING DEVICE

A device utilized on authorized vehicles to identify them to pedestrians and motorists. It provides 360 degrees of visual identification coverage. The device can also consist of an array of individual selective coverage EWD lamp assemblies within a common housing whose coverage angles overlap or adjoin such that 360 degrees of warning coverage results.

3.6 CLASS 3S SELECTIVE COVERAGE OPTICAL WARNING DEVICE

A device utilized on authorized vehicles to identify them to pedestrians and motorists. A single device of this class will not provide 360 degrees of warning coverage.

3.7 DUTY-CYCLE

The on-time divided by the flash period.

3.8 EMERGENCY WARNING DEVICE (EWD) LAMP ASSEMBLY

Any single, independently mounted, light-emitting component in the lighting system. An emergency warning device (EWD) lamp assembly may consist of a single optical element or a fixed array of any number of optical elements whose geometric positioning relative to each other is fixed by the manufacturer of the device and not intended to be modified. To be considered a single source, the optical elements must be adjacent and operate simultaneously in the mode under consideration.

3.9 EMERGENCY WARNING DEVICE PHOTOMETRIC STABILITY

The point at which the photometry value is stable to within ±3% within any 15-minute period.

3.10 FLASH

A repetitive light pulse or a train of light pulses, where a dark interval of at least 160 ms separates the light pulse or the last pulse of the train of light pulses from the next pulse or the first pulse of the next train of light pulses. To be considered a train of light pulses, each pulse in the train must begin within 100 ms after the end of the preceding light pulse. Dark interval luminous intensity shall not exceed 2% of the maximum luminous intensity of a flash.

3.11 FLASH ENERGY

The integration of the luminous intensity of the flashing EWD lamp assembly for the duration of a flash. Units are cd·s.

$$\text{Flash Energy} = \int_{t_1}^{t_2} I\,dt \qquad \text{(Eq. 1)}$$

where:

I = instantaneous intensity (candela)

t_1 = time at start of flash (seconds)

t_2 = time at end of flash (seconds)

3.12 LIGHT PULSE

A single, visually continuous emission of optical energy.

3.13 OMNIDIRECTIONAL OPTICAL WARNING DEVICE

An optical warning device that projects light in a horizontal 360-degree arc and vertically from 5 degrees up to 5 degrees down. It will project flashes of light to an observer positioned at a fixed location within the arc of coverage. This would include all 360-degree beacons.

3.14 ON-TIME

The summation of the durations of the individual light pulse or train of pulses within a flash. The duration of dark intervals within a light pulse due to pulse width modulation are ignored when determining the duration of the light pulse.

3.15 OPTICAL ELEMENT

Any discrete light emitter such as, but not limited to, an incandescent filament, HID, or individual light-emitting diode.

3.16 OPTICAL POWER

The integration of the luminous intensity of the flashing EWD lamp assembly over a period of 60 seconds ($\int$Idt). Alternatively, the optical power of a repetitive flash is the flash energy multiplied by the number of flashes produced in 1 minute. Units are cd·s/min.

3.17 PEAK INTENSITY

The highest luminous intensity of the flashing EWD lamp assembly during a flash. When a flash is also pulse width modulated, the peak intensity will be the intensity determined by Talbot's law. Units are candela (cd).

3.18 PRIMARY OPTICAL WARNING DEVICE

A device or group of devices that is intended to provide the primary visual optical warning signal as called out in each service class. Unless prohibited by law or regulation, a Class 1 device may be used in place of a Class 2 device, and a Class 1 or 2 device may be used in place of a Class 3 device.

3.19 PSEUDO-RANDOM FLASH PATTERN

A flash pattern that varies over time and is composed of blocks of compliant flashes presented in a sequential or random order.

3.20 PULSE WIDTH MODULATION

A method of reducing the visual intensity of an EWD by switching the electrical signal applied to the light source on and off at a fixed frequency thereby reducing the average power delivered to the light source.

3.21 SECONDARY OPTICAL WARNING DEVICE

A device or group of devices of lower performance that can be used to provide supplemental optical warning to that provided by the primary optical warning device or devices.

3.22 SELECTIVE COVERAGE OPTICAL WARNING DEVICE

An optical warning device that projects light in a defined horizontal arc of more than 40 degrees, but less than 360 degrees, and vertically from 5 degrees up to 5 degrees down. It will project flashes of light to an observer positioned at a fixed location within the arc of coverage. This would include all directional warning devices and omnidirectional devices within a lightbar that have a portion of their light beam blocked by internal components.

3.23 TALBOT'S LAW

If a point on the retina is excited by a light stimulus that undergoes periodic variations in magnitude at a frequency that exceeds the fusion frequency, the visual sensation produced is identical with that produced by a steady stimulus whose magnitude equals the mean magnitude of the variable stimulus taken over one period.

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3.24 WARNING MODE

One of a set of pre-defined operating states that provide a warning signal that may be chosen from a switch or switches either on the device or mounted external of the device (e.g., within the passenger compartment of the vehicle). The term "a switch or switches " is not intended to be limiting and includes any method of communicating to the device that a change in warning mode is desired (e.g., a photocell output, a vehicle CAN bus message, etc.). Operating states may include variations in the number of active EWD lamp assemblies, color, flash pattern, and/or intensity.

4. LIGHTING IDENTIFICATION CODE, MARKINGS, AND NOTICES

In accordance with SAE J759, the optical warning device may be identified by the codes:

“W3-1” for omnidirectional devices providing Class 1A performance in at least one of its warning modes.

“W3-2” for omnidirectional devices providing Class 2A performance in at least one of its warning modes.

“W3-3” for omnidirectional devices providing Class 3A performance in at least one of its warning modes.

“WS3-1” for selective coverage devices providing Class 1S performance in at least one of its warning modes.

“WS3-2” for selective coverage devices providing Class 2S performance in at least one of its warning modes.

“WS3-3” for selective coverage devices providing Class 3S performance in at least one of its warning modes.

The letter “M” shall be appended to the device code to indicate that the warning device contains warning modes:

- Of a lower Class rating than which it is marked.
- That have non-compliant flash patterns.
- That have a narrower coverage angle, e.g., an EWD with warning modes providing omnidirectional coverage and other warning modes providing selective coverage.

If the optical warning device is a selective coverage device, the angle of coverage may also be indicated in parentheses. For example, a Class 1 device providing 120 degrees of signal may be marked WS3-1 (120).

A selective coverage device with an asymmetrical beam pattern shall be provided with a marking to indicate the mounting orientation of the device.

5. TESTS

All tests shall use the test voltages for the system voltages indicated in Table 1:

Table 1 - Test voltages

System Voltage	Test Voltage	Test Voltage Tolerance
12	12.8	±0.1
24	25.6	±0.2
36	38.4	±0.3
42	44.8	±0.35
48	51.2	±0.4
72	76.8	±0.6
80	85.3	±0.66

CAUTION: Adequate care must be exercised in order to maintain a safe test environment when handling voltages higher than 36 V.

Tests are to be made using the wiring supplied by the device manufacturer or wire of the minimum size recommended by the device manufacturer. For devices intended to be hard wired into the vehicle electrical system, the voltage shall be measured at 300 mm from the point at which the wiring exits the device. For portable devices equipped with an electrical connector, the voltage shall be measured at the supply side of the connector.

5.1 SAE J2139 or SAE J575 is a part of this document. The choice of which SAE Recommended Practice is used depends on the width of the vehicle the warning light is intended to be used on. The following tests are applicable with the modifications as indicated.

5.1.1 Vibration Test

The wideband random vibration test defined in SAE J575 may be used for large devices, such as light bars, in place of the vibration test procedure specified in SAE J2139.

5.1.2 Moisture Test

5.1.3 Dust Test

The change in intensity may be measured at the H-V location.

5.1.4 Corrosion Test

5.1.5 Photometry

In addition to the test procedures in SAE J2139 or SAE J575, the photometric performance shall be determined by the optical power and the peak intensity of each flash. Photometric measurements shall be taken with the EWD lamp assembly flashing.

An integrating photometer shall be used to determine the optical power. Any integration time equal to the period of a single flash up to and including 60 seconds may be used provided the measurement error resulting from an integration time less than 60 seconds is less than or equal to 5% of the 60 second measurement.

The relationship between the light source(s) and optical beam forming elements will determine the methodology used to measure the EWD lamp assembly.

If the relationship between the light source(s) and optical beam forming element(s) is variable (e.g., a rotating beacon where the reflector orbits around a fixed filament lamp) the optical power and peak intensity shall be measured in 5-degree increments throughout the coverage angle of the device.

If the relationship between the light source(s) and the optical beam forming element(s) is fixed (e.g., fully stationary components or a rotating beacon where the reflector or lens and filament have an unchanging geometric relationship and orbit together around a fixed point) the optical power shall be measured in 5-degree increments throughout the coverage angle of the device and the peak intensity shall be measured at the H-V point of the coverage angle. Calculate an adjustment factor by dividing the peak intensity at H-V by the optical power at H-V. Multiply the optical power at each test point by this adjustment factor to determine the peak intensity of the test point.

If the flasher or power supply/flasher has more than one flash pattern the pattern with the highest optical power shall be chosen and measured as defined in the preceding paragraphs. The photometric performance of the remaining flash patterns may be directly measured or calculated by one of the following two methods:

1. Due to the dependency of duty-cycle to optical power, if the only difference between the unmeasured flash pattern and the measured flash pattern is the duty-cycle, measure the duty-cycle of both the measured and unmeasured flash patterns and perform the following calculation for each test point in the flash pattern:

$$OP_1 = OP_m \times \left(\frac{DC_1}{DC_m}\right) \text{ and } P_1 = P_m \quad \text{(Eq. 2)}$$

where:

OP_1 = optical power of unmeasured flash pattern

OP_m = optical power of measured flash pattern

DC_1 = duty-cycle of unmeasured flash pattern

DC_m = duty-cycle of measured flash pattern

P_1 = peak intensity of unmeasured flash pattern

P_m = peak intensity of measured flash pattern

2. For all other cases, measure the optical power and peak intensity at H-V of the unmeasured flash pattern and perform the following calculations for each test point in the flash pattern:

$$OP_1 = OP_m \times \left(\frac{OP_{1@H-V}}{OP_{m@H-V}}\right) \text{ and } P_1 = P_m \times \left(\frac{P_{1@H-V}}{P_{m@H-V}}\right) \quad \text{(Eq. 3)}$$

where:

OP_1 = optical power of unmeasured flash pattern

OP_m = optical power of measured flash pattern

$OP_{1@H-V}$ = optical power of unmeasured flash pattern at H-V

$OP_{m@H-V}$ = optical power of measured flash pattern at H-V

P_1 = peak intensity of unmeasured flash pattern

P_m = peak intensity of measured flash pattern

$P_{1@H-V}$ = peak intensity of unmeasured flash pattern at H-V

$P_{m@H-V}$ = peak intensity of measured flash pattern at H-V

If both methods are used, the results obtained from method (2) take precedence over method (1).

5.1.5.1 Photometric Stability

Energize the test device and record the H-V photometric values after 1 minute. Continue to energize the test device until photometric stability occurs. Record the photometric values at all the required test points. Calculate the ratio between the 1 minute H-V reading and the photometric stability H-V reading, and apply the ratio to all of the required test points to determine the 1 minute photometric performance.

5.1.5.2 Device Mounting and Orientation

Photometric measurements shall be made with the device mounted in its normal operating position and all measurements shall be made with the geometric center of the EWD lamp assembly of the device at least 18 m from the photometer sensor.

The device shall be mounted so that the horizontal plane (H-Plane) through the photometer sensor axis passes through the center of the EWD lamp assembly. The vertical axis through the center of the EWD lamp assembly shall be perpendicular to this horizontal plane. If the EWD lamp assembly is composed of an array of optical elements, the geometric center of the array shall be used.

The H-V reference point for omnidirectional devices that have a rotationally symmetric outer housing shall be chosen arbitrarily from around the device and within the H-Plane.

The H-V reference point for omnidirectional devices that do not have a rotationally symmetric outer housing shall be either the front, rear, or side of the device.

The H-V reference point for selective coverage devices shall be either: (1) the geometric center of the EWD lamp assembly, or (2) as indicated on the device, if it is so marked. The coverage angle of selective coverage devices shall be included in the test report.

If the H-V reference point is the geometric center of the EWD lamp assembly, the device coverage angle shall be twice the smallest coverage angle to the left or right of the H-V reference point.

If the H-V reference point is indicated on the device, the device coverage angle shall be the sum of the coverage angles to the left and right of the H-V reference point.

5.1.5.3 Pulse Width Modulation (PWM)

A flash pattern may be pulse width modulated with a frequency equal to or greater than 100 Hz. The peak intensity of the pulse width modulated flash pattern shall be determined by Talbot's law.

If the EWD being tested has a "low-power," "night," or other warning mode that lowers the intensity of the normal flash patterns by pulse width modulating them, the following method may be used to determine the Talbot law peak intensity of the PWM version of the flash pattern:

Measure the flash energy and peak intensity at H-V of the non-PWM flash pattern and the flash energy of the PWM flash pattern at H-V. To determine the PWM peak intensity perform the following calculations for each test point in the flash pattern:

$$I_{PWM} = I_m \times \left(\frac{FE_{PWM@H-V}}{FE_{m@H-V}}\right) \quad \text{(Eq. 4)}$$

where:

$FE_{PWM@H-V}$ = flash energy of the PWM flash pattern at H-V

$FE_{m@H-V}$ = flash energy of the non-PWM flash pattern at H-V

I_{PWM} = equivalent peak intensity of the PWM flash pattern

I_m = peak intensity of the measured flash pattern

5.1.5.4 Photometric Considerations for Devices Containing Multiple EWD Lamp Assemblies

The photometric performance and arc of coverage of light bars and other types of optical warning devices containing multiple EWD lamp assemblies can be determined directly by testing the entire device or a representative portion of the device, e.g., one half of a full size light bar. Alternatively, photometric testing of each individual EWD lamp assembly, or type of EWD lamp assembly, and combining the results both geometrically and mathematically may be done. To combine the results from individual EWD lamp assemblies, the test results from each individual EWD lamp assembly must be adjusted geometrically for its direction when mounted in the light bar. The effect of transparent and opaque structures within the light bar on the photometric performance of the individual EWD lamp assemblies must be considered and be accounted for when combining results. In addition, each individual EWD lamp assembly used to determine the total photometric performance, arc of coverage, and Class of performance of a light bar in a given warning mode must comply with the flash characteristics defined in this document and be of the same or better Class of performance. Once these requirements have been met the total photometric performance of the light bar, its arc of coverage, and its Class of performance may then be determined.

When determining the photometric performance of devices containing multiple EWD lamp assemblies, the following characteristics must be considered and satisfied:

5.1.5.4.1 The geometric positioning of the individual EWD lamp assemblies relative to each other is fixed by the manufacturer of the device and not intended to be modified.

5.1.5.4.2 The optical power of individual EWD lamp assemblies may be summed in areas where the beam pattern of two or more individual EWD lamp assemblies overlap provided the individual EWD lamp assemblies are of the same color. An example of this is shown in Figure 1.

5.1.5.4.3 The peak intensity of individual EWD lamp assemblies may be summed in areas where the beam pattern of two or more individual EWD lamp assemblies overlap provided the flash characteristics are simultaneous, synchronous, and the individual EWD lamp assemblies are of the same color. An example of this is shown in Figure 1.

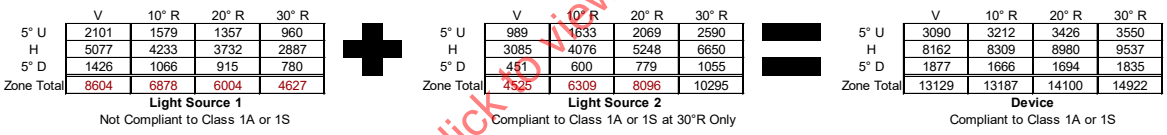


Figure 1 - Example of summing optical power or peak intensity values of overlapping, individual EWD lamp assemblies

5.1.5.4.4 Individual EWD lamp assemblies of the same class of performance, and of the same or different colors may have their arcs of coverage summed to determine the arc of coverage of the total device. An example of this is shown in Figure 2.

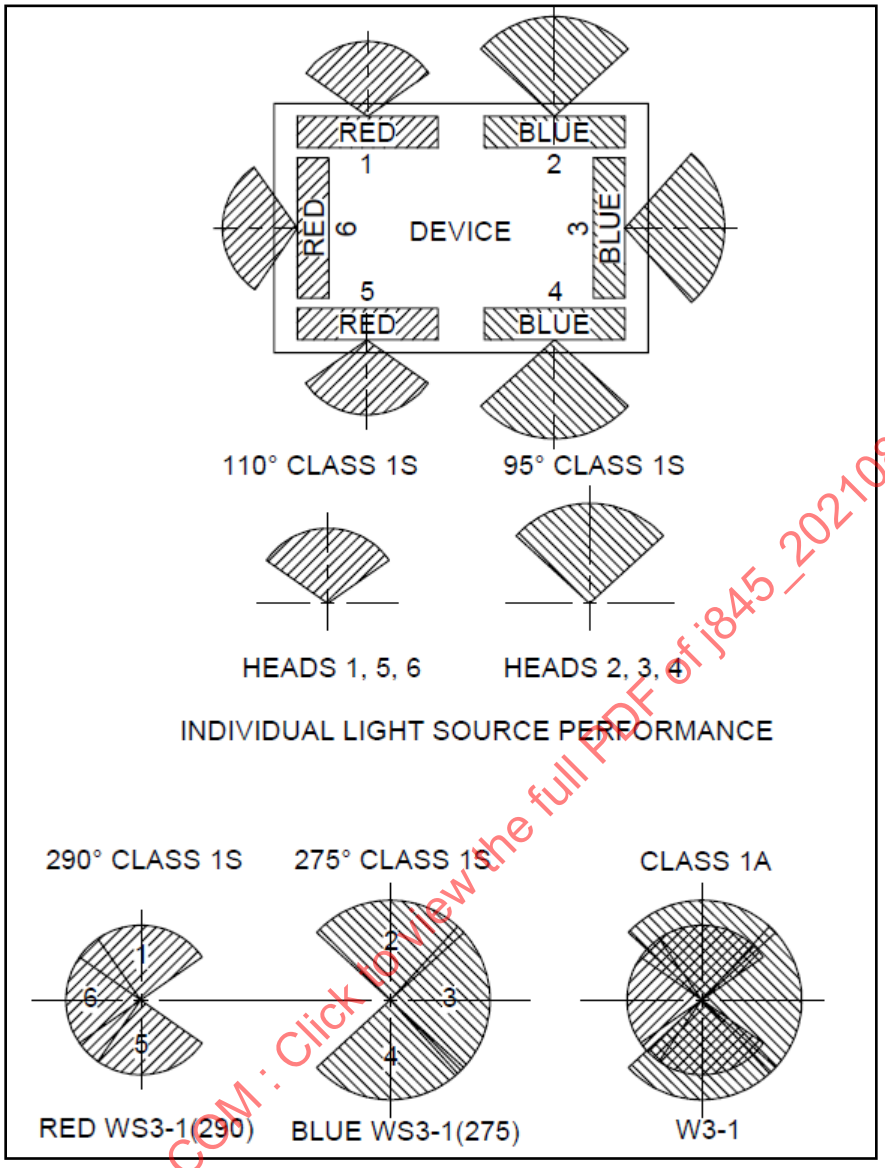


Figure 2 - Result of combining individual EWD lamp assemblies after adjusting them geometrically for their direction within the device

5.1.5.4.5 The flash pattern of all the individual EWD lamp assemblies within the device in a given warning mode must meet the flash characteristics defined in this document. In addition, the combined flash pattern of two or more adjacent individual EWD lamp assemblies of the same color and in the same warning mode shall meet the flash characteristics defined in this document.

5.1.6 Warpage Test for Plastic Components

The device shall be operated in the warning mode with the highest optical power.

5.2 Color Test

SAE J578 is a part of this document.

Incandescent devices may be measured while operating steady burning at design voltage.

The emitted color shall be measured after one minute of operation and at photometric stability.

5.3 Materials Test

SAE J576 is a part of this document.

5.4 Flash Rate and Flash Patterns

Any device incorporating an integral flasher, an external flasher, or a combined power supply and flasher supplied by the manufacturer of the device, shall be tested with this flasher.

The characteristics, including flash rate and dark interval times shall be measured and recorded. If the flasher or power supply/flasher has more than one flash pattern, the characteristics shall be measured and recorded for each pattern.

If a flasher is required and no flasher is supplied by the manufacturer of the device, the device shall be tested using a flasher having a flash rate of 1.20 Hz ± 0.14 Hz, with a 50% ± 2% current on time.

5.5 High-Temperature Flash Rate Test

The device shall be subjected to an ambient temperature of 50 °C ± 3 °C for a period of 6 hours. The device shall be off (not operating) during the first hour, and shall operate continuously for the next 5 hours of the test. The flash rate shall be measured starting 1 minute after the device is activated and at the conclusion of the test. If the device has multiple flash patterns, then the pattern with the highest optical power shall be used. The start time shall be measured at time of activation.

5.6 Low-Temperature Flash Rate Test

The device shall be subjected to an ambient temperature of -30 °C ± 3 °C for a period of 6 hours. The device shall be off (not operating) during the first 5 hours, and shall operate continuously for the last hour of the test. The flash rate shall be measured starting 1 minutes after the device is activated and at the conclusion of the test. If the device has multiple flash patterns, then the pattern with the lowest optical power shall be used. The start time shall be measured at time of activation.

5.7 Durability Flash Rate Test

The device shall be operated continuously for 200 hours at an ambient temperature of 25 °C ± 3 °C, in cycles consisting of 50 minutes on and 10 minutes off. The flash rate shall be measured starting 1 minute after the device is activated and at the conclusion of the test. If the device has multiple flash patterns, then the pattern with the highest optical power shall be used.

6. PERFORMANCE REQUIREMENTS

6.1 A device, when tested in accordance with the test procedures specified in Section 5, shall meet the requirements of SAE J2139 or SAE J575. For devices with non-replaceable sources, such as LEDs, the evaluation of the sample at the completion of the test shall also include a functional lighting check. If a partial outage is observed, a photometry test (see 6.1.5) shall be performed. The sample must still comply with the photometric requirements.

6.1.1 Vibration

6.1.2 Moisture

6.1.3 Dust

Upon completion of the test, the test device shall be considered to have met all the requirements of the dust test when complying with either of the following requirements:

- No dust shall be found on the interior surface of the test device, or
- The maximum or H-V luminous intensity measured after the dust exposure test shall be at least 90% of the initial maximum or H-V luminous intensity measured before the test.

6.1.4 Corrosion

6.1.5 Photometry

To be considered compliant, a flash pattern shall meet the optical power requirements contained in Figures 3, 4, or 5 and their footnotes. The summation of the optical power measurements for the specified test points in a zone shall be at least the optical power zone value shown. Additionally, the peak luminous intensity of the pattern shall meet the photometric requirements contained in Figures 3, 4, or 5 and their footnotes. The summation of the peak luminous intensity measurements for the specified test points in a zone shall be at least the peak luminous intensity zone value shown. Compliance shall be demonstrated both at 1 minute after the device is energized and after it has reached photometric stability.

In the case of gaseous discharge devices, only compliance to the optical power requirements is required.

6.1.6 Warpage

6.2 Color

The color of light emitted in each warning mode shall be white, yellow, red, signal blue, or green as specified in SAE J578, except that the blue boundary for white shall be x = 0.300.

Due to societal associations of the color green with the concept of normalcy (green GO signal of traffic lights, green indicator lamps to signify a device is operating within its normal operating limits, etc.), the color green shall not be used on its own for applications that require Class 1A, 1S, 2A, or 2S performance levels. For Class 1A, 1S, 2A, or 2S applications, green may be used as a secondary optical warning device(s) together with white, yellow, red, or blue primary optical warning device(s) suitable for the application. The use of the color green on its own shall be limited to applications where Class 3A or 3S devices are suitable.

6.3 Material Requirements

Plastic materials used in optical parts shall meet the requirements of SAE J576.

6.4 Flash Rate and Flash Patterns

The flash rate for devices shall be at least 1.0 Hz and not more than 4.0 Hz at all times and meet the definitions of a light pulse and flash in 3.12 and 3.10.

The use of LEDs has made it possible to create very complex flash patterns. While the flash characteristics defined in this document attempt to accommodate these possible patterns, flash patterns that do not meet these characteristics are possible and may be desirable in special circumstances. To accommodate these complex flash patterns, the manufacturer of devices with multiple flash patterns shall indicate in the instruction manual which patterns comply with the requirements of this standard and to which class of performance, i.e., Class 1A or 1S, Class 2A or 2S, or Class 3A or 3S.

Pseudo-random flash patterns that are entirely composed of blocks of compliant flashes presented in a sequential or random order are acceptable.

6.5 High-Temperature Flash Rate Test

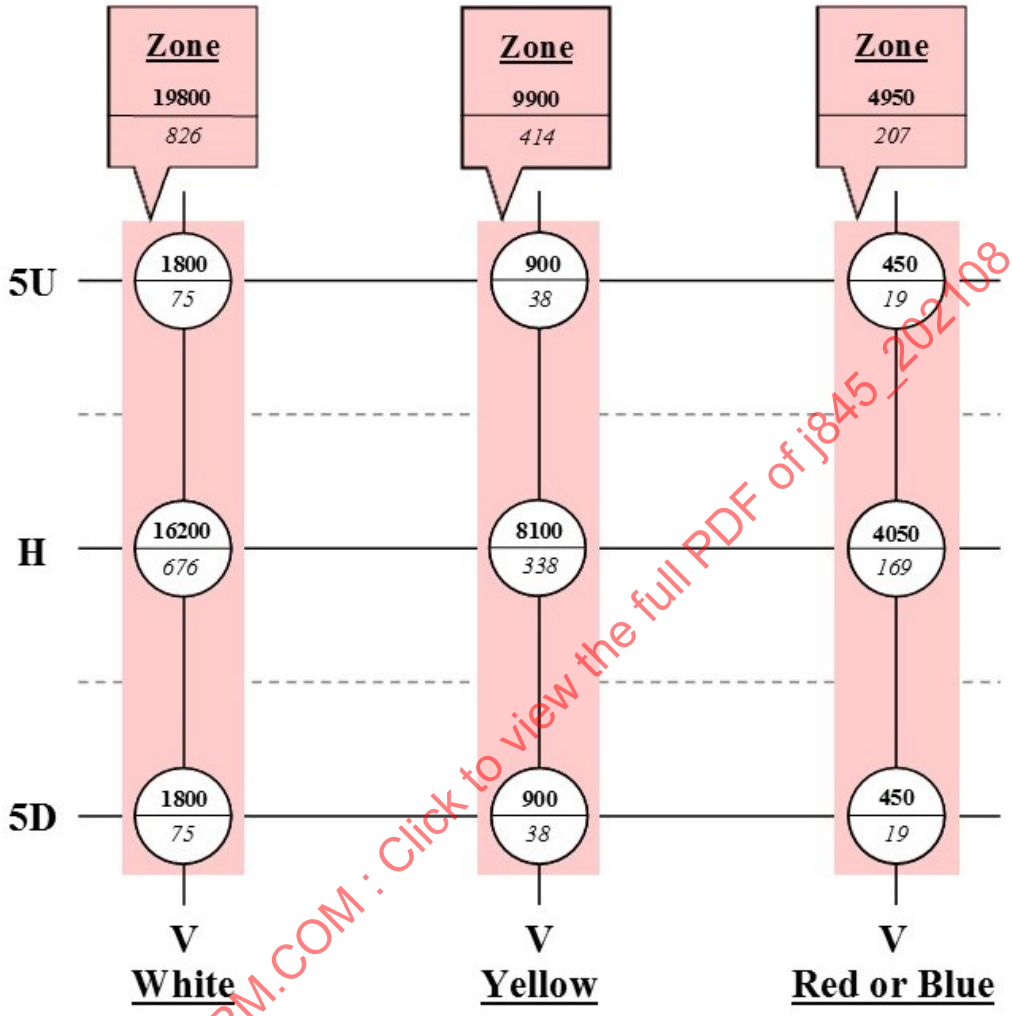
There shall be no evidence of operating conditions that would result in failure to comply with Section 6 of this document. Operation of the device shall begin and continue within 5 seconds of the beginning of each operating cycle. The measured flash rates shall not vary by more than 20% from the ambient flash rate.

6.6 Low-Temperature Flash Rate Test

There shall be no evidence of operating conditions that would result in failure to comply with Section 6 of this document. Operation of the device shall begin and continue within 5 seconds of the beginning of each operating cycle. The measured flash rates shall not vary by more than 20% from the ambient flash rate.

6.7 Durability Flash Rate Test

There shall be no evidence of operating conditions that would result in failure to comply with Section 6 of this document. The final measured flash rates shall not vary by more than 20% from the initial flash rates.



1. For each test point and zone total, the value shown in **bold** (top value) is the optical power requirement and the value shown in *italics* (bottom value) is the peak luminous intensity requirement.
2. The measured values at each test point shall not be less than 60% of the required minimum values shown for that individual test point location.
3. The sum of the optical power measurements and the sum of the peak luminous intensity measurements for each test point within a zone, shall not be less than the corresponding zone total requirement shown. The measurements at each discrete test point shown within the corresponding zone are the values used to calculate the specified zone total.
4. A single adjustment in device orientation from the design position may be made in determining compliance to the optical power and luminous intensity requirements, providing such adjustment does not exceed 1 degree in any direction. All zone totals must comply after adjustment.

Figure 3 - Photometric requirements - Class 1A or 1S colors: white, yellow, red, and blue

Optical Power (cd-s/min) shown in **bold** (top value)
Peak Luminous Intensity (candela) shown in *italics* (bottom value)