Standardization of Technical Requirements for Forward Lighting LED Replacement Light Sources
LED Forward Lighting Replacement Sources
Market Observations – Performance Concerns
Performance Comparison  
(From document GRE-69-41)

LED retrofit in front lighting  
example
approved halogen light source  vs.  non-approved LED retrofit

Luminous output: 1100 lm vs. 67 lm
Color of light: 3200K vs. 9300K (outside boundaries for white)
Emitter size: 4 mm vs. 20 mm
Intensity distribution: circular vs. non-symmetrical

looks cool
but can’t see
Early 2000’s : Coated Halogen Bulbs

- SAE Coated Bulb Task Force
- Round Robin testing
Early 2000’s : Coated Halogen Bulbs

• Test method – accepted by industry and regulators
  – ECE Regulation 37
  – SAE J 2560
  – Part 564 data sheets for coated light sources
• Full report SAE J 2739
LED Replacement Light Sources

- Signal and Marking light sources
  - Filament types
    - No FMVSS108 light source data sheets
    - Standardized in SAE J573 and ANSI SR25

- Forward Lighting
  - Fog lamps
    - No FMVSS108 light source data sheets
  - Low and high beam (DOT-marked light sources)
    - FMVSS108 Requirements and Part 564 Data sheets
Signal and Marking Lamps in FMVSS108

S14.2.1.6 Bulbs. Except for a lamp having a sealed-in bulb, a lamp must meet the applicable requirements of this standard when tested with a bulb whose filament is positioned within ± .010 in of the nominal design position specified in SAE J573d, Lamp Bulbs and Sealed Units, December 1968, (incorporated by reference, see 571.108 S5.2 of this title) or specified by the bulb manufacturer and operated at the bulb’s rated mean spherical candela.

S14.2.1.6.1 Each lamp designed to use a type of bulb that has not been assigned a mean spherical candela rating by its manufacturer and is not listed in SAE J573d, Lamp Bulbs and Sealed Units, December 1968 (incorporated by reference, see 571.108 S5.2 of this title), must meet the applicable requirements of this standard when used with any bulb of the type specified by the lamp manufacturer, operated at the bulb’s design voltage. A lamp that contains a sealed-in bulb must meet these requirements with the bulb operated at the bulb’s design voltage.

S14.2.1.6.2 A bulb that is not listed in SAE J573d, Lamp Bulbs and Sealed Units, December 1968, (incorporated by reference, see 571.108 S5.2 of this title) is not required to use a socket that conforms to the requirements of SAE J567b, Bulb Sockets, April 1964 (incorporated by reference, see 571.108 S5.2 of this title).
Demonstration

SAE Replaceable LED Sources Task Force

• Alexandria, VA on 13 September 2017

• Demonstration by light source manufacturers
  – H11 Reflector headlamp – SAE beam pattern
  – H11 Projector headlamp – SAE beam pattern

• Presentation of feasibility studies
Demonstration – Sept 2017

SAE Replaceable LED Sources Task Force
# Feasibility Studies – Headlamp Testing

## H11 LED Replacement Light Source

<table>
<thead>
<tr>
<th>Head Lamp/ Type</th>
<th>Downroad 0.86D</th>
<th>Max Search</th>
<th>Points Passed</th>
<th>Beam Flux</th>
<th>IIHS Rating</th>
<th>Fit</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Truck 1 / Reflector</td>
<td>26569 +44%</td>
<td>31901 +53%</td>
<td>22/22</td>
<td>380 +15%</td>
<td>15.6 +32%</td>
<td>Good</td>
<td>Beam spread drops slightly at edges?</td>
</tr>
<tr>
<td>Light Truck 2 / Reflector</td>
<td>27042 +71%</td>
<td>57610 +74%</td>
<td>21/22 2U-4L</td>
<td>438 +14%</td>
<td>12.9 +50%</td>
<td>Very Good</td>
<td></td>
</tr>
<tr>
<td>Minivan / Reflector</td>
<td>49329 +35%</td>
<td>59893 +48%</td>
<td>21/22 2U-4L 0.5U 1-3R +11%</td>
<td>+11%</td>
<td>10.7 +53%</td>
<td>Very Good</td>
<td></td>
</tr>
<tr>
<td>Light Truck 3 / Projector</td>
<td>20079 +59%</td>
<td>21878 +7%</td>
<td>20/22 2U-4L 0.5U 1-3R +22%</td>
<td>+22%</td>
<td>11.4 +51%</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Sedan 1 / Projector</td>
<td>15637 +142%</td>
<td>18725 +21%</td>
<td>22/22</td>
<td>+21%</td>
<td>24.4 +37%</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Sedan 2 / Reflector</td>
<td>22034 +9%</td>
<td>37898 +55%</td>
<td>22/22</td>
<td>+10%</td>
<td>12.0 +19%</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Sedan 3</td>
<td>12698 +25%</td>
<td>38088 +46%</td>
<td>22/22</td>
<td>-</td>
<td>-</td>
<td>OK</td>
<td>Striations in Beam</td>
</tr>
<tr>
<td>Sedan 4 / Reflector</td>
<td>15880 +44%</td>
<td>36843 +44%</td>
<td>21/22 10-90U</td>
<td>-</td>
<td>-</td>
<td>Very Good</td>
<td></td>
</tr>
</tbody>
</table>
## H11 LED Replacement

**Beam Performance – Light Truck 2 (Reflector)**

### Key Beam Points

<table>
<thead>
<tr>
<th>Beam Points</th>
<th>Voltage</th>
<th>Current</th>
<th>10U-90U</th>
<th>4U, 4L</th>
<th>64 Min.</th>
<th>0.6D, 1.3R</th>
<th>1000 Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>H11L+</td>
<td>12.81</td>
<td>4.19</td>
<td>125</td>
<td>127</td>
<td>127</td>
<td>20742</td>
<td>45244</td>
</tr>
<tr>
<td>LED Substitute</td>
<td>12.81</td>
<td>1.06</td>
<td>81</td>
<td>75</td>
<td>74</td>
<td>45134</td>
<td>46804</td>
</tr>
<tr>
<td>Min</td>
<td>12.81</td>
<td>1.05</td>
<td>100</td>
<td>126</td>
<td>97</td>
<td>45957</td>
<td>46644</td>
</tr>
<tr>
<td>Max</td>
<td>12.81</td>
<td>1.07</td>
<td>103</td>
<td>129</td>
<td>99</td>
<td>45302</td>
<td>45977</td>
</tr>
</tbody>
</table>

### FMVSS 108 TAB17-2

<table>
<thead>
<tr>
<th>Beam Points</th>
<th>Voltage</th>
<th>Current</th>
<th>10U-90U</th>
<th>4U, 4L</th>
<th>64 Min.</th>
<th>0.6D, 1.3R</th>
<th>1000 Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LB, visual aim (Single Filament or HB2)</td>
<td>1.5D, 2R</td>
<td>1.5D, 2R</td>
<td>15000 Min.</td>
<td>12500</td>
<td>12500 Max</td>
<td>3423</td>
<td>3217</td>
</tr>
<tr>
<td>H11-7</td>
<td>1.5D, 2R</td>
<td>1.5D, 2R</td>
<td>15000 Min.</td>
<td>12500</td>
<td>12500 Max</td>
<td>3423</td>
<td>3217</td>
</tr>
</tbody>
</table>

### Gradient

<table>
<thead>
<tr>
<th>Beam Points</th>
<th>Voltage</th>
<th>Current</th>
<th>10U-90U</th>
<th>4U, 4L</th>
<th>64 Min.</th>
<th>0.6D, 1.3R</th>
<th>1000 Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>H11L+</td>
<td>2.65</td>
<td>2.5</td>
<td>2.4</td>
<td>2.3</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>LED Substitute</td>
<td>2.5</td>
<td>2.5</td>
<td>2.4</td>
<td>2.3</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Min</td>
<td>2.6</td>
<td>2.5</td>
<td>2.4</td>
<td>2.3</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Max</td>
<td>3.3</td>
<td>2.5</td>
<td>2.4</td>
<td>2.3</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>

### Search

<table>
<thead>
<tr>
<th>Beam Points</th>
<th>Voltage</th>
<th>Current</th>
<th>10U-90U</th>
<th>4U, 4L</th>
<th>64 Min.</th>
<th>0.6D, 1.3R</th>
<th>1000 Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>H11L+</td>
<td>33201</td>
<td>58525</td>
<td>56776</td>
<td>56887</td>
<td>58302</td>
<td>57830</td>
<td>48%</td>
</tr>
<tr>
<td>LED Substitute</td>
<td>208</td>
<td>208</td>
<td>208</td>
<td>208</td>
<td>208</td>
<td>208</td>
<td>208</td>
</tr>
<tr>
<td>Min</td>
<td>208</td>
<td>208</td>
<td>208</td>
<td>208</td>
<td>208</td>
<td>208</td>
<td>208</td>
</tr>
<tr>
<td>Max</td>
<td>33201</td>
<td>58525</td>
<td>56776</td>
<td>56887</td>
<td>58302</td>
<td>57830</td>
<td>48%</td>
</tr>
</tbody>
</table>

### Notes

- **H11 LED Replacement**
- **Beam Performance – Light Truck 2 (Reflector)**
- Key Beam Points
  - H11L+
  - LED Substitute
  - Min
  - Max
- **FMVSS 108 TAB17-2**
  - LB, visual aim (Single Filament or HB2)
- **Gradient**
  - H: 2.65
  - V: -0.85
- **Search**
  - 33201
  - 58525
  - 56776
H11 LED Replacement
Beam Performance – Light Truck 2 (Reflector)

- LED Replacement – 2 failed beam points – 10-90U and 2U, 4L

- **Max Intensity**
  - **Left Ped (0.86D, 3.5 L)**: H11L+ 4476, LED Repl. 7921, +77%
  - **Downroad (0.86D)**: H11L+ 15801, LED Repl. 27042, +71%
  - **Right Lane (0.6D, 1.3R)**: H11L+ 20742, LED Repl. 45957, +122%

- **Total Lumens**
  - **Wide Spread (2D, 15L)**: H11L+ 3497, LED Repl. 5151, +47%
  - **Wide Spread (2D, 15R)**: H11L+ 3466, LED Repl. 4805, +39%
  - **Narrow Spread (2D, 9L)**: H11L+ 4858, LED Repl. 7383, +52%
  - **Narrow Spread (2D, 9R)**: H11L+ 7111, LED Repl. 11013, +55%

- **Range (1.5D, 2R)**: H11L+ 19622, LED Repl. 28232, +44%

- **1800 MIN 12000 MAX**
- **4500 MIN 10000 MIN**
- **1000 MIN 10000 MIN**
- **1250 MIN 15000 MIN**

- **12000 MAX**
- **4500 MIN**
- **10000 MIN**
- **1000 MIN**
- **1250 MIN**
- **15000 MIN**
H11 LED Replacement

Beam Performance – Sedan 2 (Reflector)

### FMVSS 108 TAB17-2

<table>
<thead>
<tr>
<th>Beam</th>
<th>LED-1</th>
<th>LED-2</th>
<th>LED-3</th>
<th>LED-4</th>
<th>LED Average</th>
<th>% Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>H11L+</td>
<td>12.81</td>
<td>12.81</td>
<td>12.81</td>
<td>12.81</td>
<td>12.81</td>
<td>12.81</td>
</tr>
<tr>
<td>Voltage</td>
<td>4.22</td>
<td>1.95</td>
<td>1.06</td>
<td>1.06</td>
<td>1.06</td>
<td>1.06</td>
</tr>
<tr>
<td>Current</td>
<td>110-900</td>
<td>87</td>
<td>68</td>
<td>74</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td>4U, 8L</td>
<td>64 Min.</td>
<td>245</td>
<td>141</td>
<td>140</td>
<td>140</td>
<td>135</td>
</tr>
<tr>
<td>4U, 8R</td>
<td>64 Min.</td>
<td>173</td>
<td>102</td>
<td>105</td>
<td>105</td>
<td>101</td>
</tr>
<tr>
<td>2U, 4L</td>
<td>135 Min.</td>
<td>313</td>
<td>159</td>
<td>149</td>
<td>152</td>
<td>156</td>
</tr>
<tr>
<td>1.5U, 1R-3R</td>
<td>Min. 200</td>
<td>495</td>
<td>200</td>
<td>239</td>
<td>212</td>
<td>211</td>
</tr>
<tr>
<td>1.5U, 1R-R</td>
<td>Max. 1400</td>
<td>567</td>
<td>447</td>
<td>417</td>
<td>423</td>
<td>381</td>
</tr>
<tr>
<td>1.5U, 1L-L</td>
<td>Max. 760</td>
<td>463</td>
<td>256</td>
<td>242</td>
<td>228</td>
<td>229</td>
</tr>
<tr>
<td>1.5U, 1R-3R</td>
<td>Min. 1000</td>
<td>638</td>
<td>431</td>
<td>403</td>
<td>362</td>
<td>349</td>
</tr>
<tr>
<td>1.5U, 1L-L</td>
<td>Max. 2700</td>
<td>814.3</td>
<td>899.0</td>
<td>833</td>
<td>1280</td>
<td>833</td>
</tr>
<tr>
<td>H</td>
<td>1.05</td>
<td>1.95</td>
<td>2.9</td>
<td>2.95</td>
<td>3</td>
<td>2.95</td>
</tr>
<tr>
<td>V</td>
<td>-0.85</td>
<td>-0.9</td>
<td>-0.95</td>
<td>-0.95</td>
<td>-0.9</td>
<td>-0.95</td>
</tr>
<tr>
<td>Gradient</td>
<td>0.238</td>
<td>0.245</td>
<td>0.221</td>
<td>0.27</td>
<td>0.225</td>
<td>0.25</td>
</tr>
</tbody>
</table>

### Key Beam Points

- **H11L+**: LED Substitute
- **Min**: Minimum
- **Max**: Maximum
- **Max.search**: Maximum search

**H11 vs LED Replacement**

![Diagram showing H11 vs LED Replacement performance](image-url)
**H11 LED Replacement**

**Beam Performance – Sedan 2 (Reflector)**

<table>
<thead>
<tr>
<th>Beam Category</th>
<th>H11L+</th>
<th>LED Repl.</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downroad (0.86D)</td>
<td>20142</td>
<td>22034</td>
<td>+9%</td>
</tr>
<tr>
<td>Wide Spread (2D, 15L)</td>
<td>3341</td>
<td>2008</td>
<td>-40%</td>
</tr>
<tr>
<td>Narrow Spread (2D, 9L)</td>
<td>8750</td>
<td>9520</td>
<td>+9%</td>
</tr>
<tr>
<td>Range (1.5D, 2R)</td>
<td>17782</td>
<td>26602</td>
<td>+50%</td>
</tr>
<tr>
<td>Left Ped (0.86D, 3.5 L)</td>
<td>11408</td>
<td>9529</td>
<td>-16%</td>
</tr>
<tr>
<td>Wide Spread (2D, 15R)</td>
<td>2926</td>
<td>4314</td>
<td>+47%</td>
</tr>
<tr>
<td>Narrow Spread (2D, 9R)</td>
<td>8150</td>
<td>10717</td>
<td>+32%</td>
</tr>
<tr>
<td>MAX Intensity</td>
<td>1800 MIN</td>
<td>12000 MAX</td>
<td>+55%</td>
</tr>
<tr>
<td>Total Lumens</td>
<td>21282</td>
<td>25730</td>
<td>+21%</td>
</tr>
</tbody>
</table>

- LED Replacement – NO failed beam points. 2 reams.
Feasibility H11 LED Replacement
Light Truck 2 – Halogen vs LED Replacement

LED

Halogen

+35M Downroad
Conditions for Equivalent Performance

- Based on light-technical “Equivalecny Principle”
- Require LED light source to have same far-field and near-field behavior as filament light source
- **Source-level compliance**
Conditions for Equivalent Performance

**Same**
- base keying
- electrical connector
- maximum outline
- test voltage
- luminous flux
- color of the emitted light
- light center length
- distortion free zone

**Similar**
- luminous intensity distribution
- size and position of light emitting area (LEA)
- homogeneity of LEA

**Different**
- Base dimensions
- Power consumption

**Additional**
- thermal behavior
- outage behavior

Filament Light Source

LED Replacement Light Source

Light Emitting Area
Draft SAE J 3145

**SURFACE VEHICLE RECOMMENDED PRACTICE**

**J3145™**

PropDft SEP2018

**Forward Lighting LED Replacement Light Sources for Halogen Light Sources**

**RATIONALE**

Apparent light emitting area is apparent because it is the size as seen from the outside (possibly through a lens or primary optics) of the LED light source, not the actual chip-size.

The contrast of the LED light source determines the minimum achievable glare compared to the maximum amount of light on the road in the far field (i.e. close to cut-off).

The size of the light-emitting-area of the LED light source (relative to the size of the nominal-emitter-box defined in the category sheet) is linked to the position accuracy of individual LEDs and impacts the range for re-aiming of the headlamp.
Thank you