Specification for Testing Automotive Miniature Bulbs

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SPECIFICATION FOR TESTING AUTOMOTIVE MINIATURE BULBS

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SUMMARY OF CONTENTS

1. SCOPE*

The procedures contained in this specification cover the laboratory testing of miniature incandescent bulbs for use in automotive illumination and signaling applications. The following tests shall be run whenever the following occurs:

- New bulb design
- Design or process change made to an existing bulb, which could affect the outcome of the test.
- The completion of one calendar year as noted in the following Test Schedule Table. Process control data is acceptable.

Test Schedule Table

Test Title	Yearly
Physical Dimensions	X
Mean Spherical Candela	X
External Visual Examination	X
Crush	X
Thermal Shock	X
Bayonet Base Retention	X
Pin Removal	X
Wedge Base Retention	X
Lead Wire Bend	X
Lead Wire Pull	X
Natural Amber Color	X
Coated Amber Color • Integrated Color • Visual Color • Point Color • Color Maintenance and Coating Durability • Amber Coating Chemical Resistance	 X X X
Resonant Frequency	
Aged Resonant Frequency	
Salt Spray	
Wire Loop Pull	X
Outgassing/Heat	
Laboratory Life	
Accelerated Life	X
Luminous Intensity Maintenance	X
Vibration Durability	
Shock	
Aged Vibration Durability	

2. REFERENCE STANDARDS

- Chrysler, Ford, and General Motors Advanced Product Quality Planning and Control Plan Reference Manual
- Measurement Systems Analysis Reference Manual (AIAG)
- SAE J1739, Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA)
- Chrysler, Ford, and General Motors Production Part Approval Process Manual
- ANSI (C78.390)
- ASTM B 117 (Standard Practice for Operating Salt Spray [Fog] Testing Apparatus)
- Chrysler, Ford, and General Motors Quality System Requirements—QS-9000 Manual
- SAE J573, Miniature Lamp Bulbs
- SAE J1330, Photometry Laboratory Accuracy Guidelines
- SAE J578, Color Specification

Unless otherwise specified or required by law, suppliers should use the most recent versions of any applicable reference documents or standards.

3. GENERAL REQUIREMENTS

3.1 Record Retention

Supplier must maintain a file for the storage of laboratory reports and calibration records, and establish a record retention policy concerning these records. These records need not follow a standard format but must present the required data in an orderly professional manner. The file must be made available to any and all PPAP approver personnel upon request, including—but not limited to representatives from the following functions: product engineering, purchasing, quality, and reliability.

3.1.1 Objectives of Record Retention

The following are the main objectives for retention of test documents or records:

1. Retain records that will evidence compliance so that the supplier can appropriately respond when or if product compliance is challenged. Files must exist for the storage of all laboratory records, data, and calibration records. The files must be available at any time for audit or inspection.
2. Retain records as needed to assist in evidencing the exercise of “due care” in matters relating to product compliance, government requirements, or product liability.
3. Comply with statutory requirements for the maintenance and retention of specific records.

3.1.2 Retention Methods

Methods of retention may include retention of original documents, the use of film, or electronic storage equipment. Store records so that they are accessible in a reasonable amount of time. Storage areas should provide adequate protection from unauthorized access, moisture, and fire.

3.2 Sample Documentations and Retention*

Engineering test samples must be identified by ANSI Trade Number and serial number unless otherwise noted. Documentation must identify the type of test performed and describe special tests that are not a part of this specification.

3.2.1 Required Data Package

Supplier must submit the data package for the appropriate level of submission to the PPAP approver’s responsible engineer and purchasing division for approval signatures.

3.2.2 Sample Selection

Test bulbs referenced in this specification are to be selected from the same "Test Lot". The minimum “Test Lot” is defined as one hour of production. Test bulbs are to be subjected to production intent processing, including final packaging.

NOTE: A test sample size of 10 would consist of one sample piece being removed from the test lot, every six minutes of production, for a one- hour production run. It is important that the test samples be identified as to location, within the test lot, throughout all testing.

3.2.3 Sample Retention

Samples tested to attain part approval must be retained by the bulb manufacturer for a period of time specified in the PPAP Manual.

3.3 Power Sources

Supplier must use voltage regulated direct current (DC) power sources for all tests to simulate an automotive battery and charging system.

3.3.1 Output Current

The power source must be capable of supplying a continuous output current as required by the design loads, including inrush current. Where required to simulate automotive inrush current conditions, an automotive battery or batteries with sufficient cold cranking amps may be connected in parallel with the power supply.

3.3.2 Output Voltage

The power source must be capable of supplying an output voltage that must not deviate more than 1.0 volt from the nominal setting over the entire load range (including surges). The power source must recover 63% of its maximum excursion within 5.0 milliseconds. Ripple voltage must not exceed 300 mV peak to peak.

Power supplies used for photometric measurements must conform to SAE J1330.

3.4 Equipment Tolerances

Supplier must use test setups and equipment capable of measuring test parameters (expressed in nominals) within the limits found in the Equipment Tolerances Table.

Equipment Tolerances Table

Test Chamber Temperature	nominal ± 3°C
Time	nominal ± 0.5%
Forces	nominal ± 0.01 N
Distances	nominal ± 0.01 mm
Voltages	nominal ± 0.01 V for photometrics
	nominal ± 0.1 V for all other tests
Mean Spherical Candela	nominal ± 2.0%

NOTE: Not to be used for performance dependent variable (see Measurement Accuracy section).

3.5 Measurement Accuracy

Meters and gages used to assess the performance dependent variable, as defined by the basic function of the test sample, must be capable of measuring to one count less than the specified value. For example, even though a 0.1 mm and 0.10 mm wire might be the same diameter, calipers capable of 0.01 mm resolution may be used to measure the first wire, but a micrometer with 0.001 mm resolution is needed for the second wire.

3.6 Test Repeatability and Calibration

3.6.1 Equipment Repeatability

All measurement equipment used for product evaluation must be repeatable to within 20% of the part tolerance according to Chrysler, Ford, and General Motors Measurement Systems Analysis Reference Manual (AIAG).

3.6.2 Equipment Calibration

Equipment used for measurement or verification of measurement must be periodically calibrated to known standards. Calibration interval must be consistent with industry practices but may not be more than 18 months.

3.6.3 Laboratory Masters

Bulbs which are traceable to known standards are laboratory masters. Each supplier must use laboratory masters for comparison measurements, calibration of test equipment, and for evaluating long-term drift in test equipment.

3.7 Test Default Conditions*

When specific test conditions are not given, the following basic conditions apply:

- Test the bulb with the base and filament parallel to the direction of excitation as shown in figure Filament Orientation.
- Perform tests or measurements at the following ambient conditions:

  Room Temperature ..... ≥ 20°C
  Atmospheric Pressure ..... 650 – 800 mm Mercury

- Conduct tests or measurements using the bulbs design voltage as published by the American National Standards Institute, Inc., (ANSI) in Special Report 25, ANSI Assigned Miniature Lamp Codes.
- Season the bulbs for 1% of the average life, 10 hours maximum at design voltage, or an equivalent period at a higher (forced) voltage as defined in Accelerated Life section. Note the seasoning method used on the test report.
- Whenever bulbs are operated at higher than design voltages, switch them on at their design voltage for at least 50 milliseconds and then step up to the appropriate design voltage. This will limit the inrush current to the design level.

3.8 Test Sharing Within Bulb Families

The results of tests performed on one bulb type may, in some cases, be used to indicate the capability of another bulb type within the same bulb family. For example, a crush test performed on a clear, S-8 wedge bulb type may be used as a demonstration of the glass strength of all clear, S-8 wedge bulb types made by the same process from the same glass from the same source. Sound judgment must guide this practice. Bulbs within the same bulb family that share components such as glass envelopes, lead wires, filaments, bases, fill gases, etc., may be able to share test results. The PPAP approver will be the final authority on whether this surrogate data may be used.

3.9 Test Failure Procedure

Should a test fail, contact the requesting party to determine if the test is to be continued to gain additional product experience or if testing is to be suspended. When contact cannot be immediately made, stop the test until the requesting party can be contacted.

3.10 Control Plans*

Supplier must maintain a control plan, consistent with Chrysler, Ford, and General Motors Advanced Product Quality Planning and Control Plan Reference Manual, for each bulb type (or bulb family), that contains appropriate controls to ensure that all the significant/critical characteristics covered by the tests in this specification are met.

3.11 Reliability Programs and Methods

3.11.1 Reliability Growth and Ongoing Quality Improvements

Bulb suppliers must establish and implement a plan to improve demonstrated product quality and reliability. They must establish procedures for analyzing and correcting end-of-line defects and predominant failure modes identified by the field return program. True reliability growth occurs when design changes to the bulb or manufacturing process are made to eliminate the failure modes.

3.11.2 Notification of Process Changes

Suppliers must notify the PPAP approver of manufacturing process, material, or design changes to determine if resubmission for PPAP approval is required.

3.11.3 Quality/Reliability Improvement Tools

Suppliers must use appropriate methods to improve the quality and reliability of their products in accordance with QS-9000. Examples of such methods are Field Return Programs, Design Failure Mode Effects Analysis (DFMEA), Process Failure Mode Effects Analysis (PFMEA), and Fault Tree Analysis (FTA) or Fishbone Diagrams. Further information on these methods is available from the Automotive Industry Action Group (AIAG).

3.12 Hazardous Material Restriction

Any regulated substance that is identified by any federal, state, provincial, or local government unit or automotive manufacturer, shall not be used in the manufacturing process of any bulb.

Any bulb manufacturer that is currently supplying hazardous material in a component will submit a timeline to General Motors, Ford, and Chrysler for the removal of said product. Interim approvals for bulbs will be handled on an individual basis designated by the individual automotive manufacturer. (Changed Paragraphs)

4. PHYSICAL PERFORMANCE

These tests are intended to measure the innate characteristics of the bulbs. All data must be recorded according to Record Retention section.

4.1 Physical Dimensions

The purpose of this examination is to verify all of the physical dimensions of the bulb.

4.1.1 Test and Measurement Apparatus

The equipment used for this examination must be capable of determining the actual dimensions within the tolerance limits specified in Measurement Accuracy section. This equipment typically includes micrometers, calipers, gages, and optical profile projectors.

4.1.2 Procedure

1. Supplier must measure a minimum of 10 bulbs chosen per description in Sample Selection section.
2. Record the data according to Record Retention section.

4.1.3 Acceptance Criteria

Any bulb with a dimension(s) outside the specified limits constitutes a failure.

NOTE: Light Center Length (LCL)

LCL is measured from the geometric center of the light source to a reference point on the bulb base (Ref. SAE J573, IEC 60061). The base reference points for the two most common types of automotive bulbs are as follows:

- Bayonet Base .....top of base reference pins
- Wedge Base .....center of notch

Control of the LCL is required to ensure consistent and uniform light output from the various bulb applications on the vehicle.

4.2 Mean Spherical Candela

4.2.1 Test and Measurement Apparatus

An integrating optical sphere with the appropriate power supply, optical detector, photometer, and traceable standard light source are required. The following test equipment or equivalent is recommended:

Mean Spherical Candela Table

Equipment	Model No.
20-inch Hoffman Integrating Sphere	IS-20-PS
Hoffman Photodetector	85-P
Hoffman System Photometer	TSP-83-A

4.2.2 Procedure

1. Select 10 bulbs chosen per the Sample Selection section.
2. Season the bulbs as described in Test Default Conditions section.
3. Measure the MSCP at design voltage in a properly calibrated photometer in accordance with accepted photometric procedures.

4.2.3 Acceptance Criteria

Any bulb with a MSCD or current value outside the specification limits constitutes a failure.

4.3 External Visual Examination

The purpose of this examination is to verify that the materials, design, construction, markings, and workmanship of the bulb are in accordance with the product design specification. Record the data according to Record Retention section.

4.3.1 Test and Measurement Apparatus

Use optical equipment having magnification capability of ≥ 1.5X.

4.3.2 Procedure

1. Select 10 bulbs per Sample Selection section.
2. Examine selected bulbs using the appropriate magnification device.

4.3.3 Acceptance Criteria

1. Bulb design, identification, or markings (content, placement, and legibility) shall be in accordance with the applicable specification.
2. There shall be no visible evidence of corrosion, contamination, breakage (including grossly bent or broken lead wires), defective, or damaged plating (peeling, flaking, or blistering), or exposed base metal
3. External wires shall be intact and aligned in their specified location and not exhibit sharp or unspecified bends
4. External wires shall be free of foreign material such as paint or other permanently adherent deposits
5. There shall be no evidence of any nonconformance with the applicable product design specification or absence of any required feature
6. There shall be no evidence of defects or damage resulting from manufacturing, handling, testing, or shipping that might impair the performance of the bulb
7. There shall be no fractured glass.
8. There shall be no glass missing from the press area of a wedge bulb, even if it does not affect the seal of the bulb
9 “Flash” on glass or plastic parts shall not exceed 0.20 mm unless otherwise noted.

4.4 Crush Strength

This test is intended to verify that the glass envelope of the bulb is strong enough to withstand normal handling and insertion operations.

4.4.1 Test and Measurement Apparatus

Use the following equipment, or equivalent, for the crush test:

Crush Table

Equipment	Model
Chatillon Universal Test Stand	UTSE-2
Load Cell	550 lbs.
Crush Fixture	figure Crush Test Fixtures

4.4.2 Procedure

1. Test a total of 50 bulbs selected per the Sample Selection section.
2. Place a test bulb in the appropriate crush fixture (see examples in figure Crush Test Fixtures).
3. Center the test bulb under the ram, start the ram down at 32 mm/min ± 5% (1.25 in./min) and record the force, in newtons, required to break the glass.
4. Record the data according to Record Retention section.
5. Repeat for each of the 50 test samples.

4.4.3 Acceptance Criteria

The criteria for the 50-bulb sample are as follows:

1. Bulb types ≥ 16mm (5/8inch) in maximum diameter
   a. Zero bulbs broken at less than 110 N (24.7 lbs)
   b. A maximum of 5 bulbs broken at less than 155 N (34.8 lbs)
2. Bulb types < 16mm (< 5/8inch) in maximum diameter and > 5mm (> 3/16inch)
   a. Zero bulbs broken at less than 75 N (16.9 lbs)
   b. A maximum of 5 bulbs broken at less than 100 N (22.5 lbs)
3. Bulb types ≥ 5mm (3/16inch) in maximum diameter
   a. Zero bulbs broken at less than 35 N (7.9 lbs)
   b. A maximum of 5 bulbs broken at less than 50 N (11.2 lbs)

4.5 Thermal Shock

Stresses are produced in the glass of a bulb during the manufacturing process. The location and magnitude of these stresses affect the strength of the glass envelope. This test is intended to expose excess stresses remaining in the glass after the manufacturing process is complete.

4.5.1 Test and Measurement Apparatus

- 10x magnifier
- Hot and cold medium with temperature differential of 96°C minimum.

4.5.2 Procedure

1. Test a total of 10 room-temperature bulbs selected from the lot being tested.
2. Submerge the , bulbs in a hot liquid or hot solid medium (sand) for 10 minutes.
3. Remove the bulbs from the hot medium, and immediately submerge the samples for 1 minute in a cold liquid medium.
4. Allow bulbs to dry and hold at room temperature for 5 days.
5. Light up bulbs at design voltage for 60 seconds.
6. Visually inspect using 10x magnifier.
7. Record data.

4.5.3 Acceptance Criteria

No bulbs may “smoke,” “blacken,” exhibit cracks in the glass (when viewed using a 10x magnification) or fail to provide light output.

4.6 Bayonet Base Retention

This test is applicable to bulbs with metal bayonet bases. The objective is to evaluate the strength of the attachment between the glass bulb and the metal base.

4.6.1 Test and Measurement Apparatus

Use the following equipment, or equivalent, for testing base retention:

Bayonet Base Retention Table

Equipment	Requirements
Torque wrench with dial readout to indicate max-min torque	0 to 2 Nm
Torque wrench sockets to fit the various metal bases	Base sizes: BA9s, BA15s, BA15d, BAY15d
Leather gloves or cloth	
Humidity chamber	50°C & 90-100% humidity

4.6.2 Procedure

1. Select 10 bulbs per the Sample Selection section.
2. Condition the bulbs in a humidity chamber for 6 hours at 50°C and 90-100% relative humidity.
3. Allow the bulbs to dry at room temperature for 1 hour.
4. Hold the glass portion of the bulb in a leather glove or cloth.
5. Insert the metal base into the appropriate torque wrench socket and rotate the bulb until the metal base loosens from the glass envelope.
6. Record the data according to Record Retention section.
7. Repeat for each of the 10 test samples.

4.6.3 Acceptance Criteria

The base shall not loosen from the glass envelope with less than the minimum torque noted in the following table:

Bayonet Base Bulbs Table

Bulb Envelope	Base Type*	Min. Torque	
T-3-1/4	BA9s	0.5 (Nm)	4.43 (in-lbs)
T-3-1/2	BA9s	0.5 (Nm)	4.43 (in-lbs)
T-4-1/2	BA9s	0.5 (Nm)	4.43 (in-lbs)
G-6	BA9s, BA15s, BA15d, BAY15d	1.0 (Nm)	8.86 (in-lbs)
B-6	BA9s, BA15s, BA15d, BAY15d	1.0 (Nm)	8.86 (in-lbs)
S-8	BA9s, BA15s, BA15d, BAY15d	1.0 (Nm)	8.86 (in-lbs)

4.7 Pin Removal

This test is applicable to bulbs with metal bayonet bases. The objective is to evaluate the strength of the attachment between the metal base and the locator pins.

4.7.1 Test and Measurement Apparatus

- Chatillon Scale – Model USTM or equivalent
- Metal box and test plate as shown in figures Pin Removal Test Fixture and Pin Removal Test Plate.

4.7.2 Procedure

1. Select 50 bulbs per the Sample Selection section.
2. Place each test bulb in the test plate.
3. Place test plate and bulb on steel box as shown in Pin Removal Test Fixture.
4. Set the test setup on the scale table center under the ram.
5. Start the ram down at a speed of 32mm/minute ± 10% (1.25 in/minute ± 10%).
6. Observe load required to remove the pins from the base.
7. Record the data according to Record Retention section.
8. Repeat for all 50 bulbs.

4.7.3 Acceptance Criteria

No bulbs shall exhibit pin removal at a force less than 18 kg (40 lbs).

4.8 Wedge Base Retention

This test determines the force required to separate the plastic base (where applicable) from the glass envelope in the direction of socket extraction. A margin safely above socket retention is required. This test applies to bulbs with plastic bases that are intended to be inserted into separate sockets (for example, S-8 Wedge or GT-8).

4.8.1 Test and Measurement Apparatus

Use the following list of equipment or equivalent:

- Chatillon Digital Force Gage – Model LTCM-3
- Apparatus shown in Wedge Base Retention Fixture

4.8.2 Procedure

1. Select 10 bulbs per Sample Selection section.
2. Measure the force required to separate the base from the glass bulb using a force gauge.
3. Record the data according to Record Retention section.
4. Repeat the test for all 10 test samples.

4.8.3 Acceptance Criteria

The force measured must be no less than 4.5 kg (10 lbs).

4.9 Lead Wire Bend

This test is applicable only to miniature bulbs with external wires designed to be soldered or welded to an assembly or subassembly (for example: wire terminal, bi-pin, etc.). It is intended to determine the ability of the bulb to withstand bending forces, which may occur during normal handling and assembly processes.

4.9.1 Test and Measurement Apparatus

Use a suitable fixture for securing the bulb and measure the bend angle specified.

4.9.2 Procedure

1. Select 10 bulbs per Sample Selection section.
2. Bend the lead wire 90° at a point no more than 1.50 mm (0.060 in.) from the exit of the lead wire out of the glass.
3. Bend the lead 180° in the opposite direction, then return the lead to its original position.
4. Record the data according to Record Retention section.
5. Repeat test for all 10 test samples.

4.9.3 Acceptance Criteria

Before and after the test, there shall be no evidence of mechanical damage or air leaks during a 60-second light-up at design voltage.

4.10 Lead Wire Pull

This test is applicable only to miniature bulbs with external wires designed to be soldered or welded to an assembly or subassembly (for example: wire terminal, bi-pin, etc.). Its purpose is to determine the ability of the bulb to withstand pulling forces, which may occur during normal handling and assembly processes.

4.10.1 Test and Measurement Apparatus

Use a suitable fixture for securing the bulbs and apply the specified weight or force to the wire leads.

4.10.2 Procedure

1. Select a total of 10 bulbs per Sample Selection section.
2. Apply a parallel force of 2.27 ± 0.14 kg (5.0 ± 0.1 lbs.) to each lead for 60 seconds.
3. Record the data according to Record Retention section.
4. Repeat test for each of the 10 test samples.

4.10.3 Acceptance Criteria

Before and after the test, there shall be no evidence of mechanical damage or air leaks during a 60-second light-up at design voltage.

4.11 Color*

This test is applicable to colored bulbs (i.e. other that clear) including those that change color appearance when lit.

4.11.1 Test and Measurement Apparatus

For color measurement, use a colorimeter or similar equipment capable of taking a color measurement within two seconds and having an accuracy of at least +/- .002 in terms of the 1931 CIE chromaticity coordinates.

4.11.2 Procedure

1. Select 20 bulbs per Sample Selection section.
2. Season 20 bulbs as described in Test Default Conditions section.
3. Allow to cool to room temperature.
4. Perform the tests listed below and record the data:

4.11.2.1 Visual

Visually inspect the color of the bulb for variation or inconsistencies. A tester may be used to aid this evaluation.

4.11.2.1.1 Acceptance Criteria

Color must be uniform as required by the approving engineer.

4.11.2.2 Integrated Color

Place the bulbs one at a time in an integrating optical sphere.

Measure the color emitted by the bulb after the filament (major filament for dual filament bulb) has been operated at design voltage for a period of 60 +/- 3 seconds and again after a total operational time of 300 +/- 3 seconds.

4.11.2.2.1 Acceptance Criteria

Any measurement outside the applicable SAE J578 chromaticity coordinate boundaries constitutes a failure of this test.

Amber	Red
Y= 0.39 (red boundary)	Y= 0.33 (yellow boundary)
Y= 0.79 – 67X (white boundary)	Y= 0.98 – X (purple boundary)
Y= X – 0.12 (green boundary)	

4.11.2.3 Point Color

a. For new bulb designs use all 20 samples, otherwise select 5 bulbs per test lot definition from the 20 samples.
b. Mount the bulb firmly as shown in figure Point Color. Position the bulb to measure the color at point 1.
c. Measure the color emitted by the bulb after the filament (major filament for dual filament bulbs) has been operated at design voltage for a period 60 +/- 3 seconds and again after a total operational time of 300 +/- 3 seconds.
d. Repeat this procedure reorienting the bulb to measure the color of points 2 through 8, allowing the bulb to cool at room temperature for at 10 minutes between each measurement.

4.11.2.3.1 Acceptance Criteria

Same as Acceptance criteria for integrated color.

4.12 Color Maintenance and Coating Durability*

This test applies to colored bulbs (i.e. other than clear bulbs) to insure the color is permanent over the temperature and the humidity conditions in most applications.

4.12.1 Test Measurement Apparatus

- Enclosure A of Figure Heat Test Enclosures.
- A test chamber for temperature and humidity ranges of -40°C to 50°C and 40% R.H. to 98% R.H.
- Power Supply.

4.12.2 Procedure

1. Select 10 bulbs that have passed the color test.
2. Mount each bulb in the enclosure and operate the bulb for the 240 hour test consisting of the following segments, which run simultaneously:
   a. Temperature: Keep the chamber at room temperature for the first 11 hours. Increase the temperature to 50°C for the next 4 hours, allowing one of the 4 hours for the transition. Drop the temperature to minus 40°C for the next 8 hours, allowing two of the 8 hours for the transition. Allow the temperature to rise to room temperature for the final hour of the test.
   b. Humidity: Begin at 40% R.H. and remain constant for 5 hours. Increase the humidity to 98% for the next 7 hours, allowing one hour of the 7 hours for the transition. Decrease the humidity to 40% for 2 hours, allowing one hour of the 2 for the transition. The remainder of the test does not require control of the humidity.
   c. Bulb Cycle: Select the service for which the bulb is intended to function, i.e. Flashing or Continuous On. Operate the bulb using the 60-minute cycle for the selected service, for each hour of the 24 hour test.

Flashing

Time (minutes)	Major Filament (13.0 Volts DC)	Minor Filament (14.5 Volts DC)
0 to 15	flashing*	continuous on
15 to 20	15 / 15 **	off
25 to 50	off	continuous on
50 to 55	flashing	continuous on
55 to 60	off	off

Continuous On

Time (minutes)	Major Filament (13.0 Volts DC)	Minor Filament (14.5 Volts DC)
0 to 15	continuous on	continuous on
15 to 20	continuous on	continuous on
25 to 50	continuous on	continuous on
50 to 55	off	off
55 to 60	off	off

* The term flashing represents the standard flashing cycle of 90 flashes per minute.
** The term 15 / 15 represents flashing consisting of 154 seconds flashing and 15 seconds off. Flashing rate is 90 flashes per minute.

d. Test each bulb for 10 complete test cycles for a total of 240 hours.

4.12.3 Acceptance Criteria

After the cycles have been completed, the bulb color must meet the requirements of the Color section.

4.13 Color Chemical Resistance*

This test applies to bulbs, other than clear, to insure the color is not adversely affected by chemicals.

4.13.1 Procedure

1. Select 10 samples per Sample Selection section.
2. Season the bulbs as described in Test Default Conditions section.
3. Allow bulbs to cool to room temperature.
4. Wipe each bulb with a 6-inch square soft cotton cloth that has been saturated once in the following chemical listing in a container with 2 oz. of one of the test chemicals listed below.

Test Chemical Table

FLUID TYPE	FLUID DESCRIPTION
Brake Fluid	SAE RM66-04
Oil	ASTM IRM-902
Gasoline	ASTM Ref. Fuel C
Engine Coolant/ Anti-freeze	ASTM Serv. Fluid 104
Automatic Transmission Fluid	Citgo #33123
Windshield Washer Solvent	50% Isopropyl Alcohol + 50% Water
Power Steering Fluid	ASTM IRM-903
Diesel Fuel	90% IRM 903 + 10% P-Xylene
E85 Ethanol Fuel	85% Ethanol + 15% ASTM reference fuel C
Tar Remover	45% Xylene + 55% Petroleum base mineral spirits
Engine Cleaner	Tital Bafal – Parafin wax CH4, Ethylene Glycol, Benzene, detergent
Grease	Petroleum base

5. Wipe the bulb within 5 seconds of removing the cloth from the test chemical.
6. Repeat wiping that same bulb with a different chemical listed below.
7. Repeat steps 2, 3, and 4 until all 10 bulbs have been wiped using all chemicals.
8. After being wiped, each bulb shall be stored for 48 hours at room temperature and a relative humidity of 30% ± 10%.
9. At the end of the 48-hour period, the bulbs shall be wiped clean with a soft dry cotton cloth and visually inspected.

4.13.2 Acceptance Criteria

After the cycles have been completed, the bulb color must meet the requirements of the Color section.

4.14 Resonant Frequency*

Each bulb design has natural resonant frequencies. If the bulb is excited at one or more of these frequencies over long periods of time, the filament could be damaged because of metal fatigue at stress concentration points. This test is intended only to identify those resonant frequencies of a seasoned bulb for use in bulb assembly design.

4.14.1 Test and Measurement Apparatus

Use the following equipment, or equivalent, to determine the resonant frequency of the bulb. Alternative test equipment with appropriate procedures may be used, such as a spectrum analyzer, etc.

Resonant Frequency Equipment Table

Equipment	Requirements
Closed loop dynamic vibration equipment and auxiliary controller capable of vibrating in sinusoidal mode	Variable from 10 - 2000 Hz with tolerance of ± 4.0 dB and min. of 5G's
Strobe light to "freeze" the vibrating filament	
Fixture to rigidly mount the bulb to the vibration table	Bulb to be mounted with filament in both the parallel and perpendicular positions with respect to the direction of excitation

4.14.2 Procedure

1. Select 10 bulbs from the test lot and test them as follows
2. Season the bulbs as described in Test Default Conditions section.
3. Mount the bulb rigidly in the fixture with the filament and main bulb axis parallel to the direction of excitation.
4. Sweep the range from 50 to 1500 Hz and back to 50 HZ (15 minutes nominal each direction) with a 5.0 g (.176 ounces) vertical input while using a strobe light to “freeze” the vibration and to permit identification of all the resonant frequency ranges.
5. Record the range, both the starting and stopping frequencies, of each resonant harmonic according to Record Retention section. For purposes of this test, resonance starts when the filament or mount structure is moved approximately 1 filament coiled diameter (perpendicular to the axis of the filament) from its normal “static” position. It continues until the filament resumes its static position as shown in Resonant Frequency Test.
6. Repeat steps 1 through 3 with the filament mounted perpendicular to the direction of excitation.

4.14.3 Acceptance Criteria

There is no Acceptance criteria, report results.

4.15 Aged Resonant Frequency

Each bulb design has a natural resonant frequency that, if present over long periods of time, could damage or destroy the filament due to metal fatigue at stress concentration points. This test is intended only to identify those resonant frequencies of an aged bulb for use in bulb assembly design.

4.15.1 Test and Measurement Apparatus

Use the following equipment, or equivalent, to determine the resonant frequency of the bulb. Alternative test equipment with appropriate procedures may be used, such as a spectrum analyzer, etc.

Aged Resonant Frequency Table

Equipment	Requirements
Closed loop dynamic vibration equipment and auxiliary controller capable of vibrating in sinusoidal mode	Variable from 10 - 2000 Hz with tolerance of ± 4.0 dB and min. of 5G’s
Strobe light to “freeze” the vibrating filament	
Fixture to rigidly mount the mounted bulb to the vibration table	Bulb to be with filament in both the parallel and perpendicular positions with respect to the direction of excitation

4.15.2 Procedure

Select 10 bulbs that have passed the color test.

1. Operate the bulbs for B_{50} of laboratory life. Forced voltage may be substituted when correlation is established between laboratory life and accelerated life (see section Accelerated Life).
2. Mount the bulb rigidly in the fixture with the filament and main bulb axis parallel to the direction of excitation.
3. Sweep the range from 50 to 1500 Hz and back to 50 Hz (15 minutes nominal each direction) at 5.0 g (176 ounces) while using a strobe light to “freeze” the vibration and to permit identification of all the resonant frequency ranges.
4. Record the range, both the starting and stopping frequencies, of each resonant harmonic according to Record Retention section. For purposes of this test, resonance starts when the filament or mount structure is moved approximately 1 filament coiled diameter (perpendicular to the axis of the filament) from its normal “static” position. It continues until the filament resumes its static position as shown in figure Resonant Frequency Test.
5. Repeat steps 1 through 3 with the filament mounted perpendicular to the direction of excitation.

4.15.3 Acceptance Criteria

There is no Acceptance criteria, report results.

4.16 Salt Spray

This test is applicable to endcapped cartridge bulbs. The objective is to evaluate the integrity of the metal endcaps when subjected to a salt spray.

4.16.1 Test and Measurement Apparatus

Use the test equipment described in ASTM B 117, Standard Practice for Operating Salt Spray (Fog) Testing Apparatus.

4.16.2 Procedure

1. Select 10 bulbs per Sample Selection section.
2. Perform a salt spray test according to ASTM B 117 for 24 hours on selected bulbs.

4.16.3 Acceptance Criteria

The samples shall exhibit no red rust after the test.

4.17 Wire Loop Pull

This test is applicable to wire loop cartridge bulbs. The objective is to evaluate the strength of the wire loop and glass interface.

4.17.1 Test and Measurement Apparatus

Use the following equipment, or equivalent, for the pull test:

Wire Loop Pull Table

Equipment	Model
Chatillon Universal Test Stand	UTSE-2
Load Cell	10 lbs.
Pull Fixture	A hook that evenly distributes the load across the wire loop

4.17.2 Procedure

1. Select 10 bulbs per Sample Selection section.
2. Perform an axial pull of 30 N (6.74 lbs) for 1 minute on each wire loop of selected bulbs.

4.17.3 Acceptance Criteria

All bulbs shall light-up for a minimum of 60 seconds at design voltage.

4.18 Outgassing/Heat

The Outgassing/Heat Test is intended to ensure that bulbs with plastic bases will not distort or out-gas to cause a fog precipitate to form on reflectors or lenses of a bulb assembly in which they may be used.

4.18.1 Test and Measurement Apparatus

Enclosures shown in figure Heat Test Enclosures (similar to figure B), modified to include removable clear glass top of the enclosure, are to be used to run this test. The enclosure bulb mounting is to be constructed of materials, such as metal and ceramic that will not out-gas during the test. The enclosure is to be placed in a temperature-controlled chamber that can maintain 50° ± 5°C.

4.18.2 Procedure

1. Perform this test on 5 representative bulbs for each of the test conditions specified in Bulb Versus Function Cross Reference Table (see Appendix B).
2. The enclosure glass is to be cleaned with glass cleaner and alcohol before testing each bulb.
3. Mount the bulb in the enclosure, place the enclosure in the test chamber, bring the test chamber to 50°C, and operate the bulb as specified in Bulb Versus Function Cross Reference Table for 2 hours.
4. After this two-hour period, allow the enclosure to cool to room temperature.

4.18.3 Acceptance Criteria

After the test, the bulb base must show no distortion, function normally, labeling must be legible, and there shall be no indication of outgassing on the glass.

5. DURABILITY

These tests are intended to evaluate the durability of the bulbs and their components under typical and extreme operating conditions on the vehicle. Record all data according to Record Retention section. All bulbs tested under this section are to be selected from the same test lot.

5.1 Laboratory Life*

This test determines bulb life at design voltage. It does not include any of the “life shortening” conditions (i.e., high temperature, vibration, shock, etc.) encountered on a vehicle.

5.1.1 Test and Measurement Apparatus

Use the following equipment and racks, or equivalent, for this test:

1. Bulb sockets firmly mounted on racks so that the filament is parallel to the direction of excitation and reliably provides electrical contact with the bulb.
2. Power supplies capable of operating the bulbs continuously at design voltage and compensating for the reduced power requirements within 1 minute of bulb burnout

5.1.2 Procedure

1. Select 30 samples per the Sample Selection section.
2. Operate the samples at room temperature and design voltage.
3. Power the bulbs for 23-1/2 hours each day and a ½ hour off each day. Monitor the bulbs at least once each day and record the amount of hours for each bulb to fail according to Record Retention section.
4. Time of failure should be recorded as the last time the bulb was known to be lit.
5. Using these results provide the Weibull plot showing B_{10}, B_{50}, and B_{70}. (NOTE: This test may be halted at 6000 hours of on-time.)

5.1.3 Acceptance Criteria

Life at design voltage must meet product specifications.

5.2 Accelerated Life*

This test provides a means of quickly verifying bulb life after laboratory life is determined and the correlation to accelerated life is established.

5.2.1 Test and Measurement Apparatus

The following equipment and racks, or equivalent, are required for this test:

1. Bulb sockets firmly mounted on racks so that the filament is parallel to the direction of excitation and reliably provides electrical contact with the bulb.
2. Power supplies capable of operating the bulbs continuously at 150% of design voltage.

5.2.2 Procedure

1. Select 20 bulbs per Sample Selection section.
2. Mount selected samples on the test rack.
3. Operate at room temperature and forced voltage to a maximum of 150% of design voltage.
4. Monitor the bulbs and record the amount of hours for each bulb to fail according to Record Retention section.
5. Time of failure should be recorded as the last time the bulb was known to be lit.
6. Using these results provide the Weibull plot showing B_{10}, B_{50}, and B_{70}. (NOTE: This test may be halted at 9000 hours of equivalent on-time at design voltage.)

Using the B life as the common factor, plot a correlation curve using the Weibull Plots from Laboratory Life and Accelerated life. The curve shall be charted in hours with Laboratory Life on the X-axis, and Accelerated life on the Y-axis showing B_{10}, B_{50}, and B_{70}.

5.2.3 Acceptance Criteria

Life must meet product specification.

5.3 Luminous Intensity Maintenance*

The objective of this test is to determine the degradation in light output (MSCD) as a function of operating time. This test may be run in conjunction with either Laboratory Life section or Accelerated Life section and Mean Spherical Candela section.

5.3.1 Test and Measurement Apparatus

The Test and Measurement apparatus is defined in the following sections:

- Mean Spherical Candela
- Laboratory Life
- Accelerated Life

5.3.2 Procedure

1. Select 10 bulbs per the Sample Selection section
2. Season the bulbs as described in Test Default Conditions section.
3. Measure the MSCD of each test bulb (Mean Spherical Candela section).

Option 1:
Operate the bulbs at design voltage and remeasure the MSCD at B_{10}, B_{50}, and B_{70} as defined by the Weibull plot of laboratory life. Record the data according to Record Retention section.

Option 2:
Operate the bulbs at forced voltage, not to exceed 150% of design voltage, and remeasure MSCD at B_{10}, B_{50}, and B_{70} as defined by the Weibull plot of laboratory life. Record the data according to Record Retention section.

5.3.3 Acceptance Criteria

At B_{70} as defined by the Weibull plot of laboratory life, the MSCD must be ≥ 70% of the initial MSCD.

5.4 Vibration Durability*

The objective of this test is to verify that the design and construction of the bulb are sufficiently robust to withstand vehicle vibrations. This is an accelerated test for the worst case orientation of the bulb filament.

5.4.1 Test and Measurement Apparatus

The following equipment, or equivalent, is required for vibration durability:

1. Closed loop dynamic vibration equipment and controller capable of vibrating the bulbs from 50 to 1000 Hz in a random mode according to the accompanying test profile.
2. Fixture to mount the bulbs rigidly to the vibration table in such a manner that voltage can be applied to the bulbs during the test.
3. Strip chart recorder, or digital monitoring device.

5.4.2 Procedure

1. Select 20 bulbs per the Sample Selection section.
2. Season the bulbs as described in Test Default Conditions section.
3. Test each filament of a dual filament bulb separately.
4. Mount the bulbs rigidly in the fixture with filaments as follows:
   a. Half of the samples positioned with the filament parallel to the direction of excitation
   b. Half of the samples positioned with the filament perpendicular to the direction of excitation
5. Vibrate the bulbs using the test profile for a total of 6 hours in the following manner:
   a. Two hours – unlit
   b. Two hours – lit at design voltage
   c. Two hours – unlit
6. During the lit cycle of this test, monitor voltage or current at ≤ 10 millisecond intervals.
7. Record the data according to Record Retention section.

Use the following breakpoints to define the random vibration input to the test specimen:

Vibration Durability Table

Break Point	Frequency (Hz)	Amplitude (G^2/Hz)
1	50	0.080
2	400	0.080
3	650	0.0025
4	1000	0.0025

The total resulting acceleration level is 5.8 G_{rms}.

5.4.3 Acceptance Criteria

Any bulb that fails to operate during the test for any length of time, or does not meet dimensional requirements, is considered a failure and shall constitute a failure of the entire test group. Any bulb that fails to operate in a normal manner for a minimum of 60 seconds, at design voltage, at the conclusion of this test shall be considered a failure and shall constitute a failure of the entire test group. Ensure that both filaments of a dual filament bulb operate at the conclusion of this test.

5.5 Shock

This test is used to determine the ability of the bulb to withstand mechanical shock resulting from rough handling, transportation, and field operation including trunk and hood "slams." Severe shocks may disturb the normal operating characteristics of the bulb, and severe or repetitive shocks may permanently damage or destroy the filament.

5.5.1 Test and Measurement Apparatus

The shock test fixture is shown in Appendix B.

5.5.2 Procedure

1. Select 40 bulbs per Sample Selection section.
2. Season the bulbs as described in Test Default Conditions section.
3. Securely mount each test bulb through the appropriate clamping fixture at the end of the cam actuated lever arm.
4. Make sure that the counter is at zero and the low current filament monitoring circuit is operational.
5. Turn on the electric motor drive and let the equipment apply 100 shock pulses.
6. The shock pulse must have a duration of at least 1 millisecond and reach at least 800 g's for bulbs ≥ 16mm (≥ 5/8inch) in maximum diameter.
7. The shock pulse must have a duration of at least 0.5 millisecond and reach at least 400 g's for bulbs <16mm (< 5/8inch) in diameter.
8. Unless otherwise noted in the product design specification, test 10 bulbs under each of the following conditions, recording data as specified in Record Retention section:
   a. Filament parallel to the direction of excitation and "off"
   b. Filament perpendicular to the direction of excitation and "off"
   c. Filament parallel to the direction of excitation and "on" at design voltage
   d. Filament perpendicular to the direction of excitation and "on" at design voltage

5.5.3 Acceptance Criteria

The criteria for each group of bulb samples is as follows:

1. No "open" filament or damage to any part of the bulb (i.e., base or glass) during or after 10 shock pulses
2. No more than 2 failures of any kind (i.e., open filaments or damaged bulbs) during or after 100 shock pulses

5.6 Aged Vibration Durability

The objective of this test is to determine the effect of bulb filament aging on vibration durability.

5.6.1 Test and Measurement Apparatus

Use the following equipment, or equivalent, for the operating life test:

- Closed loop dynamic vibration equipment and controller capable of vibrating the bulb(s) from 50 to 1000 Hz in random mode according to the accompanying test profile (see Aged Vibration Durability Test Profile Table).
- Fixture to mount the bulbs rigidly to the vibration table with the filament and main bulb axis parallel to the direction of excitation in such a manner that voltage can be applied to the bulbs during the test.

5.6.2 Procedure

Select 20 bulbs from the test lot and test them as specified below. Record the data according to Record Retention section.

1. Operate the bulbs for B_{50} of laboratory life. Forced voltage may be substituted when correlation is established between laboratory life and accelerated life (see section Accelerated Life).
2. Mount the bulbs rigidly in the fixture as described below:
   - Half of the samples positioned with the filament parallel to the direction of excitation
   - Half of the samples positioned with the filament perpendicular to the direction of excitation
3. Vibrate the bulbs using the test profile for a total of 12 hours in the following manner:
   a. Two hours – unlit
   b. Two hours – lit
   c. Four hours – unlit
   d. Two hours – lit
   e. Two hours – unlit

Use the following breakpoints to define the random vibration input to the test specimen:

Aged Vibration Durability Test Profile Table

Break Point	Frequency (Hz)	Amplitude (G^2/Hz)
1	50	0.080
2	400	0.080
3	650	0.0025
4	1000	0.0025

The total resulting acceleration level is 5.8 G_{rms}.

5.6.3 Acceptance Criteria

There is no Acceptance criteria, report results.

6. QUALITY/RELIABILITY PROGRAMS

6.1 Reliability Growth

Bulb suppliers must establish and implement a plan to improve demonstrated product reliability for reaching stated goals. Suppliers may use the Duane or other appropriate reliability growth plan to accomplish this task. True reliability growth occurs when design changes to the bulb design or manufacturing process are made to eliminate the predominate failure modes that are identified by the field return program and the ongoing reliability assurance test program.

6.2 Ongoing Quality Improvements

The bulb suppliers must establish and implement a plan to improve the demonstrated product quality. They must establish procedures for analyzing and correcting end-of-line defects. Pareto charts will help develop the detailed plans that are required to correct the most frequently occurring defects.

6.3 Quality/Reliability Improvement

6.3.1 Field Return Program

Suppliers must establish and implement a procedure for analyzing and correcting field return defects. Suppliers and PPAP approvers will establish the proper frequency of an analysis. Suppliers must use Pareto charts to help develop the detailed plans that are required to correct the most frequently occurring problems. Actual analysis and corrective action plans must be available upon request by the PPAP approver.

6.3.2 Design Failure Mode Analysis

The DFMA procedure analyzes the design of each piece part and is used to develop Key Product Characteristics. Suppliers must create a DFMA for each bulb part number supplied to the PPAP approver. These analyses are “living” documents that should be modified as knowledge about the product and process is accumulated. Once Production Part Approval Process (PPAP) approval has been obtained, revision levels showing dates and explanations of changes must be maintained. Suppliers should use the forms and methodology published in the Potential Failure Mode and Effects Analysis Reference Manual (SAE J1739) and AIAG.

6.3.3 Process Failure Mode Analysis (PFMA)

The PFMA assumes the product is adequate as designed and seeks to verify that the manufacturing and assembly controls are adequate to provide a quality product. The PFMA is used to develop Key Control Characteristics. Suppliers must create a PFMA for each bulb part number supplied to the PPAP approver. These analyses are “living” documents that should be modified as knowledge about the product and process is accumulated. Once PPAP approval has been obtained, revision levels showing dates and explanations of changes must be maintained. Suppliers should use the forms and methodology published by the AIAG.

6.3.4 Fault Tree Analysis (FTA) or Fishbone Diagram

Suppliers are urged to use the FTA or fishbone diagram on new and existing processes. This technique is a top down approach that is used to trace known failure modes back to their source. To use this technique, the supplier should start with the bulb performance requirements in this document and assess the potential failure modes. Once the bulbs are in production, suppliers should identify the root cause of end-of-line and field return failures to modify the FTA or fishbone diagrams.

7. REPORT REQUIREMENTS

7.1 Calibration Sheets

Reference must be made to measurement standards through calibration sheets and/or lab masters.

7.2 Data Requirements

The supplier must record data in accordance with Record Retention section. All original data is to be retained with the laboratory copy of the test report.

7.2.1 Data Graphics

Data graphics including graphs, bar charts, etc., must be drawn when required by the test. Examples of typical data graphics include the following:

- Normal probability plots as shown in Appendix B.
- Weibull life plots as shown in Appendix B.

APPENDIX A - GLOSSARY OF TERMS*

Accelerated Life – Bulb life as tested at forced voltage in the laboratory and recorded on a Weibull plot, showing B_{10}, B_{50}, and B_{70}. Used to verify bulb life after laboratory life is determined and the correlation to Accelerated Life is established.

Average Life – The sum of the hours it takes for each bulb to fail in a given test divided by the number of bulbs in that test.

Bayes Formula – $R_C = (1 - C)^{\frac{1}{N+1}}$

where:

R_C is the reliability at confidence level C

N is the sample size

The above formula is based on a zero failure plan and is nonparametric (no distribution function is assumed). If failures occur, test a larger sample to ensure the same reliability level.

B_x Life – B_x life represents the time for a certain percent of the bulbs to have experienced a failure. For example, a $B_{(10)}$ would indicate a point in time where 10% of the bulbs have experienced a failure. $B_{(10)}$ is equivalent to a reliability value of 90% (R=.90).

Bulb – An indivisible assembly that contains a source of light or filament and is normally used in a lamp assembly.

PPAP Approver – The organization purchasing bulbs. In the event it is a tier buyer, the automobile manufacturer will also be considered the PPAP approver.

Design Voltage – The direct current (D.C.) voltage at which the bulb is designed to operate as published by the American National Standards Institute, Inc., (ANSI) in Special Report 25, ANSI Assigned Miniature Lamp Codes. (Sometimes referred to as Rated Voltage.)

Forced Voltage – A voltage that is higher than a bulb's design voltage used to accelerate life testing.

Laboratory Life – Bulb life as tested at design voltage in the laboratory and recorded on a Weibull plot, showing B_{10}, B_{50} and B_{70}.

Lamp – A divisible assembly that contains a bulb or other light source and sometimes an optical system, such as a lens and/or reflector, and provides a lighting function.

Lead Wire – The conductive wire that extends out of the glass envelope and provides electrical contact to the lamp socket, printed circuit, etc.

Light Center Length (LCL) – The location of the filament with reference to a specified point on the bulb base.

Mean Spherical Candela (MSCD) – The average value of the luminous intensity (candle power) of a light source as measured in a sphere.

Rated Voltage – See Design Voltage.

Test Lot – The production group of bulbs from which test samples are selected. The minimum "Test Lot" is defined as one hour of production.

Test Samples – Test samples are bulbs representative of the complete test lot. EXAMPLE: A test sample size of 10 would consist of one sample piece being removed from the test lot, every six minutes of production, for a one- hour production run. It is important that the test samples be identified as to location, within the test lot, throughout all testing.

Trade Number – The identification number assigned to a specific bulb by the American National Standards Institute (ANSI). Included in this registration are the physical and electrical characteristics, including glass envelope and base type, design voltage, MSCD, life, etc. The addition of a letter after the number indicates a variance in the basic lamp construction while still maintaining the lamp's operating characteristics (i.e., NA = natural amber).

APPENDIX B - GRAPHICS, CHARTS, ETC.

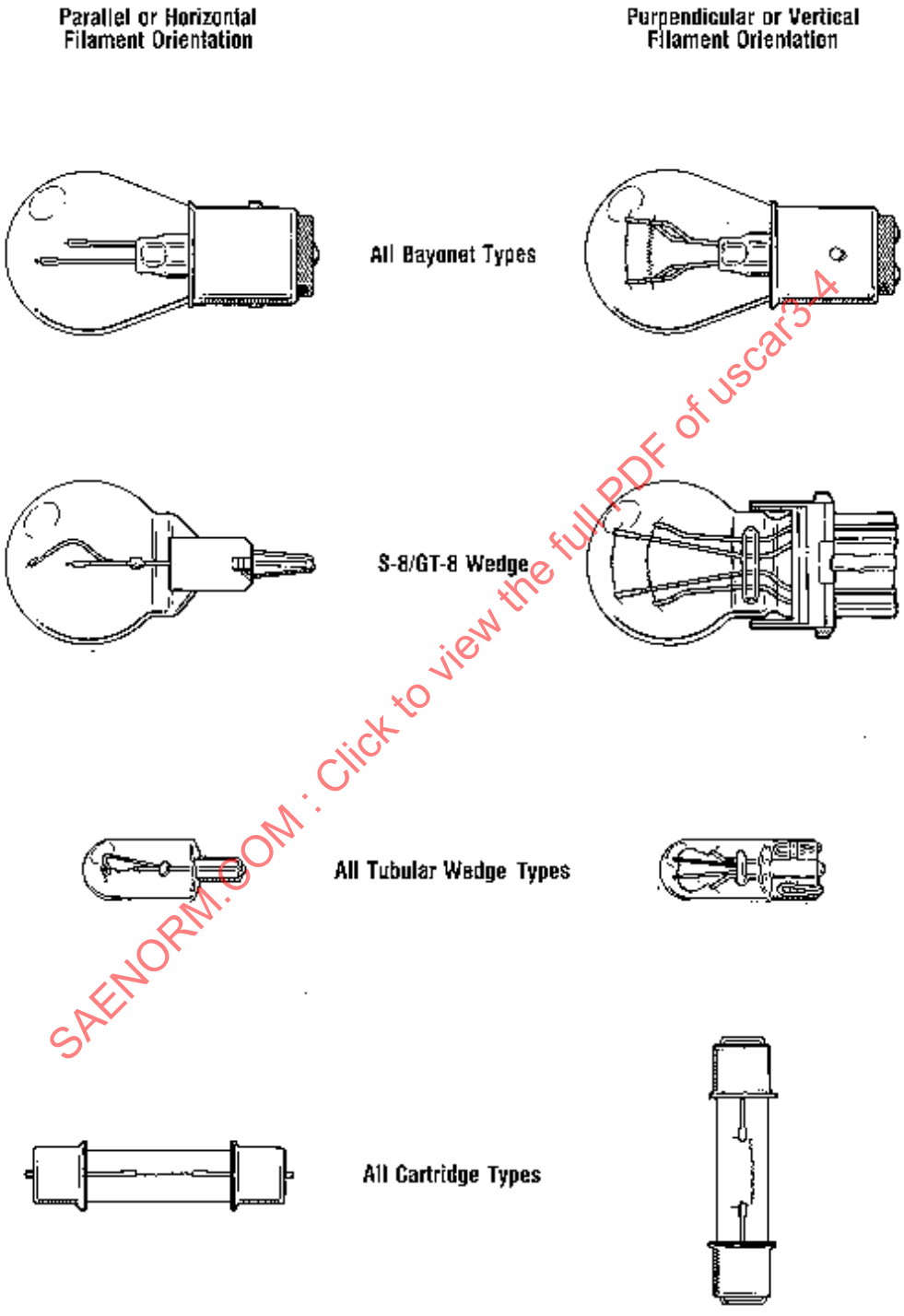
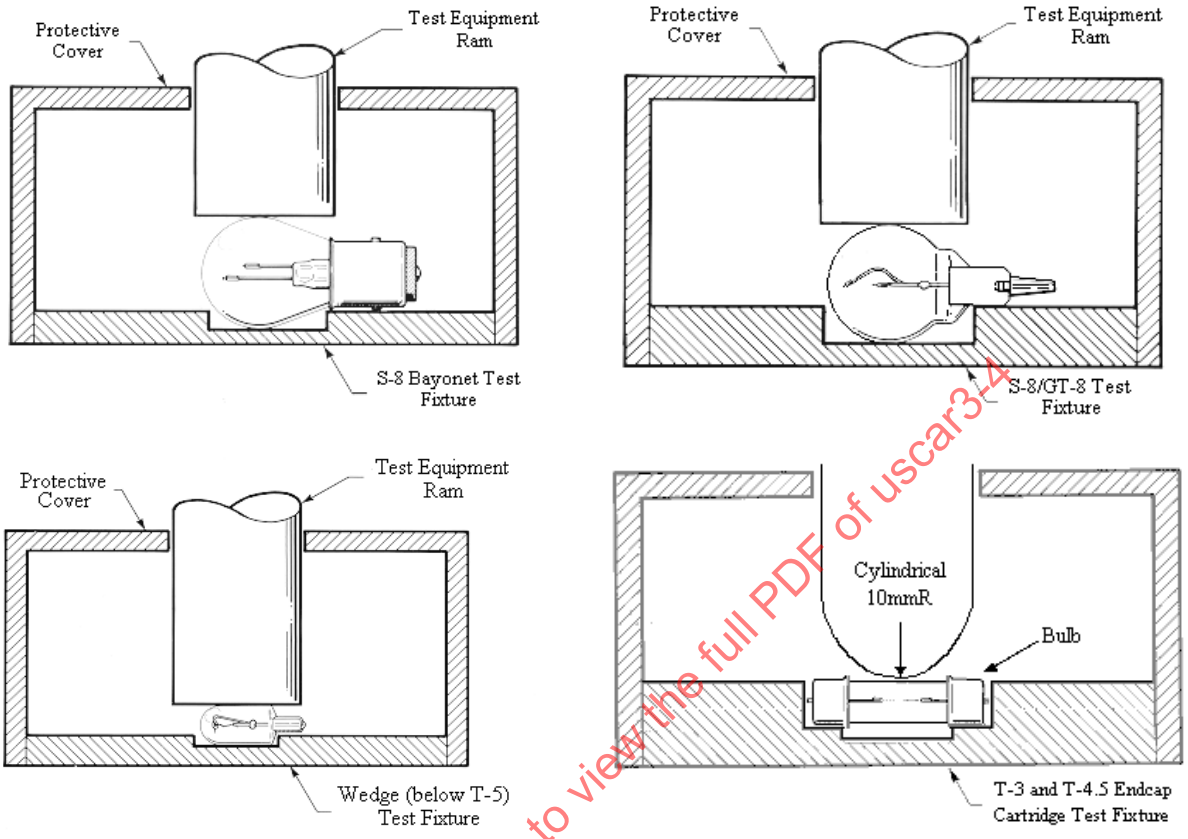


Figure B1 - Filament Orientation



Construction Notes

1. Test fixture material is 1050 Cold Rolled Steel with depressions designed to locate the bulb filaments in a horizontal position.
2. Protective cover is designed for unrestricted ram movement and to contain pieces of broken glass.

Figure B2 - Crush Test Fixtures

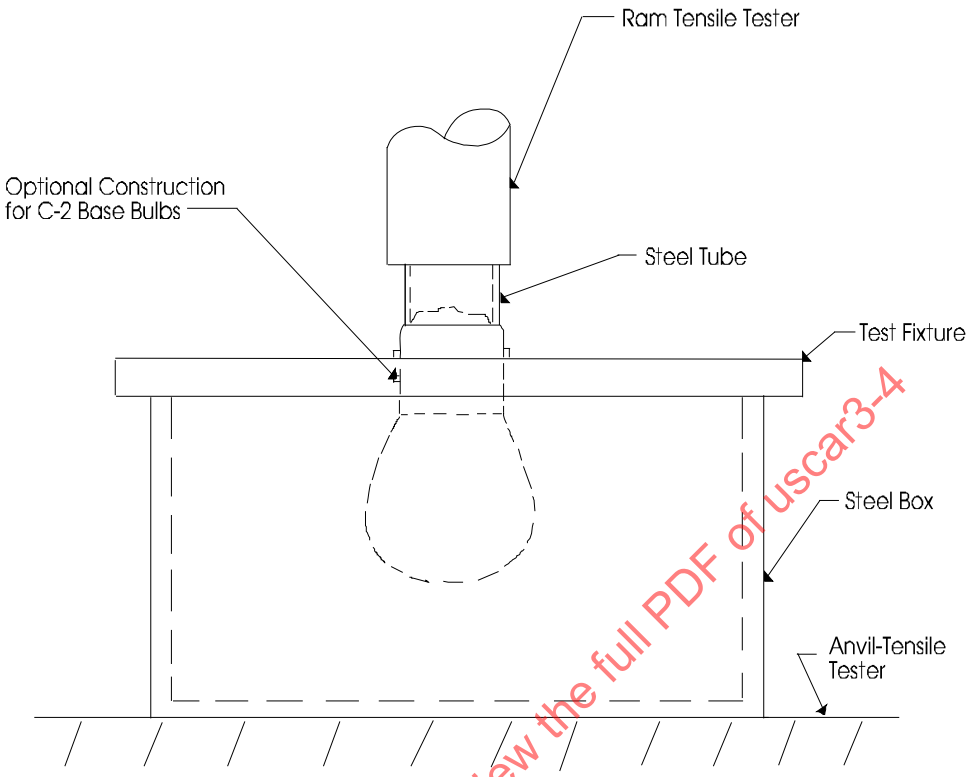
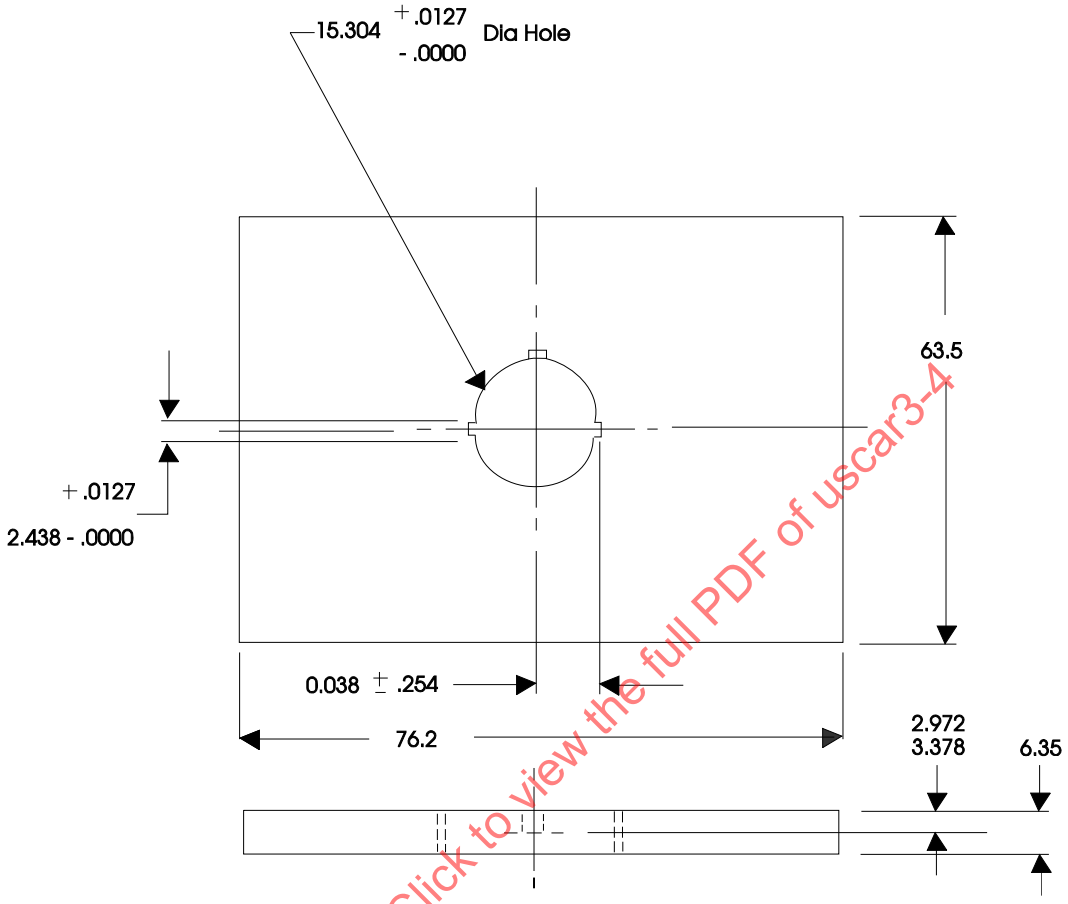


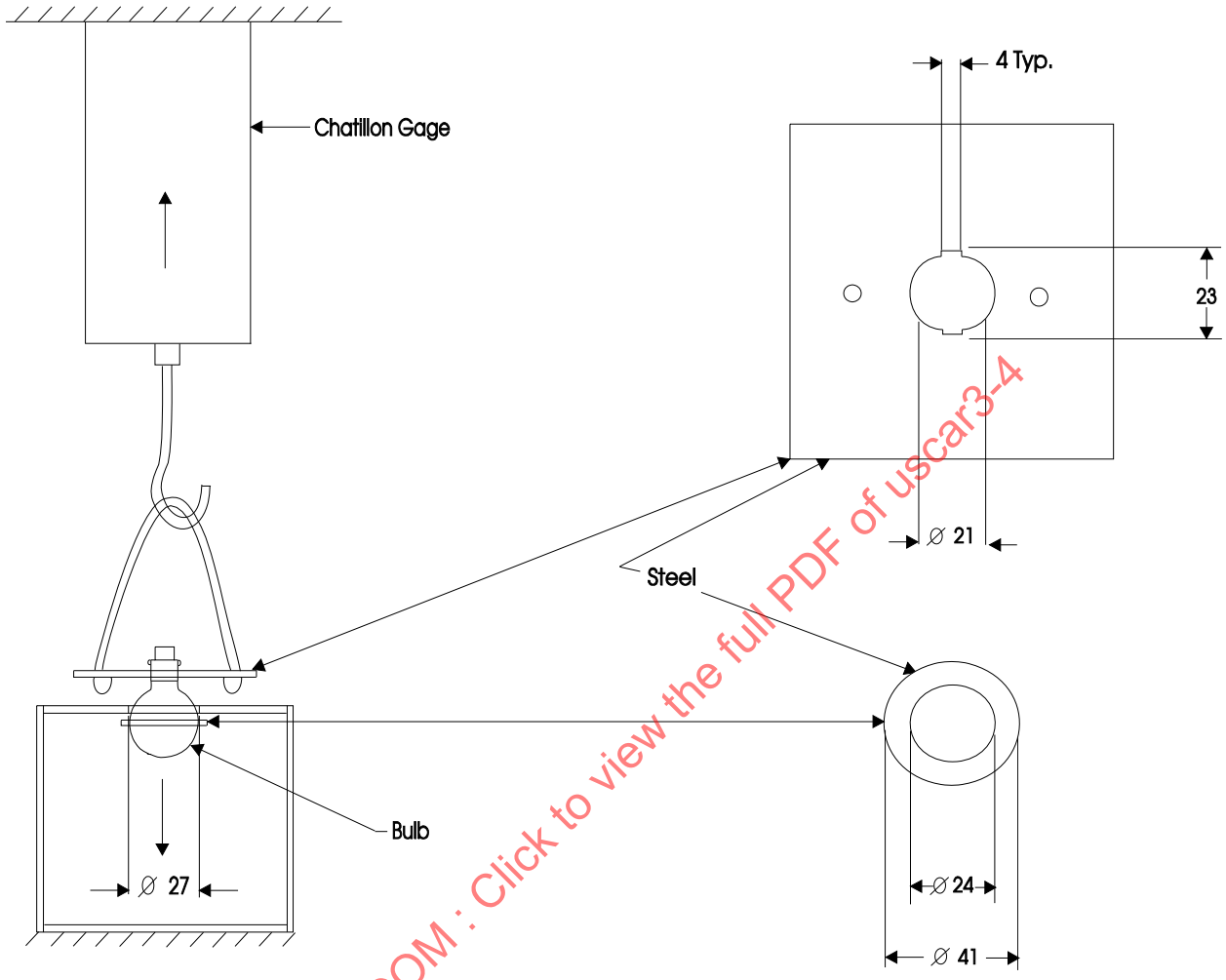
Figure B3 - Pin Removal Test Fixture (B-1, B-2, and C-2 Base Types)



NOTE: Dimensions are in millimeters

Figure B4 - Pin Removal Test Plate (B-1, B-2, and C-2 Base Types)

Material: Hardened Steel



NOTE: Dimensions are in millimeters

Figure B5 - Wedge Base Retention Fixture

Figure __ a -- TOP VIEW

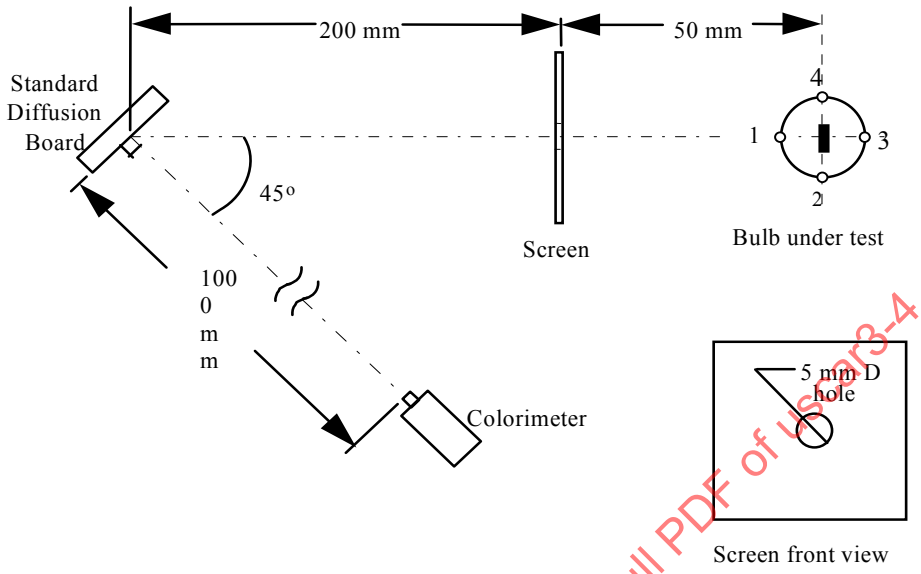


Figure __ b -- SIDE VIEW

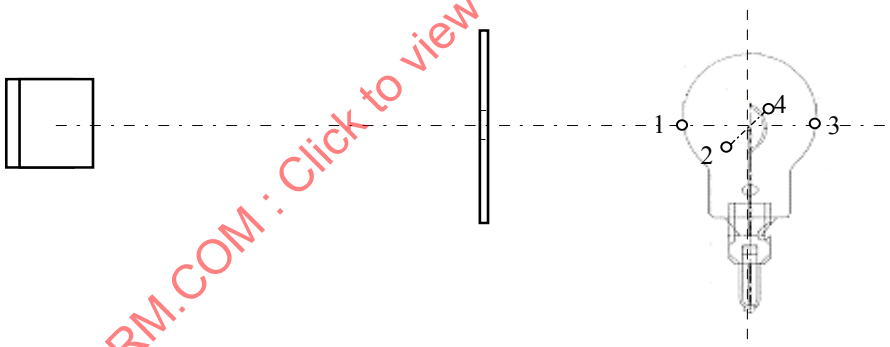


Figure __c -- SIDE VIEW

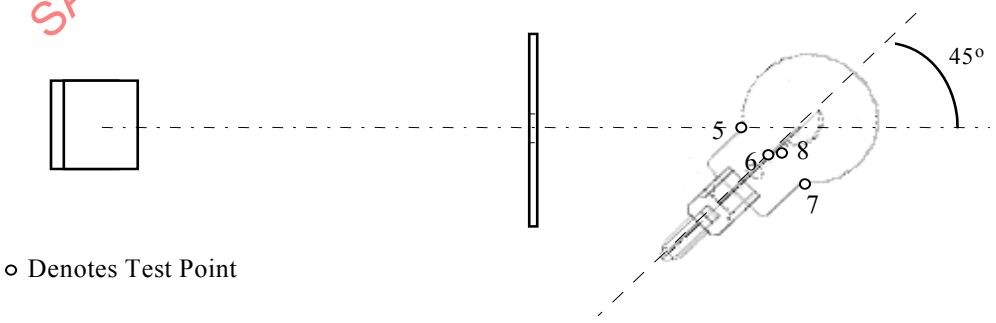


Figure B6 - Point Color

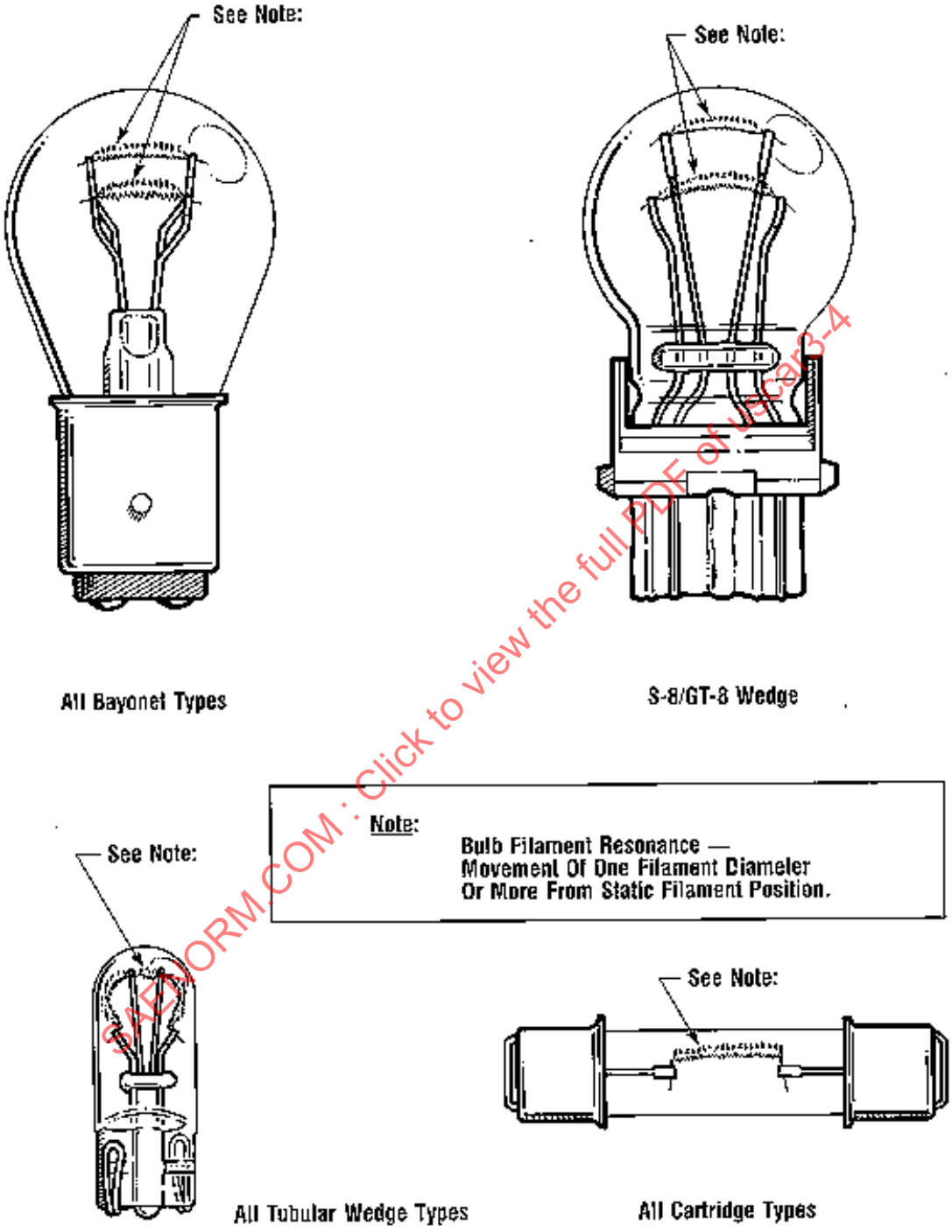


Figure B7 - Resonant Frequency Test

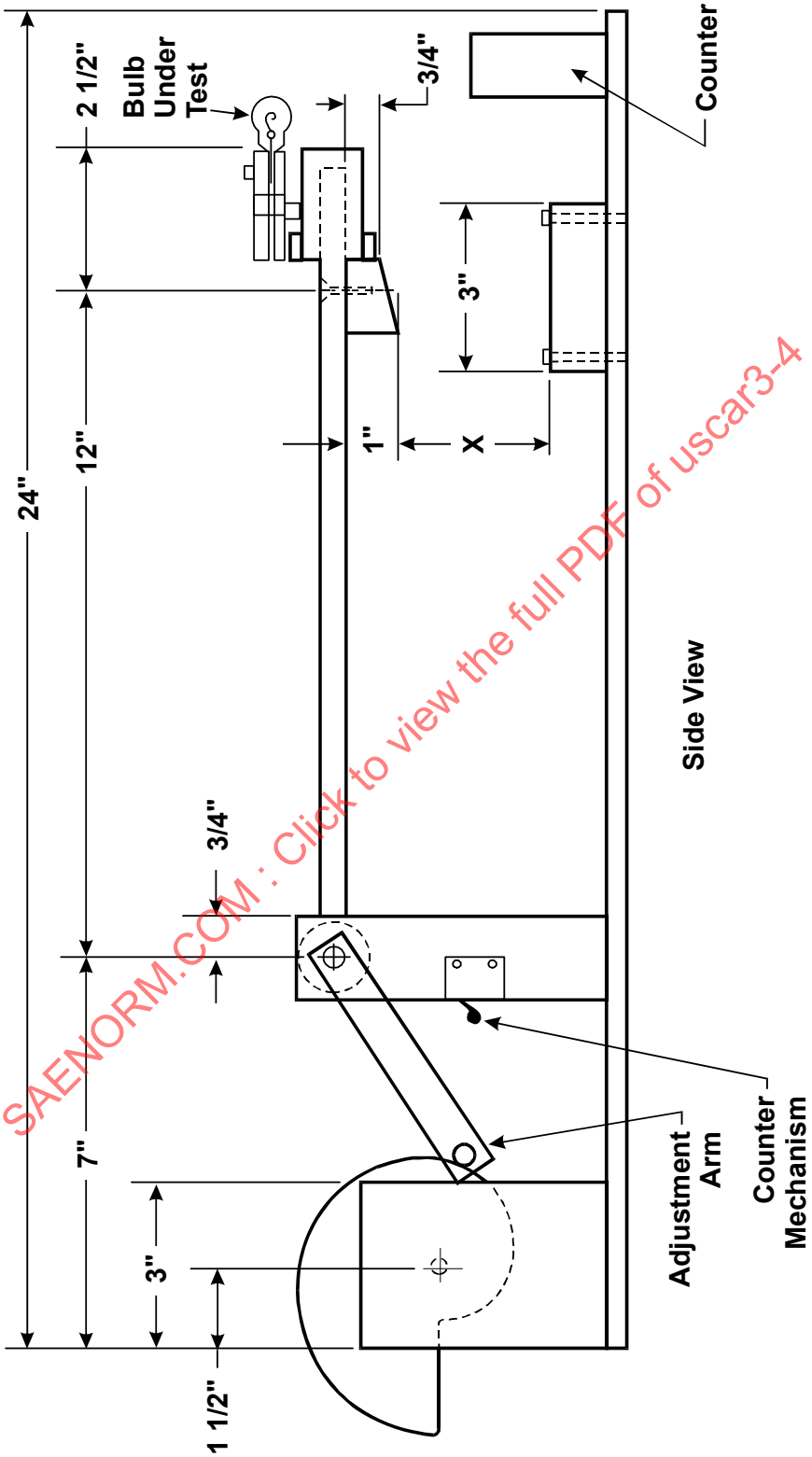


Figure B8 - Shock Tester (Side View)