SURFACE VEHICLE RECOMMENDED PRACTICE

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Discharge Forward Lighting System and Subsystems

RATIONALE

This document has been determined to contain stable technology not likely to change in the near future.

STABILIZED NOTICE

This document has been declared “STABILIZED” by SAE Road Illumination Devices Standards Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. SCOPE

This SAE Recommended Practice applies to motor vehicle forward illumination systems and subsystems generated by discharge sources. It provides test methods, requirements, and guidelines applicable to the special characteristics of gaseous discharge lighting devices which supplement those required for forward illumination systems using incandescent light sources. The document is applicable to both discharge forward lighting systems, subsystems and components. This document is intended to be a guide to standard practice and is subject to change to reflect additional experience and technical advances.

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 J578	Chromaticity Requirements for Ground Vehicle Lamps and Lighting Equipment
SAE J759	Lighting Identification Code
SAE J1383	Performance Requirements for Motor Vehicle Headlamps
SAE J1647	Plastic Materials and Coatings for Use In or On Optical Parts Such as Lenses and Reflectors of High-Intensity Discharge Forward Lighting Devices Used in Motor Vehicles
SAE J2320	Discharge Signal Lighting System
SAE J2357	Application Guidelines for Electronically Driven and/or Controlled Exterior Automotive Lighting Equipment

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at http://webstore.ansi.org/. Copies of ANSI/IESNA documents are available online at http://www.iesna.org/.

ANSI Z535.4	Product Safety Signs and Labels
ANSI/IESNA RP 16-96	American National Standard Nomenclature and Definitions for Illuminating Engineering
ANSI/IESNA RP 27.1	Photobiological Safety for Lamps and Lamp Systems - General Requirements
ANSI/IESNA RP 27.2	Photobiological Safety for Lamps and Lamp Systems - Measurement Techniques

2.1.3 Code of Federal Regulations (CFR) Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

CFR Title 49 Part 571	Lamps, Reflective Devices and Associated Equipment (FMVSS 108)
CFR Title 49 Part 564	Replaceable Light Source Information (Part 564)

2.1.4 Transport Canada Publications

Transport Canada documents are available from Transport Canada, Tower C, Place de Ville, 330 Sparks Street Ottawa, Ontario K1A 0N5, Tel: 1-800-305-2059, www.tc.gc.ca.

CMVSS 108	Lighting Systems and Reflective Devices

2.1.5 UN Publications

Available from United Nations Economic Commission for Europe, Palais des Nations, CH-1211, Geneva 10, Switzerland, Tel: +41-0-22-917-12-34, www.unece.org.

UN Regulation 99 — Uniform Provisions Concerning the Approval of Gas-Discharge Light Sources for Use in Approved Gas-Discharge Lamp Units of Power-Driven Vehicles

UN R.E.5 — Consolidated Resolution on the common specification of light source categories (R.E.5) (ECE/TRANS/WP.29/1127 and revisions)

2.1.6 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60061 — Lamps for Road Vehicles - Performance Requirements

IEC 60810 — Lamp Caps and Holders Together with Gauges for the Control of Interchangeability and Safety

2.1.7 IES Publications

Available from Illuminating Engineering Society, 120 Wall Street, Floor 17, New York, NY 10005-4001, Tel: 212-248-5000, www.ies.org.

IES Procedure LM-45 — Approved Method for Electrical and Photometric Measurements of General Service Incandescent Filament Lamps, IES Lighting Handbook, Reference Volume, III

2.1.8 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E308-15 — Standard Practice for Computing the Colors of Objects by Using the CIE System

2.2 Related Publications

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

2.2.1 CIE Publications

Available from CIE Central Bureau, Babenbergerstrasse 9/9A, 1010 Vienna, Austria, Tel: +43 1 714 31 87, www.cie.co.at.

CIE 013-3-1995 — Method of Measuring and Specifying Colour Rendering Properties of Light Sources

2.2.2 ACGIH Publications

Available from American Council of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, OH 45240.

Threshold Limit Values and Biological Exposure Indices for 1989-1990, American Conference of Governmental Industrial Hygienists

2.2.3 UN Publications

Available from United Nations Economic Commission for Europe, Palais des Nations, CH-1211, Geneva 10, Switzerland, Tel: +41-0-22-917-12-34, www.unece.org.

UN Regulation 98 Uniform Provisions Concerning the Approval of Motor Vehicle Headlamps Equipped with Gas-Discharge Light Sources

2.2.4 UL Publications

Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 935 Fluorescent-Lamp Ballasts

2.2.5 IES Publications

Available from Illuminating Engineering Society, 120 Wall Street, Floor 17, New York, NY 10005-4001, Tel: 212-248-5000, www.ies.org.

IES RP-27.1-05 Photobiological Safety for Lamps and Lamp Systems - General Requirements

2.2.6 Other Publications

“Safety with Lasers and Other Optical Sources” by Sliney and Wolbarsht (1980, Plenum Press)

3. DEFINITIONS

3.1 DISCHARGE FORWARD LIGHTING (DFL) SYSTEM

An automotive road illumination system comprising of one or more headlamps, discharge light sources, ballast/starting system, and interconnecting wiring.

3.2 DISCHARGE SOURCE

An electric light source in which light is produced by a stabilized arc.

3.3 RUN-UP TIME

The period of time between when the DFL system is switched ON and when the DFL system reaches a specified output level.

3.4 HOT RESTRIKE

The ability of a DFL system to restart operation, within a specified time period, after being switched OFF from a steady-state (“hot”) condition.

3.5 PHOTOMETRIC MAINTENANCE

Change in luminous intensity (DFL system) or luminous flux (light source) during operational life.

3.6 SUBSYSTEM

A component or assembly of components, which comprise a portion of the entire system (assembly).

3.7 LIGHT SOURCE RATED LABORATORY LIFE

A claim made by the manufacturer of operating time and starting cycles, under laboratory test conditions, over which at least 50% of the light sources will meet the life test performance specifications in this standard.

3.8 COLOR RENDERING INDEX (CRI), Ra

A quantitative measure of the color appearance of objects under a given light source in comparison with their color appearance under a reference or standard illuminant.

3.9 ULTRAVIOLET RADIATION

Radiation in the spectral region between 100 nm and 400 nm. Definitions and terminology are adopted in accordance with IES RP-27.1-05.

3.10 STEADY STATE

A condition under which the light output of the device is considered to be stable or changing at such a slow rate as to be insignificant. This condition is generally measured in terms of a maximum percent change per time period. Steady-state parameters are established by allowing the system to operate for a designated time after being switched ON.

3.11 BALLAST (AUTOMOTIVE BALLAST)

A device for stabilizing the operating characteristics of a discharge lamp. The ballast contains all the necessary circuitry to start a lamp and cause it to operate within a specified power profile range. It controls the required light output characteristics of the automotive discharge lighting system. The ballast may consist of one or more separate components.

3.12 SPECTRAL IRRADIANCE, $E\lambda(\lambda)$

The spectral concentration of irradiance in accordance with ANSI/IESNA RP-16-96.

3.13 SPECTRAL LUMINOUS EFFICIENCY FUNCTION, $V(\lambda)$

Standard spectral efficiency function for the human eye under photopic conditions as defined by ANSI/IESNA RP-16-96.

3.14 COLOR CONTENT (RED)

The percentage of total visible light energy in the spectral region of 610 to 780 nm.

4. LIGHTING IDENTIFICATION CODES, MARKINGS, AND NOTICES

4.1 Lamps may be marked in accordance with SAE J759 for the applicable forward lighting system and discharge system, “HG.”

4.2 The DFL system shall contain a label indicating the presence of high voltage, e.g., the international electric shock hazard symbol (“lightning bolt”) per ANSI Z535.4.

4.3 Subsystem components shall be marked per 49 CFR 564 Part 564 for light sources and ballast subsystems.

4.4 If applicable, subsystem components shall be marked for mercury content per ANSI Z535.4.

5. TESTS

Unless otherwise indicated, all sample DFL systems shall be seasoned at design voltage and steady operation for 20 hours prior to being subjected to the tests that follow. Alternatively, these tests shall be carried out with light sources which have been seasoned for a minimum of 15 cycles having the following switching cycle: 45 minutes on, 15 seconds off, 5 minutes on, 10 minutes off.

The power supply used in a test shall be capable of supplying the proper current the subsystem requires during the specified conditions.

A new DFL system may be used for each test.

5.1 Light Source Photometry

5.1.1 Nominal Operating Position

The nominal operating position shall be horizontal within ±10 degrees with the lead wire down. Seasoning and testing positions shall be identical. If the lamp is accidentally operated in the wrong direction, it shall be re-seasoned before measurements begin. During seasoning and measurements no electrically conducting objects shall be allowed within a cylinder having a diameter of 32 mm and a length of 60 mm concentric with the reference axis and symmetric to the arc. Stray magnetic fields shall be avoided.

If the light source is part of an integral assembly with other electronics, the accompanying components shall be shielded (covered) in such a manner that the transmission and absorption of these components is nulled (measurement system calibration to “zero” components) in determination of the flux measurement.

5.1.2 Test Wattage

For the photometric test, the ballast output wattage under steady-state conditions shall meet the system rated wattage specifications in Table 1.

NOTE: The input wattage to the ballast is typically higher.

5.1.3 Stabilization

Before any measurement, the light source shall be stabilized for a period of 20 minutes.

5.1.4 Luminous Flux Measurement

The test shall be conducted in accordance with IES Approved Method for Electrical and Photometric Measurements of General Service Incandescent Filament Lamps, IES Lighting Handbook, Reference Volume, Illuminating Engineering Society, New York, NY. Procedure LM-45.

5.1.5 Spherical Color

The color of the light source shall be measured in an integrating sphere using a measuring system which shows the CIE chromaticity coordinates of the received light with a resolution of ±0.002.

Table 1 - Luminous flux requirements

Design Designation[a]	Alternate Designation (ANSI)	Light Source Voltage[b] [V]		Rated Wattage [W]		Rated Luminous Flux at rated Wattage [lm]		Accurate Rated Luminous Flux [lm]		Rated Average Life[d] [hours]	Cap (Base)	Cap (Base) Number[e]
D1R	-	85	±17	35	±3.0	2800	±450[c]	2800	±150[c]	2000	N/A	Pk32d-3
D1S	-	85	±17	35	±3.0	3200	±450	3200	±150	2000	N/A	Pk32d-2
D2R	9706	85	±17	35	±3.0	2800	±450[c]	2800	±150[c]	2000	Axial	P32d-3
D2S	9705	85	±17	35	±3.0	3200	±450	3200	±150	2000	Axial	P32d-2
D3R	-	42	±9	35	±3.0	2800	±450[c]	2800	±150[c]	2000	N/A	Pk32d-6
D3S	-	42	±9	35	±3.0	3200	±450	3200	±150	2000	N/A	Pk32d-5
D4R	-	42	±9	35	±3.0	2800	±450[c]	2800	±150[c]	2000	Axial	P32d-6
D4S	-	42	±9	35	±3.0	3200	±450	3200	±150	2000	Axial	P32d-5
D5S		12	±24	31	Max	2000	±300	2000	±100	2000	N/A	Pk32d-7
D6S		42	±9	25	±3.0	2000	±300	2000	±100	2000	Axial	P32d-1
D7S		42	±9	28	Max	2000	±300			2000	N/A	Pk32d-4
D8S		42	±9	25	±3.0	2000	±300	2000	±100	2000	N/A	Pk32d-1
D8R		42	±9	25	±3.0	1900	±300[c]	1900	±100[c]	2000	N/A	Pk32d-8
D9S[f]		34	±6	27	±3.0	2000	±300	2000	±100	2000	N/A	Pk32d-9
		38	±8	35	±3.0	3000	±450	3000	±150	2000		

[a] 49 CFR 564, UN Regulation 99, and UN R.E.5 designation.
[b] At rated design wattage.
[c] With opaque coating.
[d] Minimum laboratory life, Tc.
[e] Cap data from IEC 60809.
[f] Two operating modes.

5.2 Light Source Starting Procedures - Initial Run-Up and Hot Restrike

5.2.1 Nominal Position

See 5.1.1.

5.2.2 Luminous Flux Run-Up Measurement

The output flux of the light source shall be measured and recorded as a function of time (no less than 0.1 second intervals) until steady-state operation of the subsystem is achieved.

5.2.3 Initial Run-Up

The initial (cold) run-up test shall be applied with light sources, which have not been used for a period of at least 1 hour prior to the test. The subsystem shall be measured at “cold” run-up continuously until the light output reaches a steady state.

5.2.4 Hot Restrike

The subsystem shall be operated for at least 20 minutes. Then the supply voltage to the ballast shall be switched off for 10 seconds and be switched on again.

5.3 DFL System Photometry

5.3.1 A seasoned light source(s) shall be chosen which meets the requirements for the accurate rated luminous flux according to Table 1 at the system rated wattage. A ballast which can be adjusted to the wattage specified in Table 1 may be used. The source(s) shall be placed in the DFL system(s) to be tested.

5.3.2 The system rated voltage shall be applied to the DFL system and the system shall be aimed. After 20 minute stabilization, photometer the DFL system per SAE J1383 procedures. Photometric measurements shall be made at a minimum distance of 18.3 m (60 feet) from the unit.

5.3.3 Multiple measurements can be made using the same DFL system with various rated light sources (per 5.1) or a chosen rated light source (per 5.1) may be used to test multiple DFL systems. The DFL system shall be measured and recorded at the nominal voltage specified and the minimum and maximum voltage values designated for stabilized light output for the particular DFL system under test.

5.4 DFL System Starting Procedures - Initial Run-Up and Hot Restrike

5.4.1 Set-Up

The DFL system shall be held in its nominal operating position and mechanically aimed with a photocell or cells at the test points shown in Table 2. Tests shall be conducted at room temperature (25 °C ± 5 °C), design voltage ±0.1 V, and for a duration required to obtain a reading. The response time of the measurement instrument should be less than 0.1 second.

Table 2 - Test points for DFL system starting tests

Low Beam	High Beam
1.5 D - 2 R	H - V

5.4.2 Initial Run-Up

The initial run-up test shall be applied with light sources, which have not been operated for a period of at least 1 hour prior to the test. The DFL system shall be activated and the luminous intensity at the photometric test points of Table 2 sampled and recorded for each headlamp from initial actuation through steady-state operation for the specific lamp type specified in Table 3. The DFL system is then turned off.

Table 3 - Light output characteristic during start-up

DFL System Type	Time (Seconds)	Low Beam Intensity (cd)	High Beam Intensity (cd)
non-continuous low beam	0.5 1.5	5000 (3125) 10000 (6250)	15000 (9375) 30000 (18750)
continuous low beam	4.0	10000 (6250)	30000 (18750)

NOTES:
Each beam should be measured at the point prescribed in Table 2 with the other beam blocked or not operating.
Values in ( ) are for D5, D6, D7, D8, D9 systems rated at 2000 lumens.

5.4.3 Hot Restrike

The DFL system shall be energized for 20 minute minimum. After this time period, a restart test shall be conducted once for each time interval as indicated in Table 4.

Table 4 - Restart cool down times

Interval	Time (seconds)
1	1
2	4
3	10
4	30
5	60

The DFL system shall be switched off for the period of time indicated in Table 4. The DFL system shall be energized and the luminous intensity at the test points shown in Table 2 sampled. For DFL systems designed to have the low beam on continuously, the low beam lamp shall be operated during the test. However, only the photometric characteristics of the high beam switching shall be measured.

5.5 Red Spectral Content

A spectrophotometric method shall be used to check the red spectral content, k_{red}, of the light from the light source for compliance with minimum red content specifications. Refer to ASTM E308-15 for more details on spectrophotometric measurement.

$$k_{red} = \frac{\int_{\lambda=610nm}^{780nm} E_e(\lambda)V(\lambda)d\lambda}{\int_{\lambda=380nm}^{780nm} E_e(\lambda)V(\lambda)d\lambda} \quad \text{(Eq. 1)}$$

where:

$E_e(\lambda)$ [W/nm] = spectral distribution of radiant flux

$V(\lambda)$ = spectral luminous efficiency

λ [nm] = wave length

5.6 Color in Beam Pattern

The color coordinates at the test points in Table 2 (beam pattern) shall be tested per SAE J578.

5.7 Ultraviolet (UV) Test

The UV energy shall be measured per ANSI C78.376.

$$k_{UV} = \frac{\int_{\lambda=250nm}^{400nm} E_e(\lambda)S(\lambda)d\lambda}{k_m \int_{\lambda=380nm}^{780nm} E_e(\lambda)V(\lambda)d\lambda} \quad \text{(Eq. 2)}$$

where:

$E_e(\lambda)$ [W/nm] = spectral distribution of radiant flux

$V(\lambda)$ = spectral luminous efficiency

λ [nm] = wave length

$S(\lambda)$ = spectral weighting function

K_m = 683 [lm/W] is the photometric radiation equivalent

The value shall be calculated using intervals of 1 nm. The UV-radiation shall be weighted according to the values as indicated in Table 5.

Table 5 - UV weighting factors

l	S(λ)	l	S(λ)	λ	S(λ)
250	0.430	305	0.060	355	0.00016
255	0.520	310	0.015	360	0.00013
260	0.650	315	0.003	365	0.00011
265	0.810	320	0.001	370	0.000090
270	1.000	325	0.00050	375	0.000077
275	0.960	330	0.00041	380	0.000064
280	0.880	335	0.00034	385	0.000053
285	0.770	340	0.00028	390	0.000044
290	0.640	345	0.00024	395	0.000036
295	0.540	350	0.00020	400	0.000030
300	0.300				

NOTES:
Wavelengths chosen are representative; other values should be interpolated.
Values according to "IRPA/INIRC Guidelines on Limits of Exposure to Ultraviolet Radiation" [or other reference].

5.8 Light Source Life and Photometrical Maintenance

5.8.1 Nominal Position

The nominal position shall be horizontal within ±10 degrees with the lead wire down.

5.8.2 Test Voltage

The voltage for the life test shall be design voltage ±0.1 VDC as measured at the terminals of the ballast.

5.8.3 Test Operating Cycle

The light source shall be energized per the operating cycle shown in Table 6.

5.8.4 Photometric Maintenance

Initially and after 75% of rated laboratory life, the light source shall be subjected to the tests of 5.1.

5.8.5 Reported Life Value

The test life shall be reported as the accumulated “on” time hours up to the point at which it fails to start after any “off” period or the point at which it last meets all the requirements of 6.8.

Table 6 - Life test cycle

On-Time (Minutes)	Off-Time (Minutes)
20	0.2
8	5
5	3
3	3
2	3
1	3
0.5	3
0.3	0.3
20	4.7
20	15

NOTE:
Properties of this life test cycle:
Total cycle time = 120 minutes
On time = 79.8 minutes
Percent on time = 66.5%
Off time = 40.2 minutes
Cold starts per hour of on time = 6.01
Hot restarts per hour of on time = 1.51

5.9 Environmental Tests

Testing shall be accomplished on a complete DFL system, i.e., ballast, interconnections, and headlamp unless otherwise specified in the specific test.

5.9.1 Leakage Current/Breakdown

The test shall be made on a system positioned in its design orientation by completely covering the exterior of the DFL system to be tested with aluminum foil. The foil is to be connected to a current-sensing device, which terminates at the power source common (chassis ground). The sensing device shall be a non-inductive resistor of 1000 Ω. The leakage current occurring during starting and operating (transient and steady state) shall be measured using an oscilloscope with a bandwidth capability five times the bandwidth being measured for the observed frequencies and rise times. Current readings shall be recorded during the first 10 seconds of the initial start. The unit shall then continue to operate for 30 minutes, be turned off, and immediately restarted. The current readings shall again be recorded during the first 10 seconds after restart. After completion of this procedure, and without submitting the unit to any other tests, the environmental test shall be carried out on the unit. Within 30 minutes (maximum) of completion of the specified environmental test, the breakdown test shall be repeated. The final readings are then compared with the respective (initial and 30 minute) readings made before the environmental test.

5.9.2 Thermal Cycle

The DFL system shall be tested according to SAE J2357 thermal cycle test.

5.9.3 Thermal Shock

The DFL system shall be tested according to SAE J2357 thermal shock test.

5.9.4 Humidity/Moisture

The DFL system shall be subjected to the test described in SAE J2357 humidity/moisture test like a non-discharge headlamp or according to its specific function. The DFL system shall be tested before and after the tests in accordance with the breakdown test in 5.9.1. In addition, electronic components shall be subjected to the test in SAE J2357 humidity/moisture test for components, if appropriate.

5.9.5 Internal Heat Test

The DFL system shall be subjected to the conditions specified in SAE J575 internal heat test for headlamp applications or according to its specific function.

5.9.6 Dust Test

The DFL system shall be subjected to the conditions specified in SAE J575 dust test for headlamp applications or according to its specific function.

5.9.7 Corrosion Test

The DFL system shall be subjected to the test described in SAE J2357 corrosion test like a non-discharge headlamp or according to its specific function. In addition, electronic components shall be subjected to the test in SAE J2357 corrosion test for components, if appropriate.

5.9.8 Chemical Resistance Test

The DFL system shall be subjected to the test described in SAE J2357 chemical resistance test like a non-discharge headlamp or according to its specific function. In addition, electronic components shall be subjected to the test in SAE J2357 chemical resistance test for components, if appropriate.

5.9.9 Vibration Test

The DFL system shall be subjected to the conditions specified in SAE J575 vibration test. The DFL system shall be tested before and after the vibration test in accordance with the breakdown test in 5.9.1.

In addition, electronic components shall be subjected to the test in SAE J2357 vibration test for components, if appropriate.

5.10 Electromagnetic Interference

5.10.1 Conducted Emissions

DFL system shall be tested to conducted emissions testing per sAE J2357.

5.10.2 Radiated Emissions

DFL system shall be tested to radiated emissions testing per SAE J2357.

5.11 Electromagnetic Susceptibility

5.11.1 Conducted Immunity

DFL system shall be tested to conducted immunity testing per SAE J2357.

5.11.2 Radiated Immunity

DFL system shall be tested to radiated immunity testing per SAE J2357.

5.11.3 Electrostatic Discharge

DFL system shall be tested to electrostatic discharge testing per SAE J2357.