

ENERGY STAR® LED LAMP THIRD PARTY TESTING AND VERIFICATION

2013-2017 Testing Result Summary



October 30, 2019

For more information, please contact lighting@energystar.gov.

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Introduction

The 2019 ENERGY STAR® LED Lamp Third Party Testing and Verification Report presents detailed summary results for the ENERGY STAR LED Lamps verification testing initiated between November 2013 and December 2017, and that completed full verification testing by June 30, 2018. Verification testing is conducted in order to ensure that ENERGY STAR labeled products continue to meet performance requirements. Each year, a subset of models are subject to verification testing administered by EPA-recognized certification bodies (CBs).

During the period covered by the report, verification testing was conducted on 564 ENERGY STAR certified LED Lamps products, including 133 omnidirectional lamps, 369 directional lamps, and 62 decorative lamps.¹ The models tested in the report were tested to the ENERGY STAR specification they were certified to, which includes Integral LED Lamps (ILL) Version 1.4, Lamps Version 1.0, Lamps Version 1.1, Lamps Version 2.0, or Lamps Version 2.1.

Use discretion when generalizing from the results described in this report to the entire market of ENERGY STAR certified LED bulbs. The test data summarized in this report is informative, but not necessarily reflective of the most prominent models in the market, or those with the largest shipments (that data is not immediately available to EPA). The products tested for verification testing, and included in this report, reflect both nominations and random selections. In addition, products included in this report may no longer be on the ENERGY STAR Qualified Products List, as the Qualified Products List is a contemporaneous listing that continues to shift after product selection occurs and verification testing has begun. This report includes the verification testing data available on the performance of ENERGY STAR certified LED lamps sold at retail up to the beginning of 2017.

¹ Excludes two models for the following reasons: lab error during product selection, and lab testing error.

Methodology

Models were tested in accordance with the version of the ENERGY STAR Lamps specification to which they were certified. The majority of LED lamps tested prior to 2017 were certified and verified to Version 1.1 of the ENERGY STAR Lamps specification effective September 30, 2014.² All LED lamps tested in 2017 were certified and verified to Version 2.0 or V2.1 of the ENERGY STAR Lamps specification, (effective January 2, 2017). [ENERGY STAR verification testing requirements](#) call for 10% of unique ENERGY STAR certified LED lamp models to undergo verification testing during a calendar year. Models that undergo verification testing are either selected randomly, or nominated by EPA, utilities, brand owner organizations, states, efficiency program sponsors, and other government entities.

Product selection is conducted in December of the year prior to the verification testing year. For example, 2013 selections were determined in December 2012, 2014 selections in December 2013, and so on. Verification testing of LED lamps includes lifetime testing requirements, and can take over nine months from the product selection date to complete.

For verification testing, certification bodies (CBs) test certified lamps against a limited set of core performance requirements, as applicable to the specific model.³ Each model is subjected to the same nine core tests, plus two out of five additional tests chosen at random.⁴ In addition to these core and randomly selected tests, omnidirectional and decorative lamps are also tested for luminous intensity distribution, and directional lamps for color angular uniformity and light output ratio.


At the conclusion of each test, the laboratory sends the completed lab report to an EPA-recognized CB. The CB reviews the test report and determines whether the test results meet the relevant ENERGY STAR specification. If the CB determines that the model fails to meet any of the requirements including the verification testing directive, the CB refers the failure to EPA.

The criteria for an LED lamp tested in 2017 to be considered passing are listed in Table 1.

Table 1: Tests Required for ENERGY STAR Verification Testing⁵

Omnidirectional and Decorative	Directional	Test type	Passing Criteria
Efficacy	Efficacy	Photometric Performance	Varies depending upon lamp type and CRI, and eight or more units must individually meet the requirement.
Light Output	Light Output (R, BR, ER) Center Beam Intensity (PAR, MR, MRX)	Photometric Performance	Varies depending upon wattage equivalency claim, and eight or more units must individually meet the requirement

² The ENERGY STAR Lamps [Version 1.1](#) and [Version 2.1](#) Program Requirements can be downloaded from the ENERGY STAR website. Lamps tested before August 28, 2014 were tested against the [Integral LED Lamps V1.4 specification](#).

³ Per [Directive #2015-01, Revised March 1, 2017, ENERGY STAR Lamps Verification Testing – Test Requirements, Sample Sizes and Reporting Failures](#)  (178KB)

⁴ The nine core tests include efficacy, correlated color temperature, color rendering index, color maintenance, light output, rapid cycle (V1 and earlier products only), rated life, 3,000-hour lumen maintenance, and 6,000-hour lumen maintenance. CBs randomly selected two of the following five tests: power factor, frequency, start time, transient protection, and dimensions.

⁵ For power factor, frequency, start time, transient protection, and dimensional requirements: per Directive #2015-01, the CB randomly selects two of the five tests for verification testing.

Omnidirectional and Decorative	Directional	Test type	Passing Criteria
N/A	Elevated Temperature Light Output Ratio	Photometric Performance	Varies depending upon beam angle and wattage equivalency claim
Luminous Intensity Distribution	N/A	Photometric Performance	Varies by lamp type
Correlated Color Temperature	Correlated Color Temperature	Photometric Performance	9 out of 10 samples must fall within the a seven-step quadrangle
Color Rendering Index (Ra)	Color Rendering Index (Ra)	Photometric Performance	Color Rendering Index (Ra) \geq 80. The average of units tested shall meet the requirements and no more than 3 units shall have Ra < 77. No unit shall have Ra < 75.
Color Rendering Index (R9)	Color Rendering Index (R9)	Photometric Performance	Color Rendering Index (R9) \geq 0.
Color Maintenance	Color Maintenance	Photometric Performance	Lamp change in chromaticity from 0-hour measurement, at any required measurement point, shall be within a total distance of 0.007 on the CIE 1976 (u'v') diagram. All units shall meet the requirement.
N/A	Color Angular Uniformity	Photometric Performance	Variation of chromaticity across the beam angle of the lamp shall be within a total distance of 0.006 from the weighted average point on the CIE 1976 (u'v') diagram.
3,000-hour Lumen Maintenance	3,000-hour Lumen Maintenance	Lifetime Performance	\geq 15,000 hour rated life: \geq 93.1% \geq 20,000 hour rated life: \geq 94.8% \geq 25,000 hour rated life: \geq 95.8%
6,000-hour Lumen Maintenance	6,000-hour Lumen Maintenance	Lifetime Performance	\geq 15,000 hour rated life: \geq 86.7% \geq 20,000 hour rated life: \geq 89.9% \geq 25,000 hour rated life: \geq 91.8% \geq 30,000 hour rated life: \geq 93.1% \geq 35,000 hour rated life: \geq 94.1% \geq 40,000 hour rated life: \geq 94.8% \geq 45,000 hour rated life: \geq 95.4% \geq 50,000 hour rated life: \geq 95.8%
Rated Life	Rated Life	Lifetime Performance	All lamps: \geq 15,000 hours All units operational at 3,000 hours All units operational at 6,000 hours
Power Factor	Power Factor	Electrical Performance	Omnidirectional lamps \geq 10 watts : \geq 0.6 All other lamps: \geq 0.7
Frequency	Frequency	Electrical Performance	\geq 120 Hz
Start Time	Start Time	Electrical Performance	Non-connected lamps: < 750 milliseconds Connected lamps: < 1 second
Transient Protection	Transient Protection	Electrical Performance	Lamp shall survive 7 strikes of a 100 kHz ring wave, 2.5 kV level. All units shall be fully operational at the completion of testing.
Dimensional Requirements	Dimensional Requirements	Dimensional Requirements	Omnidirectional Lamp: -5% tolerance if the lamp exceeds the ANSI MOL

Summary Results

The performance of the 564 models that were selected for verification testing between November 2013 and December 2017 is summarized in this section, both for aggregate results and for results from 2017 selections.

Figure 1: 2017 Summary Results by Requirement, All Lamp Types⁶

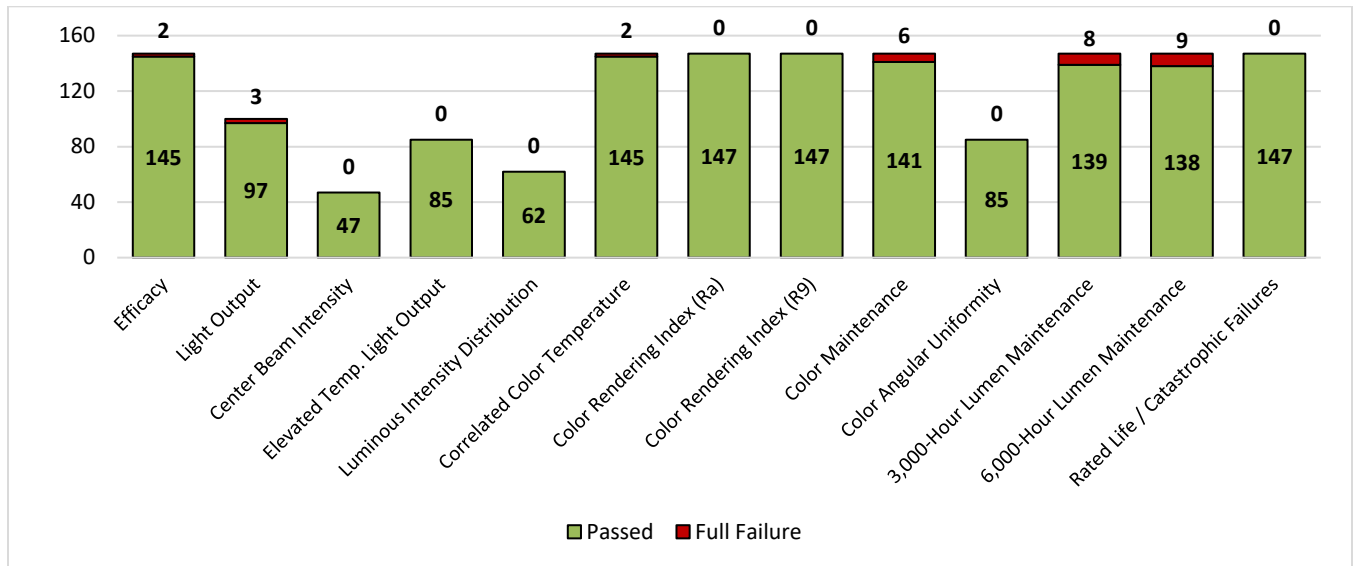
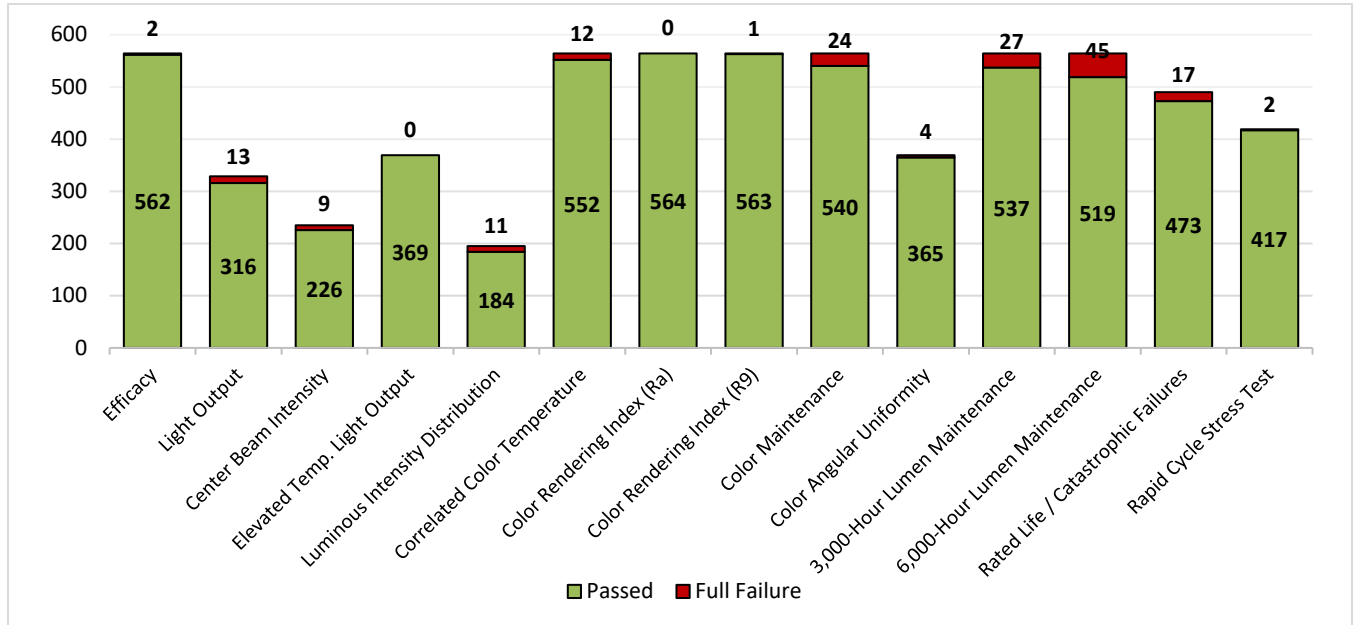


Figure 2: Summary Results (2013-2017) by Requirement, All Lamp Types⁶



See following Tables 2-4 and Figures 3-6 for additional summary results.

⁶ Light Output applies to omnidirectional, decorative, and some directional (R, BR, ER) lamps only. Center Beam Intensity applies to some directional (PAR, MR, and MRX) lamps only. Elevated Temperature Light Output Ratio applies to directional lamps only; omnidirectional, decorative, and lamps labeled “not for use in enclosed or recessed fixtures” or equivalent statement are exempt. Luminous Intensity Distribution test applies to omnidirectional and decorative lamps only.

Table 2: Percent of Lamps Passing Each Requirement by Lamp Type⁷

Test	Lamp Type	2017		All Years	
		Models Tested	% Passed	Models Tested	% Passed
Efficacy	Omnidirectional	36	100.0%	133	100.0%
	Directional	85	97.6%	369	99.5%
	Decorative	26	100.0%	62	100.0%
	All Types	147	98.6%	564	99.6%
Light Output	Omnidirectional	36	94.4%	133	93.2%
	Directional	38	100.0%	134	98.5%
	Decorative	26	96.2%	62	96.8%
	All Types	100	97.0%	329	96.0%
Center Beam Intensity	Directional	47	100.0%	235	96.2%
Elevated Temperature Light Output Ratio	Directional	85	100.0%	369	100.0%
Luminous Intensity Distribution	Omnidirectional	36	86.1%	133	92.5%
	Decorative	26	100.0%	62	98.4%
	All Types	62	100.0%	195	94.4%
Correlated Color Temperature	Omnidirectional	36	97.2%	133	97.7%
	Directional	85	98.8%	369	98.1%
	Decorative	26	100.0%	62	100.0%
	All Types	147	98.6%	564	97.9%
Color Rendering Index (Ra)	Omnidirectional	36	100.0%	133	100.0%
	Directional	85	100.0%	369	100.0%
	Decorative	26	100.0%	62	100.0%
	All Types	147	100.0%	564	100.0%
Color Rendering Index (R9)	Omnidirectional	36	100.0%	133	100.0%
	Directional	85	100.0%	369	100.0%
	Decorative	26	100.0%	62	98.4%
	All Types	147	100.0%	564	99.8%
Color Maintenance	Omnidirectional	36	97.2%	133	94.7%
	Directional	85	96.5%	369	96.2%
	Decorative	26	92.3%	62	96.8%
	All Types	147	95.9%	564	95.7%
Color Angular Uniformity	Directional	85	100.0%	369	98.9%

⁷ Excludes: Tests where CB randomly selects two out of five tests: power factor, frequency, start time, transient protection, and dimensions.

Test	Lamp Type	2017		All Years	
		Models Tested	% Passed	Models Tested	% Passed
3,000-Hour Lumen Maintenance	Omnidirectional	36	94.4%	133	94.7%
	Directional	85	95.3%	369	95.1%
	Decorative	26	92.3%	62	96.8%
	All Types	147	94.6%	564	95.2%
6,000-Hour Lumen Maintenance	Omnidirectional	36	97.2%	133	92.5%
	Directional	85	95.3%	369	92.1%
	Decorative	26	84.6%	62	90.3%
	All Types	147	93.9%	564	92.0%
Rated Life / Catastrophic Failures	Omnidirectional	36	100.0%	122	96.7%
	Directional	85	100.0%	313	96.2%
	Decorative	26	100.0%	55	98.2%
	All Types	147	100.0%	490	96.5%
Rapid Cycle Stress Test (V1 and earlier products only)	Omnidirectional	N/A	N/A	97	99.0%
	Directional	N/A	N/A	286	99.7%
	Decorative	N/A	N/A	36	100.0%
	All Types	N/A	N/A	419	99.5%

Figure 3: Number of Tests Failed (2017)

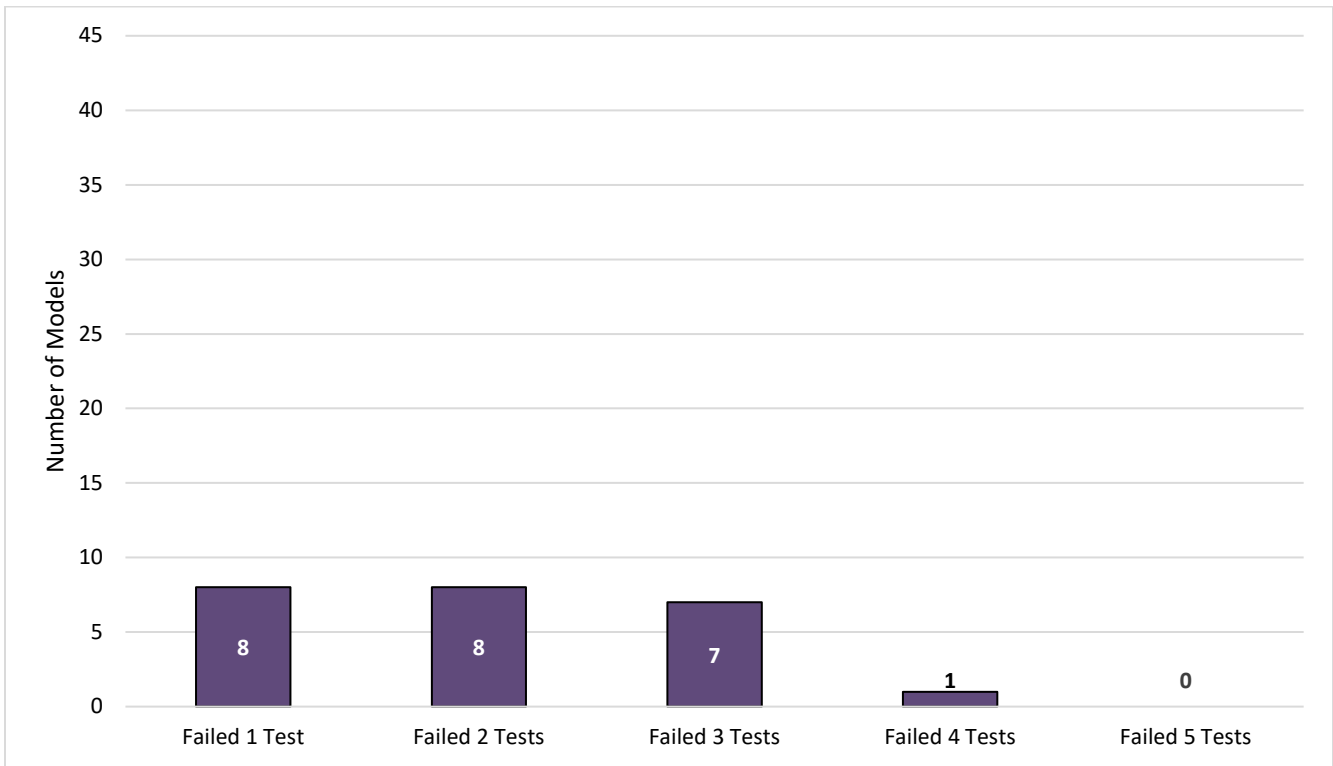


Figure 4: Number of Tests Failed (2013-2017)

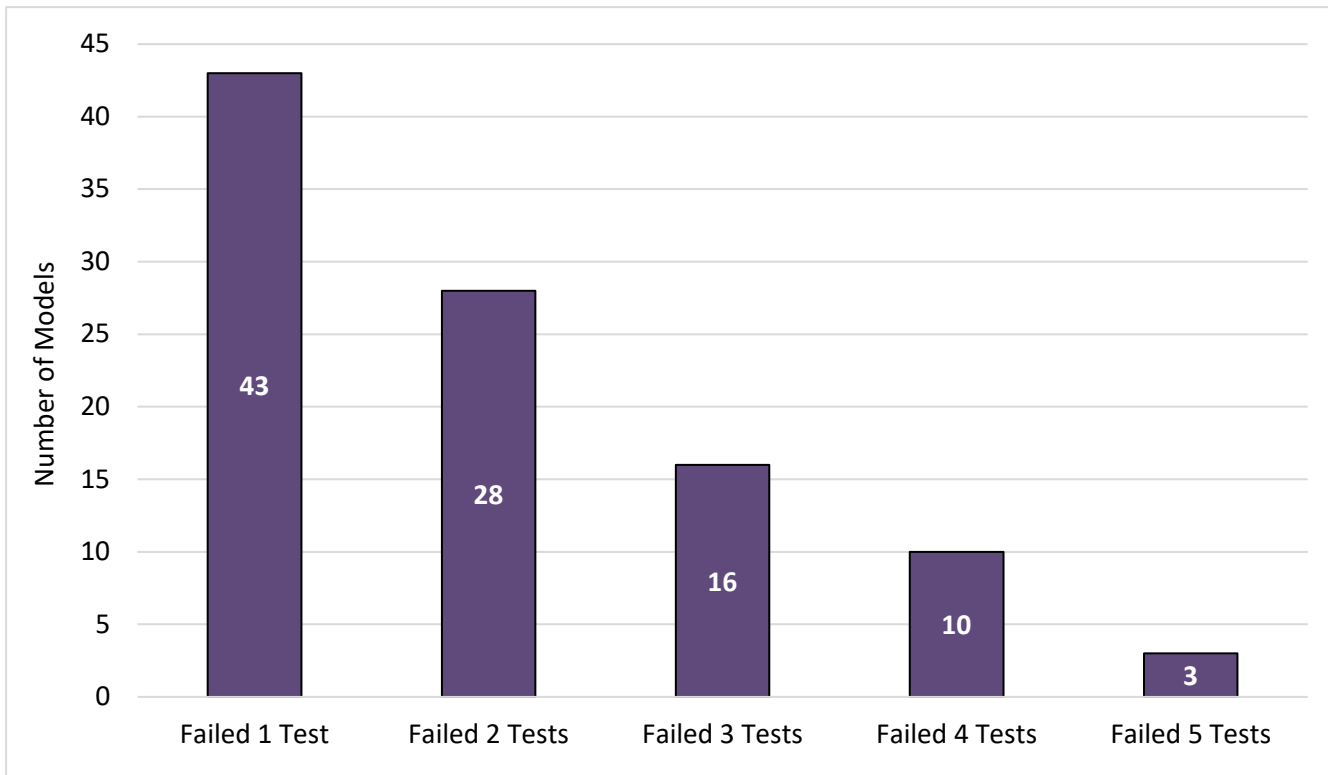


Figure 5: Test Results by Model Type (2017)

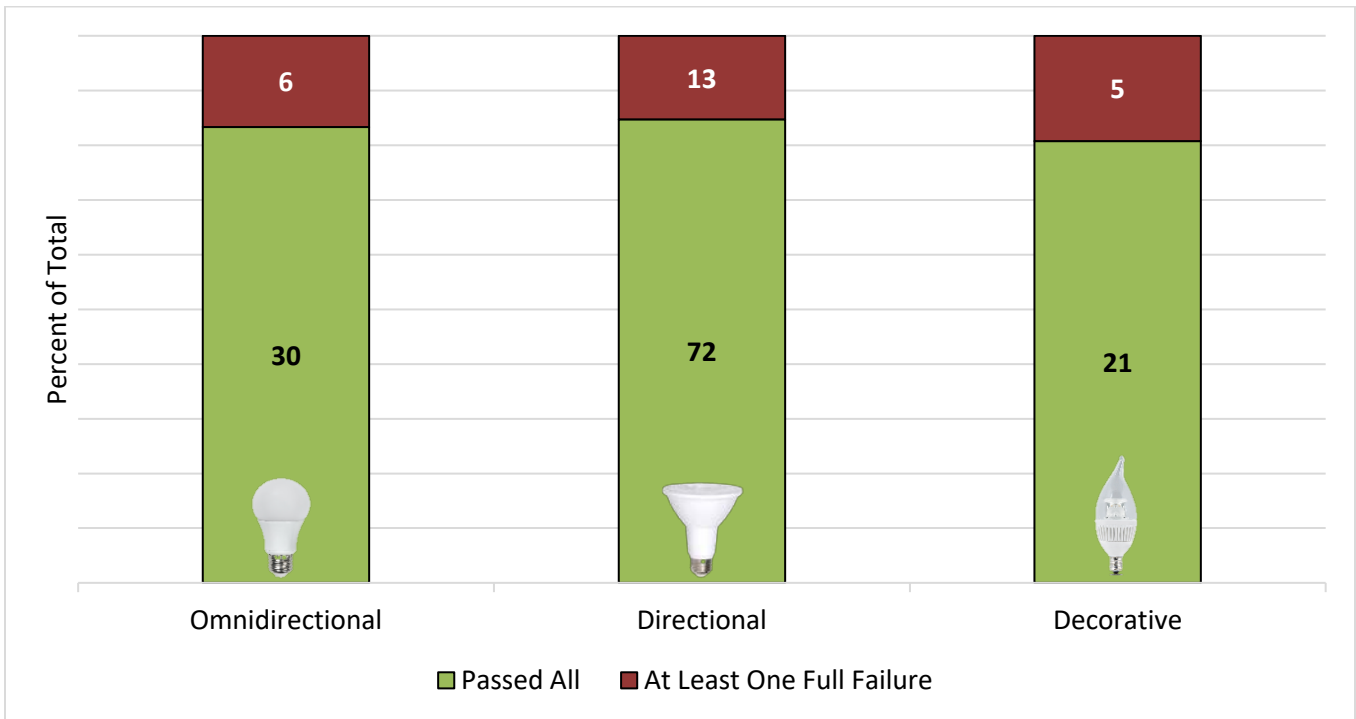


Figure 6: Test Results by Model Type (2013-2017)

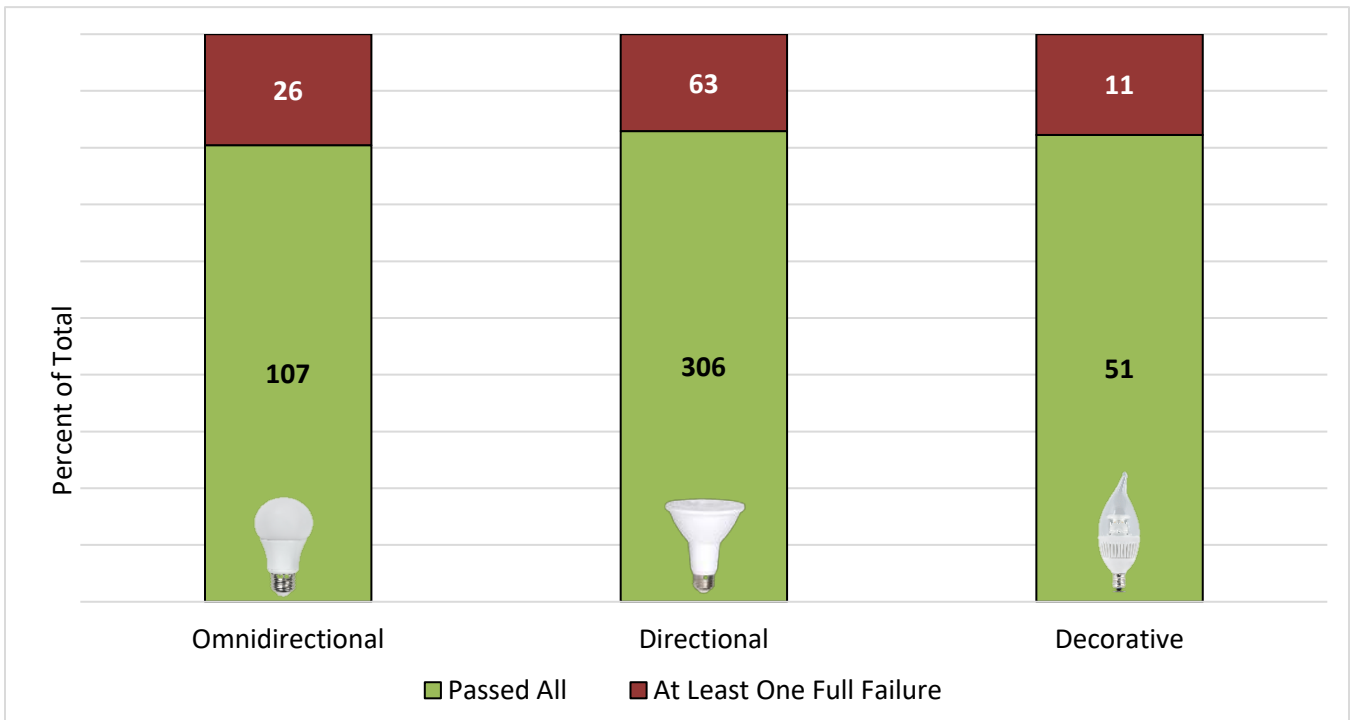


Table 3: Failures for All Models Tested

	2017						All Years					
	Omnidirectional		Directional		Decorative		Omnidirectional		Directional		Decorative	
	#	%	#	%	#	%	#	%	#	%	#	%
Passed All	30	83%	72	85%	21	81%	107	80%	306	83%	51	82%
At Least One Full Failure	6	17%	13	15%	5	19%	26	20%	63	17%	11	18%
<i>Failed 1 Test</i>	1	3%	5	6%	2	8%	9	7%	30	8%	4	6%
<i>Failed 2 Tests</i>	1	3%	6	7%	1	4%	6	5%	18	5%	4	6%
<i>Failed 3 Tests</i>	3	8%	2	2%	2	8%	5	4%	8	2%	3	5%
<i>Failed 4 Tests</i>	1	3%	0	0%	0	0%	5	4%	5	1%	0	0%
<i>Failed 5 Tests</i>	0	0%	0	0%	0	0%	1	1%	2	1%	0	0%
Total Models Tested	36	100%	85	100%	26	100%	133	100%	369	100%	62	100%

Table 4: Requirements Failed by Lamp Type^{8,9}

Requirement Failed	Omnidirectional		Directional		Decorative	
	2017	All Years	2017	All Years	2017	All Years
Luminous Efficacy	0	0	2	2	0	0
Light Output	2	9	0	2	1	2
Center Beam Intensity	N/A		0	9	N/A	
Luminous Intensity Distribution	5	10	N/A		0	1
Correlated Color Temperature	1	4	1	8	0	0
Rapid Cycle Stress Test	N/A	1	N/A	1	N/A	0
Color Rendering Index (R9)	0	0	0	0	0	1
Color Maintenance	1	8	3	14	2	2
Color Angular Uniformity	N/A		0	4	N/A	
3,000-Hour Lumen Maintenance	2	7	4	18	2	2
6,000-Hour Lumen Maintenance	1	10	4	29	4	6
Rated Life / Catastrophic Failures	0	4	0	12	0	1
Transient Protection	1	2	1	3	1	1
Dimensional Requirements	0	0	2	5	0	1
Total Failures	13	55	17	107	10	17

⁸ No verification testing failures for the following tests: Color Rendering Index (Ra), power factor, or frequency.

⁹ Not all models were tested for the transient protection and dimensional requirements. For these requirements, the CB chose two out of five requirements to test at random.

Detailed Results by Requirement

This section presents detailed failure results for the ENERGY STAR LED lamps verification testing initiated between November 2013 and December 2016. For each of the 18 requirements, results are presented by lamp type.

Luminous Efficacy

Efficacy is light output divided by power; it is measured in lumens per watt. Models must have a measured efficacy of at least the ENERGY STAR efficacy requirement for that model type (with a tolerance of 3%) to pass the requirement.

Two directional models tested in 2017 failed the luminous efficacy requirement. For one MR16 model, only six out of 10 units met the requirement. For one PAR30L model, the reported value (i.e., the average of all 10 units) deviated from the requirement by 4.1%.

Light Output (exemption: PAR, MR, and MRX lamps)

Reported initial light output (measured in lumens) for each lamp model must fall within the range of the referenced incandescent lamp (i.e., for wattage equivalency claim made on the lamp, its base or packaging, product literature or point-of-purchase materials, either printed or electronic). In addition, eight or more units (out of 10) shall individually meet the requirement.

There were thirteen reported light output failures.

Figure 7: Light Output Percent Deviation from Specification

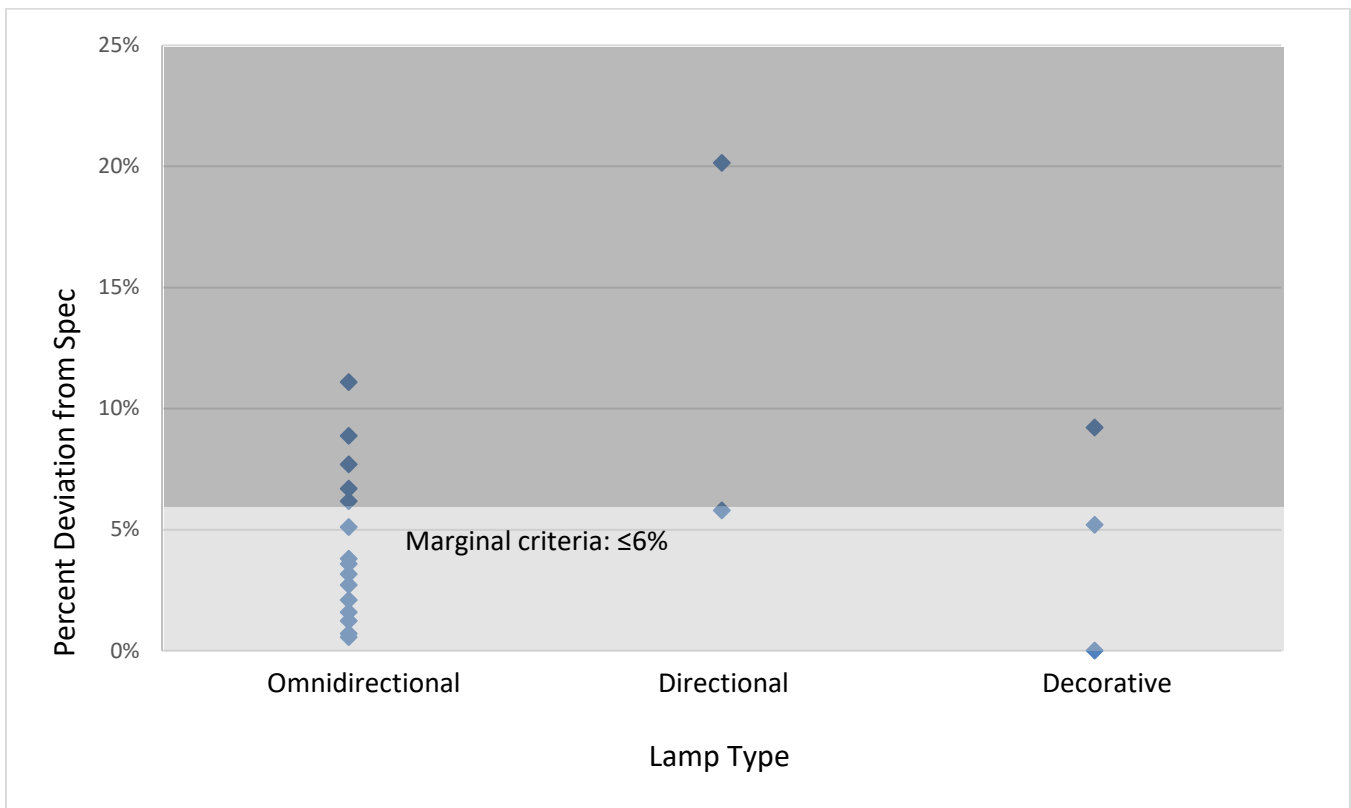


Table 5: Light Output Summary Results

Requirement	Lamp Type	2017				All Years			
		Passed		Failures		Passed		Failures	
		%	#	%	#	#	%	#	%
Light Output	Omnidirectional	34	94.4%	2	5.6%	133	93.2%	9	6.8%
	Directional	38	100.0%	0	0.0%	134	98.5%	2	1.5%
	Decorative	25	96.2%	1	3.8%	62	96.8%	2	3.2%
	All Types	97	97.0%	3	3.0%	329	96.0%	13	4.0%

Light Output - Center Beam Intensity (PAR, MR, and MRX lamps)

The center beam intensity requirement specifies the light emitting power of a point source in a particular direction. For directional PAR, MR, and MRX lamps, the center beam intensity, also known as the center beam candlepower (CBCP), must exceed the minimum value calculated by the ENERGY STAR Lamp Center Beam Intensity Benchmark Tool (i.e., for the wattage equivalency claim made on the lamp, its base or packaging, product literature or point-of-purchase materials, either printed or electronic).

As detailed in Table 6, nine models (all tested prior to 2017) were reported as having failed the center beam intensity requirement.

Table 6: Center Beam Intensity Detailed Failure Information

Lamp Shape	Target Minimum CBCP (candela)	Test Result (candela)	Deviation from Target CBCP
MR16	1323	1225	7.7%
MR16	2323	2148	7.8%
PAR38	2231	2061	7.9%
MR16	1315	1198	9.3%
MR16	8413	7078	17.2%
MR16	2308	2858	21.3%
PAR30L	2910	2203	27.7%
PAR30	2910	2151	30.0%
MR16	906	658	31.7%

Elevated Temperature Light Output Ratio (Directional lamps)

Elevated temperature is the ratio of the light output of the lamp when tested in the same elevated temperature condition required for lumen maintenance, to its initial light output. The tested lamp shall maintain $\geq 90\%$ of initial light output measured at ambient temperature when tested in the same elevated temperature condition required for lumen maintenance.

Only directional lamps are required to meet the elevated temperature light output ratio requirement. There were no elevated temperature light output ratio failures.

Luminous Intensity Distribution (Omnidirectional and Decorative lamps)

The luminous intensity distribution requirement specifies the light emitting power of a point source in a particular direction. Luminous intensity distribution shall emulate that of the referenced incandescent lamp.

Only omnidirectional and decorative lamps are required to meet the luminous intensity distribution requirement.

For Decorative lamps, no less than 5% of total flux (lumens) shall be emitted in the 110° to 180° zone. One decorative lamp tested prior to 2017 failed to meet this requirement by 20.5%, emitting only 4.1% of total lumens in this zone.

Omnidirectional lamps tested in 2016 were subject to the following Lamps Version 1 requirements:

- 90% of the measured luminous intensity values (candelas) shall vary by no more than 25% from the average of all measured values in all planes in the 0° to 135° zone.
- All measured values (candelas) in the 0° to 135° zone shall vary by no more than 50% from the average of all measured values in that zone.
- No less than 5% of total flux (zonal lumens) shall be emitted in the 135° to 180° zone.

Omnidirectional lamps tested in 2017 were subject to the following Version 2 requirements:

- 80% of the measured luminous intensity values may vary by no more than 35% from the average of all measured values in all planes in the 0° to 130° zone.
- All measured values (candelas) in the 0° to 130° zone shall vary by no more than 60% from the average of all measured values in that zone.
- No less than 5% of total flux (lm) shall be emitted in the 130° to 180° zone.

Prior to 2016 testing, no luminous intensity distribution failures were observed. During 2016 testing, three omnidirectional models failed two requirements. During 2017 testing, two omnidirectional models failed two or more of the requirements. Details are provided in Table 7 below.

Table 7: Luminous Intensity Distribution Detailed Failure Information

Test Year	Test Result	Deviation
2016	68% of measured values vary by < 25% 29.2% of measured values vary by > 50%	27.8% for measured values < 25% N/A for measured values > 50%
2016	74.7% of measured values vary by < 25% 45.8% of measured values vary by > 50%	18.5% for measured values < 25% N/A for measured values > 50%
2016	78.4% of measured values vary by < 25% 43% of measured values vary by > 50%	13.8% for measured values < 25% N/A for measured values > 50%
2017	54% of measured values vary by < 35% 101 measured values vary by > 60%	32.5% for measured values < 35% N/A for measured values > 60%
2017	33.8% of measured values vary by < 35% 738 measured values vary by > 60% 4.4% of total flux produced (130° to 180° zone)	57.8% for measured values < 35% N/A for measured values > 60% 12% for total flux

Correlated Color Temperature

Correlated color temperature (CCT) is a measure of the color appearance of a lamp model measured in Kelvin. CCT is scored based on the American National Standards Institute (ANSI) 7-step quadrangle for the manufacturer’s specified color temperature. Nine out of ten units within the sample and the 10-unit average value are required to fall within the ANSI-defined quadrangle for the designated nominal CCT.

All models were tested to this requirement, out of which there were eleven models reported as failures. Failures occurred across multiple nominal CCTs. Five models failed to have any units in the designated quadrangle. One model had two units fall outside the designated quadrangle, one had three, one had four, one had five, and two had eight units outside the designated quadrangle.

Table 8: Correlated Color Temperature Detailed Failure Information

Model Type	Designated Nominal CCT (K)	ANSI-Defined Quadrangle (K)	10-Unit Average CCT Test Result (K)	Units Meeting the Requirement
Directional	2700	2580 – 2870	3019	0
Directional	5000	4746 – 5312	N/A	7
Directional	2700	2580 – 2870	N/A	8
Directional	5000	4746 – 5312	4621	0
Directional	3000	2870 – 3220	3270	0
Omnidirectional	2700	2580 – 2870	2890	0
Directional	5000	4746 – 5312	5676	0
Omnidirectional	5000	4746 – 5312	5372	2
Directional	5000	4746 – 5312	5346	6
Directional*	2700	2580 – 2870	2895	2
Omnidirectional*	2700	2580 – 2870	N/A	5

*2017 Test Year

Color Rendering Index - Ra and R9

Light sources differ in their ability to render the color of objects in a realistic or natural manner as we expect to see them. On a 0-100 scale, Color Rendering Index (CRI, also known as Ra) is the average measured degree of color shift that eight reference color samples undergo when illuminated by a light source as compared with the color of those same samples when illuminated by a reference source of comparable CCT. The measured degree of color shift that a ninth, saturated red, color sample undergoes when illuminated by the light source as compared with its color when illuminated by a reference source of comparable CCT is known as R9. Certified lamps are required to have Ra ≥ 80 and R9 > 0.

No models failed the CRI Ra requirement, while one decorative model tested prior to 2017 failed the CRI R9 requirement.

Color Maintenance

Color maintenance is a measure of the variation in chromaticity from 0-hour measurement, at any measurement point during the first 6,000 hours of lamp operation. Lamp change in chromaticity from 0-hour measurement, at any measurement point during the first 6,000 hours of lamp operation must fall within a certain distance (≤ 0.007) on the CIE 1976 $u'v'$ diagram. Nine or more samples shall meet the requirement.

Twenty-four models failed to meet the color maintenance requirement. Of these, 12 models had one or fewer catastrophic failures, and are depicted in Table 9 below. Six models had more than one catastrophic failure, and therefore were not able to meet the color maintenance requirement. All reported failures were full failures. The average change in chromaticity of surviving units deviated from 13.3% to 161.6%.

Table 9: Color Maintenance Detailed Failure Information

Model Type	Average Change in Chromaticity from 0 Hours (Surviving Units) ¹⁰	Deviation from Average Change Requirement	Units Meeting the Requirement	Number of Operational Units at 6,000 Hours
Omnidirectional	0.010	35.3%	0	9 out of 10
Omnidirectional	0.066	161.6%	0	No catastrophic failures
Omnidirectional	0.009	25.0%	2	No catastrophic failures
Omnidirectional	0.010	35.3%	4	No catastrophic failures
Omnidirectional	0.008	13.3%	5	7 out of 10
Omnidirectional	N/A	N/A	6	6 out of 10
Omnidirectional*	0.014	66.7%	N/A	No catastrophic failures
Directional	0.011	44.4%	0	No catastrophic failures
Directional	0.0083	17.0%	1	No catastrophic failures
Directional	0.002	N/A	2	2 out of 10
Directional	0.007	N/A	2	2 out of 10
Directional	N/A	N/A	3	3 out of 10
Directional	0.008	13.3%	4	No catastrophic failures
Directional	0.006	N/A	6	No catastrophic failures
Directional	0.006	N/A	6	No catastrophic failures
Directional	0.004	N/A	7	7 out of 10
Directional	0.006	N/A	8	9 out of 10
Directional	0.06	158.2%	6	9 out of 10
Directional	0.03	128.2%	N/A	No catastrophic failures
Directional*	0.01	35.3%	N/A	No catastrophic failures
Directional*	N/A	N/A	5	No catastrophic failures
Directional*	N/A	N/A	6	No catastrophic failures
Decorative*	N/A	N/A	8	No catastrophic failures
Decorative*	N/A	N/A	8	No catastrophic failures

*2017 Test Year

Color Angular Uniformity (Directional lamps)

Color angular uniformity is a measure of the variation of chromaticity across the beam angle of the lamp. Color angular uniformity shall be within a total distance of 0.006 from the weighted average point on the CIE 1976 (u'v') diagram.

Only directional lamps are subject to the color angular uniformity requirement. Of all directional lamps, four lamps (all tested prior to 2017) failed to meet this requirement.

¹⁰ Some test data was not available due to limitations in reported information from certification bodies

Table 10: Color Angular Uniformity Detailed Failure Information

Lamp Shape	Test Result	Deviation
MR16	0.0158	89.9%
MR16	0.0083	32.0%
PAR30	0.0113	61.3%
PAR30	0.0082	31.0%

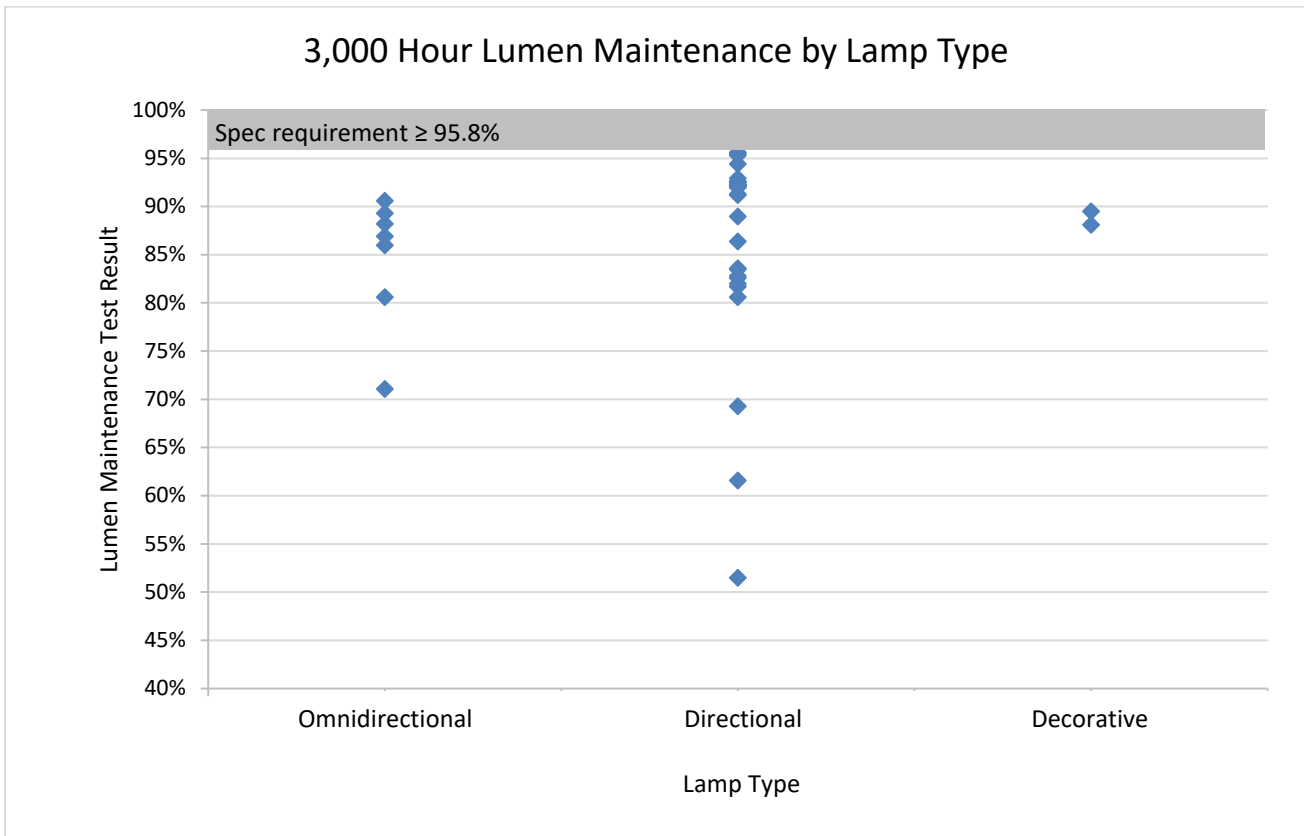
3,000-Hour Lumen Maintenance

The 3,000-hour lumen maintenance test is an initial measurement of how well a product maintains its light output level over time. The lumen output is measured after 3,000 hours of time and is expressed as a percentage of the measured initial lumen output. Lumen maintenance is the converse of lumen depreciation.

Models with a rated life claim of 25,000 hours must maintain at least 95.8% of initial light output at 3,000 hours. Models with a rated life claim of 15,000 hours must retain at least 93.1% of initial light output.

Twenty-seven models (all with a rated life claim of 25,000 hours) failed this requirement, with test results ranging from a 0.5% to 46.2% deviation from the specification requirement.

Figure 8: 3,000-Hour Lumen Maintenance Results by Lamp Type¹¹



¹¹ Five models experienced >1 catastrophic failure and so are excluded from this figure.

Table 11: 3,000-Hour Lumen Maintenance Summary Results

Specification Requirement	Model Type	2017				All Years			
		Passed		Failures		Passed		Failures	
		#	%	#	%	#	%	#	%
3,000-hour Lumen Maintenance	Omnidirectional	34	94.4%	2	5.6%	126	94.7%	7	5.3%
	Directional	81	95.3%	4	4.7%	351	95.1%	18	4.9%
	Decorative	24	92.3%	2	7.7%	60	96.8%	2	3.2%
	All Types	139	94.6%	8	5.4%	537	95.2%	27	4.8%

6,000-Hour Lumen Maintenance

6,000-hour lumen maintenance measures the lumen output after 6,000 hours of testing and is expressed as a percentage of the measured initial lumen output. Depending upon the maximum life (hours) claimed by the partner, Table 12 below shows the required minimum lumen maintenance after required test duration:

Table 12: Lumen Maintenance Requirement by Rated Life Claim

Maximum Life Claim (hours to L ₇₀)	Minimum Lumen Maintenance After Test Duration ¹²
15,000	86.7%
20,000	89.9%
25,000	91.8%
30,000	93.1%
35,000	94.1%
40,000	94.8%
45,000	95.4%
50,000	95.8%

For models certified to Version 2, all units are required to remain operational at all measurement intervals and the reported values are the average lumen maintenance of all ten units. For models tested prior to 2017, the reported values are the average lumen maintenance of ≥ 9 surviving units for lamps certified to Lamps Version 1.1, and the average lumen maintenance of all 10 units for lamps certified to Integral LED lamps Version 1.4. Four Version 1.1 Lamp models experienced a single catastrophic failure; in those cases, the calculated 6,000-hour lumen maintenance was based on the performance of the nine operational units.

Forty-five models failed the 6,000-hour lumen maintenance requirement (8% of total tested). The worst performing model (tested in 2016) had a 64.7% deviation from the specification requirement. Twenty-five models that failed at the 3,000-hour measurement interval also failed at the 6,000-hour interval. One model discontinued verification testing after failing at 3,000 hours.

¹² A 3% tolerance may be applied to all measured luminous flux values (e.g., [luminous flux X 1.03]) except at the 0-hour measurement, if the calculated lumen maintenance value fails to meet the requirement without the tolerance.

Figure 9: 6,000-Hour Lumen Maintenance Results by Lamp Type¹³

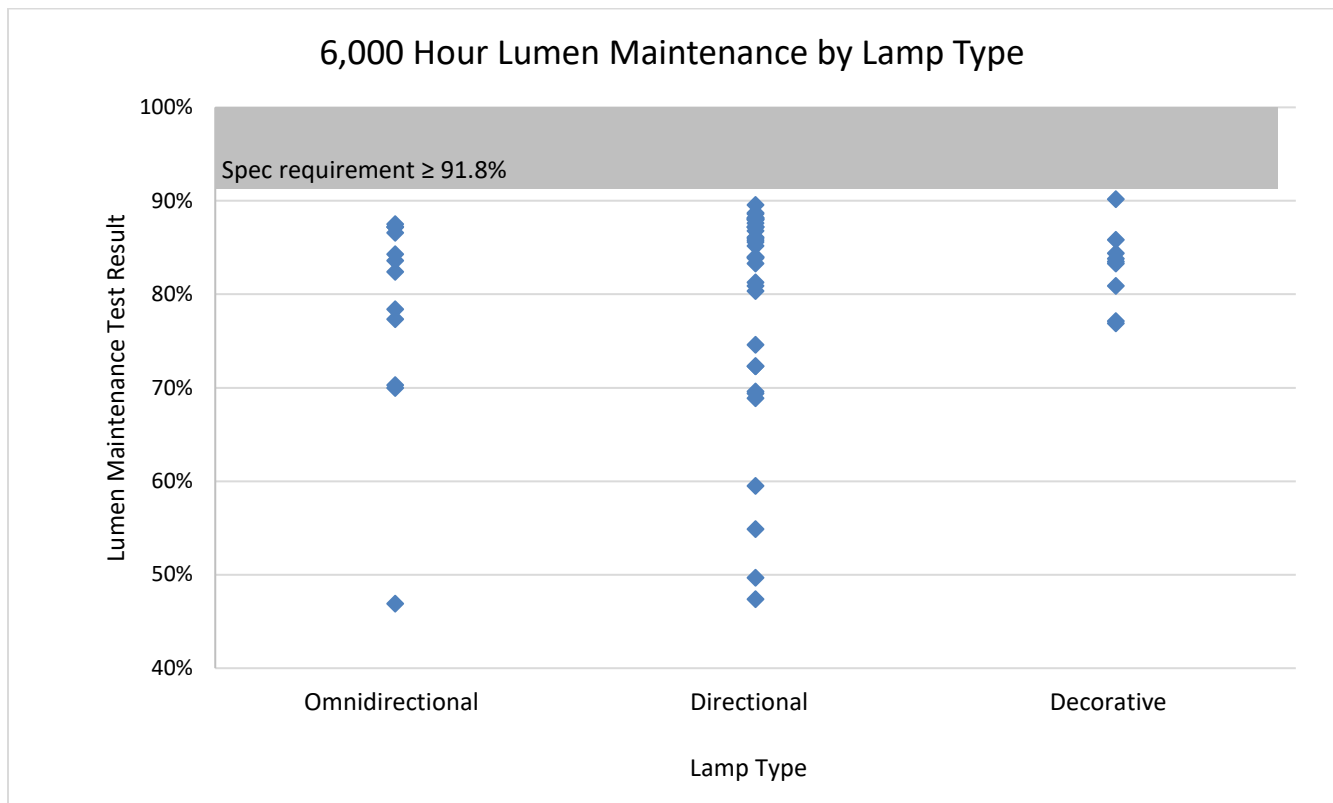


Table 13: 6,000-Hour Lumen Maintenance Summary Results

Requirement	Model Type	Specification requirement ¹⁴	2017				All Years			
			Passed		Failures		Passed		Failures	
			#	%	#	%	#	%	#	%
6,000-hour Lumen Maintenance	Omnidirectional	≥ 91.8%	35	97.2%	1	2.8%	123	92.5%	10	7.5%
	Directional	≥ 91.8%	81	95.3%	4	4.7%	340	92.1%	29	7.9%
	Decorative	≥ 86.7%	22	84.6%	4	15.4%	56	90.3%	6	9.7%
	All Types		138	93.9%	9	6.1%	519	92.0%	45	8.0%

Rated Life (Catastrophic Failures)

The rated life criteria sets the requirement of the minimum elapsed operating time over which the defined population of LED lamps should maintain a target percent of initial light output. Additionally, at 3,000 hours, any catastrophic failure - where a lamp is no longer operational - is considered a rated life failure. At 6,000 hours, two or more catastrophic failures is considered a rated life failure.¹⁵

¹³ Seven models experienced >1 catastrophic failure so are excluded from this figure.

¹⁴ All but three models that failed 6,000-hour lumen maintenance claimed rated life of 25,000 hours; two claimed 15,000 hours and one claimed 40,000 hours. Test results for those models were 76.9% and 83.5% (15,000-hour models), and 83.3% (40,000-hour model).

¹⁵ Rated life was not a requirement of Integral LED Lamps Version 1.4, so 74 LED lamps were not evaluated for this requirement.

Models that failed to meet rated life as a result of lumen maintenance have been captured in the 3,000-hour and 6,000-hour lumen maintenance sections of this report. Seventeen models (all tested prior to 2017) failed the rated life requirement as a result of catastrophic failures. Of these failures, ten models failed because they experienced one catastrophic failure at 3,000 hours, and seven models failed because they had two or more catastrophic failures at 6,000 hours. Details on these failures can be found in Table 14.

Table 14: Rated Life (Catastrophic Failures) Detailed Failure Information

Model Type	Lamp Shape	Catastrophic Failures Observed at 3,000 hours (Units) ¹⁶	Total Catastrophic Failures Observed (Units)
Omnidirectional	A19	N/A	4
Omnidirectional	A19	2	3
Omnidirectional	A19	1	1
Omnidirectional	A19	1	1
Directional	MR16	8	8
Directional	MR16	1	1
Directional	MR16	1	1
Directional	PAR16	2	3
Directional	PAR30	1	1
Directional	PAR30	1	1
Directional	PAR38	N/A	2
Directional	PAR38	N/A	1
Directional	R20	0	7
Directional	R20	4	8
Directional	R20	1	1
Directional	R20	1	1
Decorative	Other	1	1

Rapid Cycle Stress Test

A lamps' ability to survive frequent switching cycles is tested by the rapid cycle stress test, during which the lamp is cycled at 2 minutes on, 2 minutes off, or 5 minutes on 5 minutes off for the lesser of one cycle per hour of rated life or 15,000 cycles. At least 5 units shall survive the minimum number of cycles. LED lamps certified under the V2 specification are exempt from this requirement.

Three models tested prior to 2017 failed the Rapid Cycle Stress Test requirement, with only two, three, and four units within the sample surviving.

Power Factor

Power factor is the measure of the active power of the LED lamp divided by the apparent power. In other words, it is the input power in watts divided by the product of root mean square (RMS) input voltage and RMS input current of a ballast or driver.

¹⁶ Three models were not evaluated for catastrophic failures at 3,000 hours because they did not utilize early certification.

During verification testing, CBs may select this requirement out of a list of five at random. There were no reported power factor failures.

Frequency

Frequency measures the number of complete oscillations per second of the lamp light output waveform. During verification testing, CBs may select this requirement out of a list of five at random.

There were no reported frequency failures.

Start Time

The start time criteria measures the time (in milliseconds) after switching an LED lamp on for it to start and remain lit. In other words, it is the time from application of electrical power to when the lamp remains continuously illuminated. In Lamps Version 1, the requirement for LED lamps to start within 1 second of application of power.

During verification testing, CBs may select this requirement out of a list of five at random. There were no reported start time failures.

Transient Protection

Transient protection is a measure of the lamp’s ability to protect against surges in voltage. Lamps are subjected to seven strikes of a 100 kHz ring wave, at 2.5 kV.

During verification testing, CBs may select this requirement out of a list of five at random. Five models (including three tested in 2017) were reported to have failed the transient protection requirement.

Dimensional Requirements

Dimensional requirements address whether a lamps’ minimum overall length (min OAL), maximum overall length (MOL), and diameter meet the ANSI standard for the claimed lamp shape. Six models failed to meet the dimensional requirements.

Table 15: Dimensional Requirements Detailed Failure Information

Model Type	Lamp Shape	Specification Requirement (mm)	Test Result (mm)	Deviation
Directional	PAR30	MOL is 95.3	121.7	24.3%
Directional	PAR16	Min OAL is 69.9	63.7	9.3%
Directional	R20	Max OAL is 90.5 – 100	87.3	3.6%
Directional*	PAR30L	MOL is 93.7	93.87	0.18% ¹⁷
Directional*	BR30	Min OAL is 123.8	117.7	4.93%
Decorative	B13	Min OAL is 41.3	34.9	16.7%

*2017 Test Year

¹⁷ This model also significantly failed the center beam intensity requirement.