ENERGY STAR® CFL THIRD PARTY TESTING AND VERIFICATION

Off-the-Shelf CFL Performance, Trends, and Implications: Batch 4

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U.S. Environmental Protection Agency

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Table of Contents

Executive Summary ***3***

Summary Results ***5***

Methodology ***13***

Product Selection 13

Product Procurement 13

Product Testing 14

Detailed Results for Batch 4 ***15***

Luminous Efficacy 15

Starting Time 16

Run-Up Time 17

Power Factor 19

Color Rendering Index 20

Chromaticity 21

1,000-Hour Lumen Maintenance 23

Rapid Cycle Stress Test 25

Lumen Maintenance at 40% of Rated Life 28

Interim Life Test 30

Initial Elevated Temperature Output Ratio 32

All Tests 33

Comparison of Batches 1, 2, 3, and 4 ***37***

Summary of Results by Product Type 37

Summary of Results by Test 42

OEM Analysis 51

Conclusion ***52***

Appendix ***54***

EXECUTIVE SUMMARY

As of May 31, 2015, the Independent ENERGY STAR CFL Third Party Testing and Verification Program had tested and verified the performance of 438 base models. Each product was procured "off the shelf" by an independent testing laboratory and subjected to the same tests that are required for initial certification.

Overall, 69% of models in Batch 4 passed every test, meeting the requirements for ENERGY STAR qualification. Covered lamps and bare specialty models, which include dimmable and 3-way bare lamps, failed at a higher rate than bare spiral models, a trend seen throughout the five-year CFL testing program. In Batch 4, 82% of bare spiral models passed all tests, compared to 60% of bare specialty models and only 52% of covered models.

Performance of the products tested in Batch 4 was better than the performance of the products tested in Batches 2 and 3 and comparable to the performance of products in Batch 1. Based on the results from Batches 2 and 3, the Environmental Protection Agency (EPA) amended the product selection guidelines for Batch 4. The changes included lifting the six-product cap on the number of products a labeler could have tested each year, which made testing more balanced between larger and smaller manufacturers relative to their share of the ENERGY STAR certified products list. In addition, EPA nominations targeted products with a history of poorer performance, such as covered lamps. Batch 1 covers the 68 models that completed testing by February 5, 2011; Batch 2 covers the 68 models that completed testing between February 6 and July 31, 2011; and Batch 3 covers the 118 models that completed testing between August 1, 2011 and July 31, 2012. In Batch 4, of the 184 models that completed testing between August 1, 2012 and May 31, 2015, 43% were products other than bare spiral, compared to 26% in Batch 1, 38% in Batch 2, and 44% in Batch 3.

Although there was an improvement in Batch 4, the performance of covered products throughout this CFL testing program has been consistently poor. In Batch 3, 78% of covered models failed at least one test, compared with 65% in Batches 1 and 2. In Batch 4, 48% of covered models failed at least one test. While this represents a significant improvement, it still does not indicate performance at a desirable level. The causes of this improved performance are unclear, but possible explanations include improvements in technology, the removal of older models from the certified product list and/or the market (possibly as a result of the testing program), and/or testing of a larger number of covered lamps. Because of the high failure rate, it would be beneficial to continue to have covered lamps be a focus of testing.

Performance on individual tests was mixed, but the tests that measure lumen maintenance continue to have the highest failure rates. Every product included in Batch 4 passed the Starting Time Test. For bare specialty products, three of the four failures were for the Chromaticity Test. The two Lumen Maintenance Tests (1,000-Hour and 40% of Life) and the Interim Life Test had the lowest passing rates – 90%, 88%, and 88%, respectively – which is consistent with the previous batches. These three tests accounted for a greater percentage of failures in Batch 4 than in previous batches.

There is a wide range of performance among original equipment manufacturer (OEM) partners with at least 5 models tested in Batch 4. In Batch 4, 10 OEMs had 5 or more products tested, with overall failure rates ranging from 11% to 50%. Those 10 OEM partners represent 85% of all models

tested and 87% of all model failures in Batch 4; 2 had failure rates of 40% or higher. Most OEMs had improved performance in Batch 4 compared to Batch 3. Of the 18 OEMs that had 5 or more products tested through Batch 3, 14 had equal or better cumulative passing rates after including the test results from Batch 4.

Use care when generalizing from the test results described in this report to the entire market of ENERGY STAR certified CFLs. The sample of models tested is not representative of ENERGY STAR shipments because the CFL models tested were selected by nomination or at random rather than by market share. The results are not representative of the current list of ENERGY STAR certified models, as product selections were made annually throughout the five-year program, and the list of qualified products grew over that same five-year period. Nevertheless, the test results are the best data available on the performance of ENERGY STAR certified CFLs sold at retail.

It is likely that some of the specialty models, both bare and covered, currently being sold in the market are poor performers. While some of the specialty models have passed all 10 tests, almost half have not. It is impossible to assess the extent of consumer exposure to failing specialty models without sales or shipment data. However, as nearly half of covered models tested in Batch 4 failed at least one test, additional market exposure is certainly possible.

Testing of 4 batches of products including more than 430 base models has identified areas of concern in the CFL market. Overall, bare spirals have consistently been the best-performing CFLs, and their performance has improved; these products passed all tests at increasing rates. Bare specialty and covered products have consistently had high failure rates, indicating that the technology used in these products is not yet perfected.

The performance of bare specialty products varied greatly. The overall pass rate of bare specialty products across the four batches ranged from 29% to 83%, with an average of 55%. This variance is likely due to the fact that only 31 products have been tested to date. The small sample makes drawing significant conclusions difficult. Those 31 products represent almost one-third of products identified as bare specialty products on the ENERGY STAR certified product list (60 products as of August 27, 2015). This product type does not make up a large share of the market, so it is unclear whether this product category should remain a priority for the CFL testing program.

SUMMARY RESULTS

This is a summary of Batch 4 results, covering findings from verification testing completed between August 1, 2012 and May 31, 2015. It is the final report of the ENERGY STAR CFL Third Party Testing and Verification Program. This report was originally completed on May 13, 2014 and was updated on August 31, 2015. Batch 4 contains a total of 184 ENERGY STAR certified models: 105 bare spiral models, 10 bare specialty models, and 69 covered models.

Reports showing verification testing results from three previous batches were published as follows:

- Batch 1: June 2011, with an update in July 2011.[1]
- Batch 2: February 2012.[2]
- Batch 3: December 2012.[3]

This report discusses findings from Batch 4 and compares results from all four batches, representing the entire set of products tested through the CFL verification testing program.

All 184 products underwent 10 different tests: the Lumen Efficacy Test, the Starting Time Test, the Run-up Time Test, the Power Factor Test, the 1000-Hour Lumen Maintenance Test, the Color Rendering Index Test, the Chromaticity Test, the Rapid Cycle Stress Test, and the Interim Life Test. Indoor covered lamps, of which there were 17, were also subject to the Initial Elevated Temperature Test. Key findings from Batch 4 testing include the following (see Figure 1):

- Every product in Batch 4 passed the test for Starting Time.
- No more than three models failed the Efficacy Test, Power Factor Test, Color Rendering Index Test, Rapid Cycle Stress Test, or Initial Elevated Temperature Test, which indicates that there is no significant issue with the performance measured by these tests.
- Only 7% of models failed the Chromaticity Test.
- The majority of failures (and marginal failures[4]) occurred with the 1,000-Hour Lumen Maintenance Test, the 40% Lumen Maintenance Test, and the Interim Life Test, each with 19-23 failures.

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[1] D&R International, "ENERGY STAR CFL Third Party Testing and Verification Cycle 1: Results," June 2011. (www.energystar.gov/ia/partners/downloads/Cycle_1_Final_Report_Public_7-18-11.pdf)

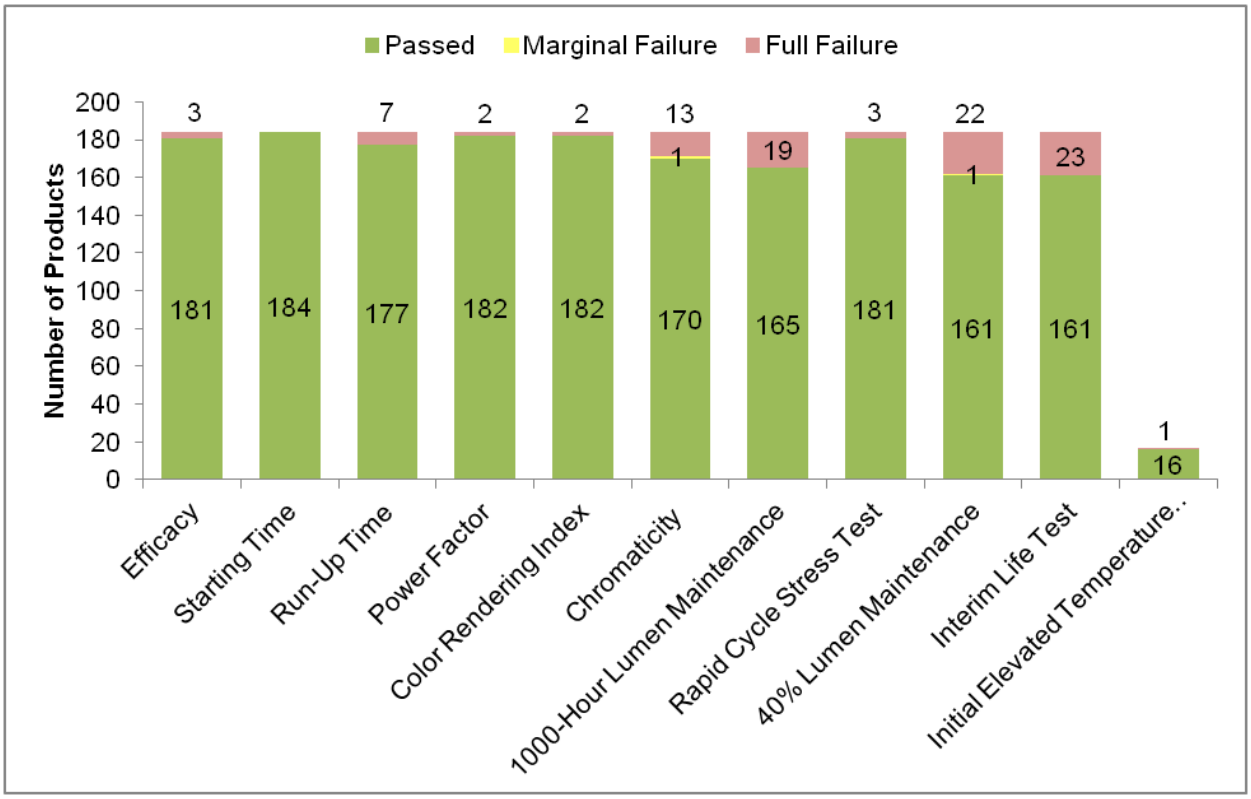
[2] D&R International, "ENERGY STAR CFL Third Party Testing and Verification Cycle 2: Off-the-Shelf CFL Performance, Trends, and Implications," May 2012. (http://www.energystar.gov/ia/partners/downloads/ENERGY_STAR_CFLs_Batch_2_Report_Public_Feb_2_2012.pdf)

[3] D&R International, "ENERGY STAR CFL Third Party Testing and Verification Cycle 3: Results," February 2013 (www.energystar.gov/ia/partners/downloads/ENERGY_STAR_CFLs_Batch_3_Report_Public_Feb_2013.pdf?f7fb-5617).

[4] A marginal failure is defined as a tested unit with one less sample passing a test than required. For example, a product that failed the Rapid Cycle Stress Test with 4 of 6 samples passing instead of the required 5 of 6 is scored as a marginal failure. Models that have one or more marginal failures but no other failures must undergo a retest.

- Six models marginally failed a test. Of those, two products failed other tests and were not retested, two passed their retests and remained ENERGY STAR certified, and the other two are expected to undergo re-testing that is likely to be completed by the end of 2015.

Figure 1: Summary Results by Test: All Model Types



There was some variation in the results among different lamp types.

- Bare spiral lamps performed worst on the Interim Life Test, with a failure rate of 9%. Less than 5% of bare spiral models failed each of the remaining nine tests.
  - No bare spiral lamps failed the 1000-Hour Lumen Maintenance Test, and only 2% failed 40% Lumen Maintenance.
- Bare specialty lamps had a high failure rate on the Chromaticity Test (30% failed and 10% had a marginal failure). However, because of the small sample size – only 10 bare spiral specialty lamps were tested, compared to 105 bare spiral and 69 covered lamps – the findings are inconclusive.[5] An additional bare specialty product failed the 40% Lumen Maintenance Test, but bare specialty products failed no other tests.
- Covered lamps performed poorly on the Interim Life Test (19% failed), 1,000-Hour Lumen Maintenance (27% failed), and 40% Lumen Maintenance Tests (26% failed); they had a moderate level of failure on the Chromaticity (7% failed) and Run-Up Time (7% failed) Tests.

[5] There are only 101 bare specialty products on the ENERGY STAR certified product list.

Figure 2: Summary Results by Test: Bare Spiral Models

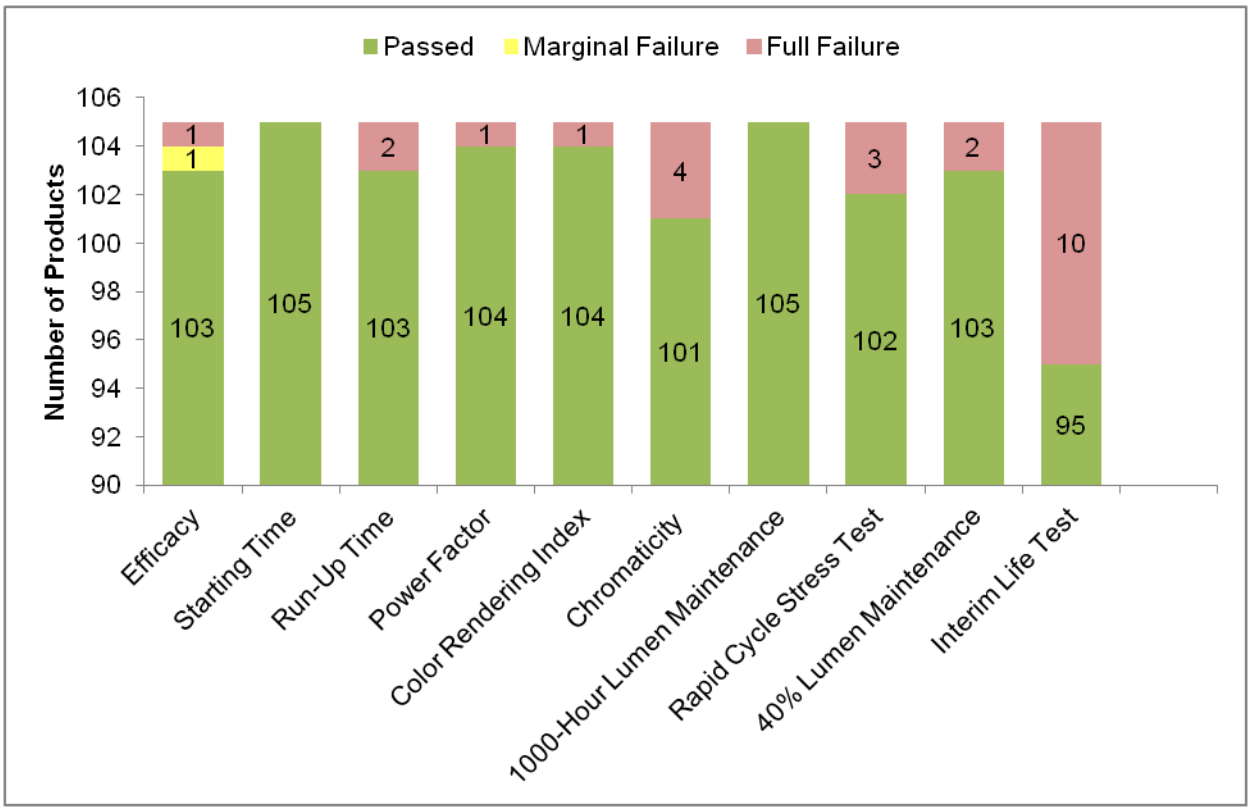


Figure 3: Summary Results by Test: Bare Specialty Models

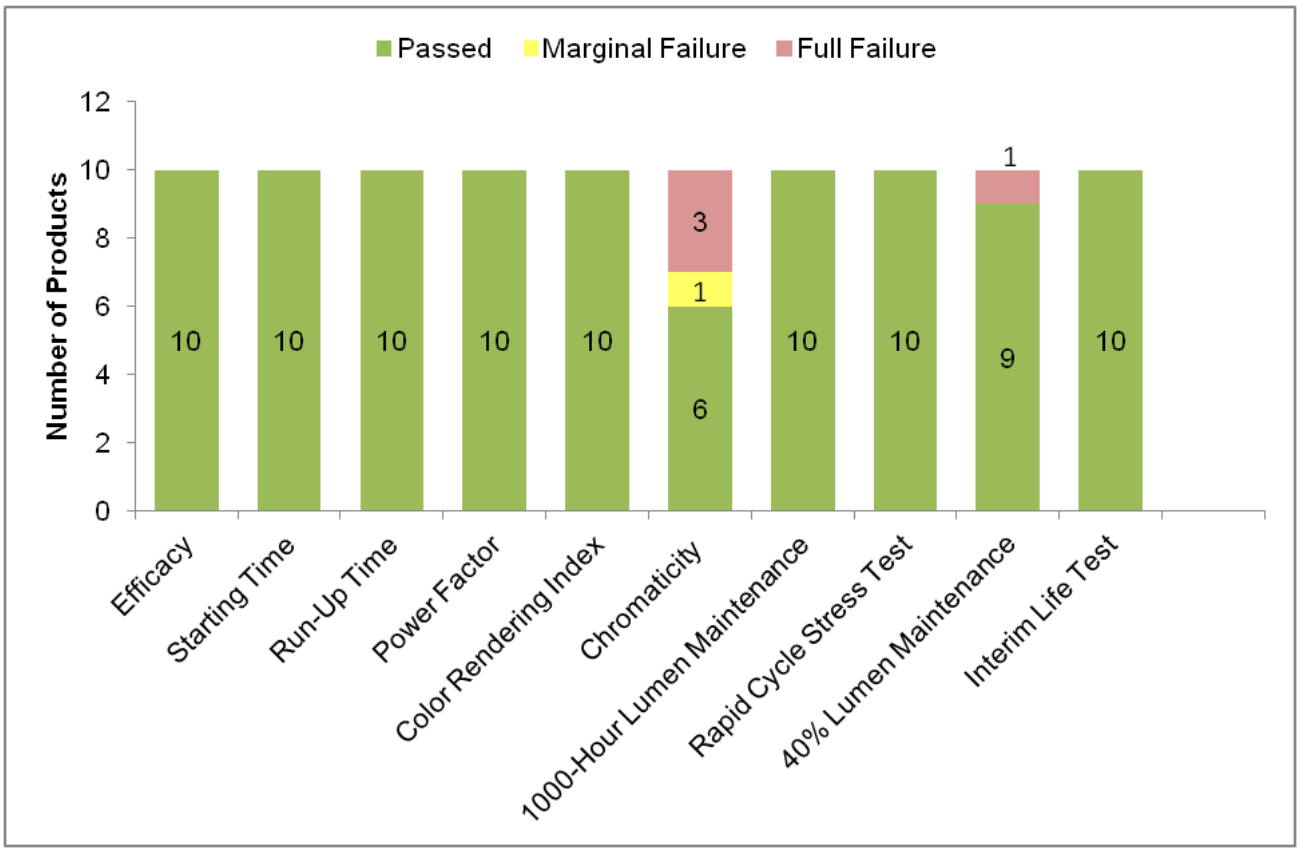


Figure 4: Summary Results by Test: Covered Models

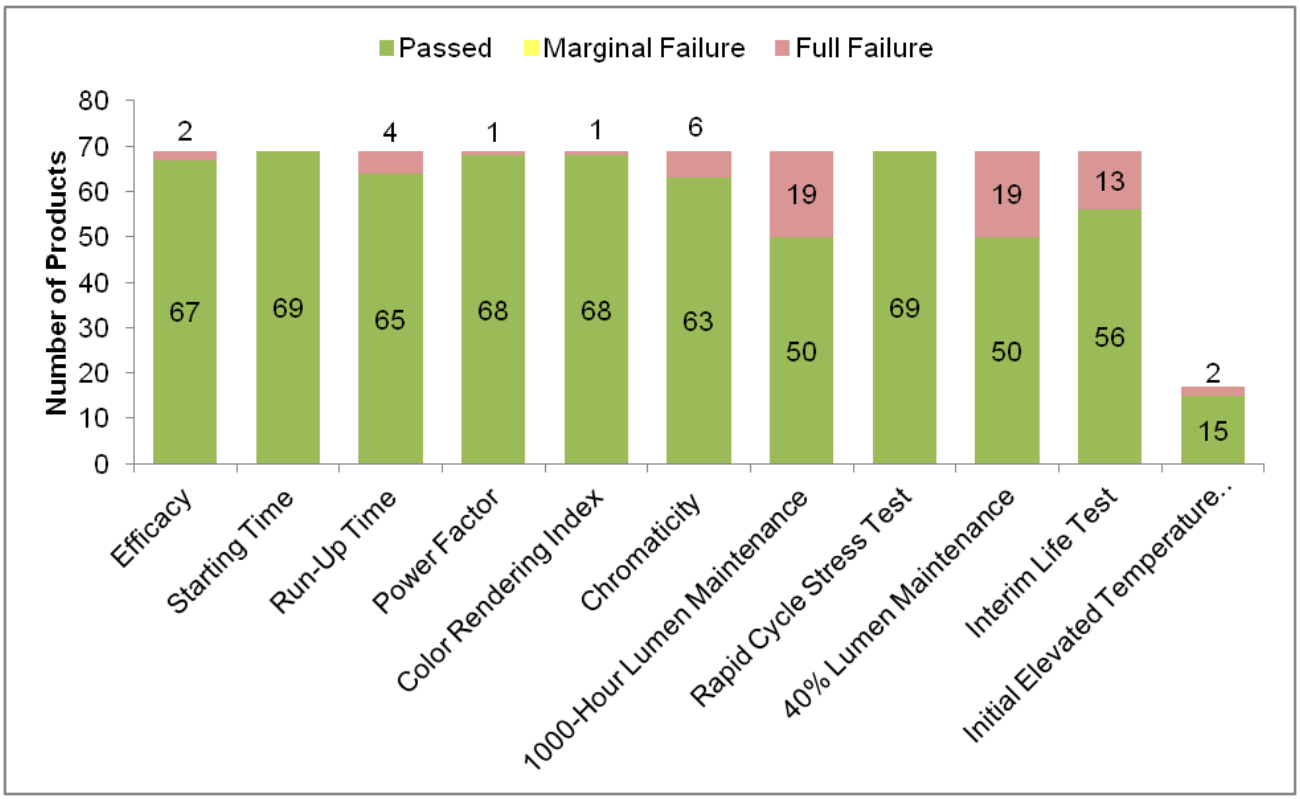


Table 1: Mean and Median Test Results, and Percent Passing and Failing Each Test by Lamp Type

Note: The lamp counts for each model type are as follows: All Types, 184; Bare Spiral, 105; Bare Specialty, 10; Covered, 69.

Test	Model Type	Mean Test Values	Median Test Values	Passing Criteria	Passing Rate (%)	Failure Rate (Marginal Failure Rate) (%)
Efficacy	All Types	61.1	63.7	Varies by model type	98	2
	Bare Spiral	66.7	67.6		98	1(1)
	Bare Specialty	66.3	66.7		100	0
	Covered	51.7	52.4		97	3
Starting Time	All Types	261	104	<1000 milliseconds	100	0
	Bare Spiral	170	54		100	0
	Bare Specialty	240	189		100	0
	Covered	401	310		100	0
Run-Up Time	All Types	73	55	<60 or <180 seconds	96	4
	Bare Spiral	46	39		98	2
	Bare Specialty	71	55		100	0
	Covered	116	104		93	7
Power Factor	All Types	0.569	0.560	>0.5	99	1
	Bare Spiral	0.573	0.564		99	1
	Bare Specialty	0.559	0.543		100	0
	Covered	0.566	0.552		99	1
Color Rendering Index	All Types	82.9	82.8	>80	99	1
	Bare Spiral	82.9	82.8		99	1
	Bare Specialty	81.9	81.8		100	0
	Covered	83.2	83.0		99	1
Chromaticity	All Types			9/10 coordinates inside ellipse or *17/20 coordinates inside ellipse	92	7 (1)
	Bare Spiral				96	4
	Bare Specialty				60	30 (10)
	Covered				91	9
1,000-Hour Lumen Maintenance	All Types	92	93	>90%	90	10
	Bare Spiral	94	94		100	0
	Bare Specialty	94	94		100	0
	Covered	89	90		72	28
Rapid Cycle Stress Test	All Types			5/6 survive to half of rated life or *10/12 survive to half of rated life	98	2
	Bare Spiral				97	3
	Bare Specialty				100	0
	Covered				100	0
	All Types	84	86	>80%	88	11 (1)

Test	Model Type	Mean Test Values	Median Test Values	Passing Criteria	Passing Rate (%)	Failure Rate (Marginal Failure Rate) (%)
40% Lumen Maintenance	Bare Spiral	86	87		98	2
	Bare Specialty	87	88		90	10
	Covered	81	81		72	28
Interim Life Test	All Types			9/10 survive to 40% of rated life or *17/20 survive to half of rated life	88	12
	Bare Spiral				90	0
	Bare Specialty				100	0
	Covered				81	19
Initial Elevated Temperature Output Ratio	Covered	94	95	>90%	94	6

*Double sample size

The 184 models tested each underwent 10 or 11 different tests. Of the 1,857 total tests performed, there were 95 individual test failures. Table 2 summarizes the test failures (excluding marginal failures).

Table 2: Summary of Test Failures for All Models Tested

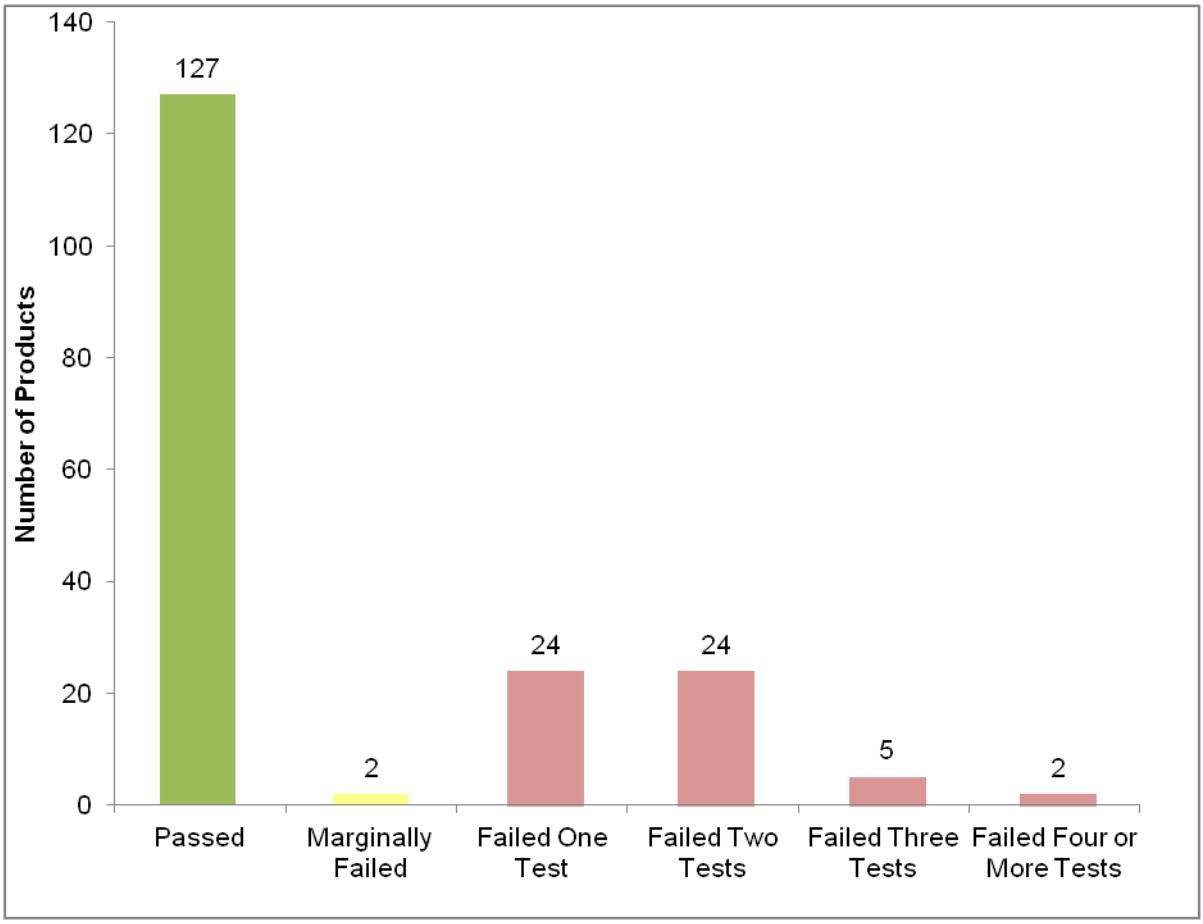
Test	All Models	Full Failures	
	Mean Test Result	Failure Criteria	Number of Failures
Efficacy	61.1	Varies	3
Starting Time	261	>1000 ms	0
Run-Up Time	59.9/77.4	<60/180 seconds	8
Power Factor	0.569	<0.50	2
Color Rendering Index	82.9	≤80.0	2
Chromaticity	10 samples or 19* samples	≤7 samples or ≤16* samples	12
1,000-Hour Lumen Maintenance	92%	≤90%	19
Rapid Cycle Stress Test	6 or 11* samples	<4 samples or ≤8* samples	3
40% Lumen Maintenance	84%	<80%	22
Interim Life Test	9 samples or 18* samples	≤7 samples or ≤16* samples	23
Initial Elevated Temperature Output Ratio	94%	≤90%	1
All Tests	n/a	n/a	95

* Double sample size

Of the 184 models tested, 127 (69%) passed all tests performed, 2 (1%) marginally failed one test but had no full failures, and 55 (30%) fully failed at least one test; 31 (56%) of the failing models failed only one test. Figure 5 presents summary results of the number of tests failed.

The manufacturer could opt to retest a model that marginally failed. If the manufacturer declined a retest, the OEM could choose a retest. If the manufacturer and OEM both declined a retest, the product was listed as a failure. If the product passed the retest, it was listed as a pass. There were four marginal failures in Batch 4 for which a retest was declined by both the manufacturer and the OEM. In previous batches, 13 products marginally failed; only 1 of those was not retested and therefore counted as a failure.

Figure 5: Number of Tests Failed: All Products



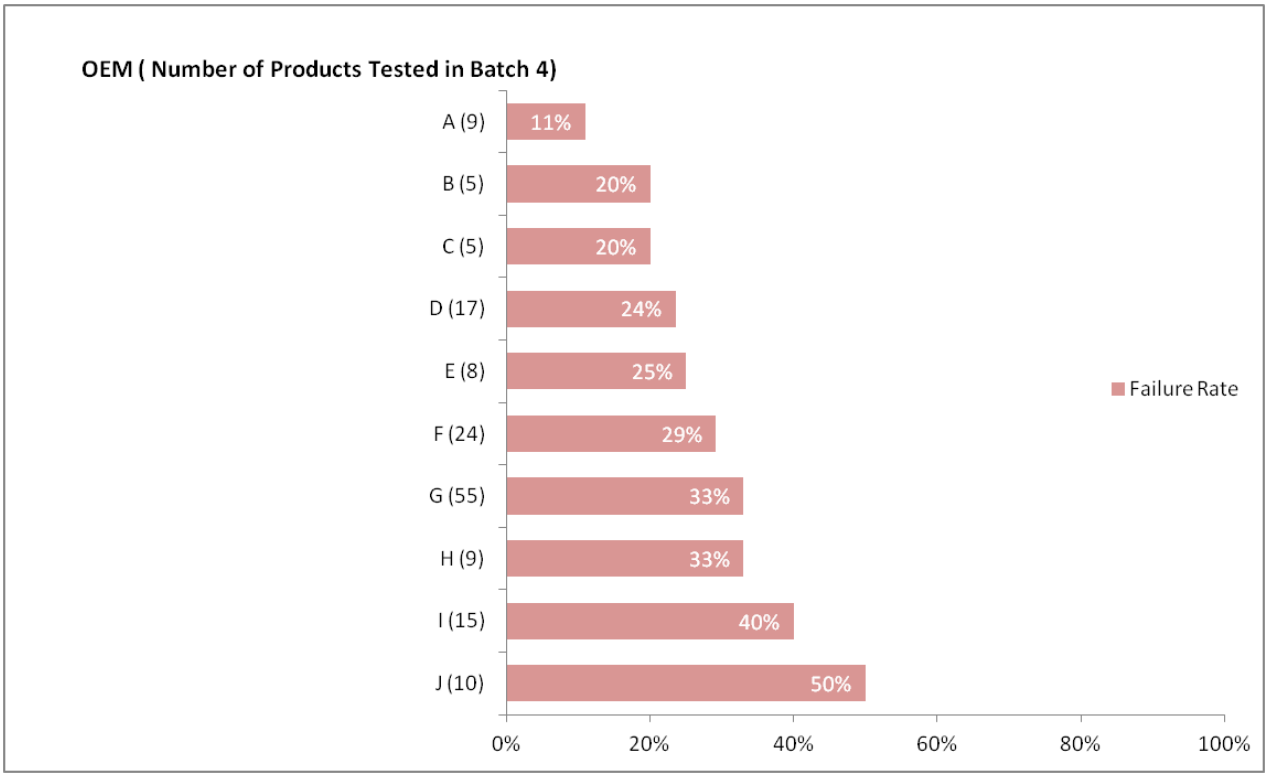
Failure rates among covered and bare specialty models were much higher than among bare spiral models. While 81% of the bare spiral models tested passed all tests, only 60% of bare specialty and 52% of covered models passed all tests. As shown in Table 3, covered lamps were more likely to fail more than 1 test, and only covered lamps failed 3 or more tests.

Table 3: Number of Tests Failed by Lamp Type

	All Lamp Types		Bare Spiral		Bare Specialty		Covered	
Results	#	%	#	%	#	%	#	%
Passed All Initial Tests	127	69%	85	81%	6	60%	36	52%
Marginally Failed	2	1%	1	1%	1	10%	0	0%
Failed at Least 1 Test	55	30%	19	18%	3	30%	33	48%
Failed 1 Test	24	13%	14	13%	2	20%	8	12%
Failed 2 Tests	24	13%	5	5%	1	10%	18	26%
Failed 3 Tests	5	3%	0	0%	0	0%	5	7%
Failed 4 or More Tests	2	1%	0	0%	0	0%	2	3%
Total Models Tested	**184**	**100%**	**105**	**100%**	**10**	**100%**	**69**	**100%**

Batch 4 included products from 18 OEMs. Several OEMs had very few products tested and any findings about them would be inconclusive. However, 10 OEMs had at least 5 of their products tested and have at least 25 models listed on the Certified Products List. The large number of models tested from these OEMs means test results are a good indication of overall performance. Figure 6 shows the failure rates of products from these 10 OEMs. The overall failure rate for each OEM was calculated using incidences of full failure, not marginal failures. Failure rates for these 10 OEMs ranged from 11% to 50%. Six OEMs had failure rates under 30%.

Figure 6: Failure Rates of the 10 OEMs with ≥5 Models Tested in Batch 4



METHODOLOGY

PRODUCT SELECTION

Models were selected for testing in accordance with version 4.3 of the ENERGY STAR CFL Program Requirements, published on March 7, 2008 and effective December 2, 2008.[6] These requirements specify that the program shall "target to test 20% of the total number of current [distinct ENERGY STAR] certified bulbs during a calendar year; half of the models will be selected via a random generator, the other half will be selected by EPA and participating ENERGY STAR partners (utilities, manufacturers, states, efficiency program sponsors, or other government entities)."

This Batch 4 report presents results for the 184 models selected in Cycles 3 and 4 that completed testing between August 1, 2012 and May 31, 2015. Table 4 presents the breakdown of randomly selected and EPA-nominated models for each product type. Note that many models are privately labeled and sold under multiple brand names, so the impact of those products extends beyond the 184 models tested.

Table 4: Type of Selection for Models in this Report (Batch 4)

Model Type	Nominated Models	Randomly Selected Models	Total
All Types	44	140	184
Bare Spiral	12	93	105
Bare Specialty	2	8	10
Covered	30	39	69

PRODUCT PROCUREMENT

Manufacturers had two sample size options for testing each model selected[7]:

- 6 or 12 samples for the Rapid Cycle Stress Test
- 10 or 20 samples for the other nine tests

For covered products designated for indoor use, partners were also required to have one sample selected for the Initial Elevated Temperature Output Ratio Test.

The testing laboratories sought to purchase each product from at least two geographic regions and three retail locations, as requested by the CFL 4.3 Criteria, but in some cases, a product could be procured from only one or two locations.

[6] The ENERGY STAR CFL Program Requirements are available at the ENERGY STAR website: www.energystar.gov/ia/partners/product_specs/program_reqs/Compact_Flourescent_Lamps_Program_Requirements.pdf.

[7] Two or four additional lamps were procured as backups in case of breakage.

PRODUCT TESTING

The tests performed on each product are listed in Table 5. Six (or twelve) samples of each product were used for the Rapid Cycle Stress Test and ten (or twenty) samples of each product were used for all other tests except the Initial Elevated Temperature Output Ratio Test, which requires only one sample. For full details on product testing requirements, see the CFL 4.3 Criteria.

At the conclusion of each test, the laboratory sent the completed test report to the ENERGY STAR partner and to D+R International, Program Administrator for the CFL Third Party Testing and Verification program.

Table 5: Passing Criteria for ENERGY STAR Certification and Verification Tests

	Bare, Covered, or Outdoor Reflector Models	**Reflector CFLs for Recessed Downlights/ Indoor Use (Reflectors)**[8]	**Test Type**	**Passing Criteria**
1	Efficacy	Efficacy	Photometric	Varies by type
2	Starting Time	Starting Time	Electronic	<1000 ms
3	Run-Up Time	Run-Up Time	Electronic	<60 s (amalgam)/ <180 s (non-amalgam)
4	Power Factor	Power Factor	Electronic	>0.500
5	Color Rendering Index	Color Rendering Index	Photometric	>80.0
6	Chromaticity	Chromaticity	Photometric	≥9/10 samples/ ≥17/20 samples
7	1,000-Hour Lumen Maintenance	*Elevated Temperature* 1,000-Hour Lumen Maintenance	Photometric	>90%
8	Rapid Cycle Stress Test	Rapid Cycle Stress Test	Lifetime Performance	≥5/6 samples/ ≥9/12 samples
9	Lumen Maintenance at 40% of Rated Life	*Elevated Temperature* Lumen Maintenance at 40% of Rated Life	Lifetime Performance	> 80%
10	Interim Life Test	*Elevated Temperature* Interim Life Test	Lifetime Performance	≥9/10 samples/ ≥17/20 samples
11	N/A	Initial Elevated Temperature Output Ratio	Lifetime Performance	>90%

[8] Covered reflectors designated for indoor use underwent the Initial Elevated Temperature Output Ratio Test, in addition to the 10 tests required for all other models. Those indoor covered reflector products also underwent 1,000-Hour Lumen Maintenance, Lumen Maintenance at 40% of Rated Life, and Interim Life testing at an elevated temperature.

DETAILED RESULTS FOR BATCH 4

For each of the 10 tests applicable to all models, results are shown below for all lamps and for each of the three lamp types—bare spiral, bare specialty, and covered—separately. For the Initial Elevated Temperature Output Ratio Test, results are shown only for covered indoor reflector models, which are the only models subjected to this test.

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 test. Normalized results are presented for this test to show how far each product is from the required result; to normalize the data points, the measured efficacy is divided by the required efficacy. The red-shaded region of Figure 7 indicates test failure, and the gray-shaded region indicates the 3% tolerance. The blue triangle indicates the median value.

RESULTS:

- Three models (one bare spiral and two covered products) failed this test.
- Only one model (a bare spiral product) marginally failed this test.

Figure 7: Normalized Luminous Efficacy Test Results by Product Type

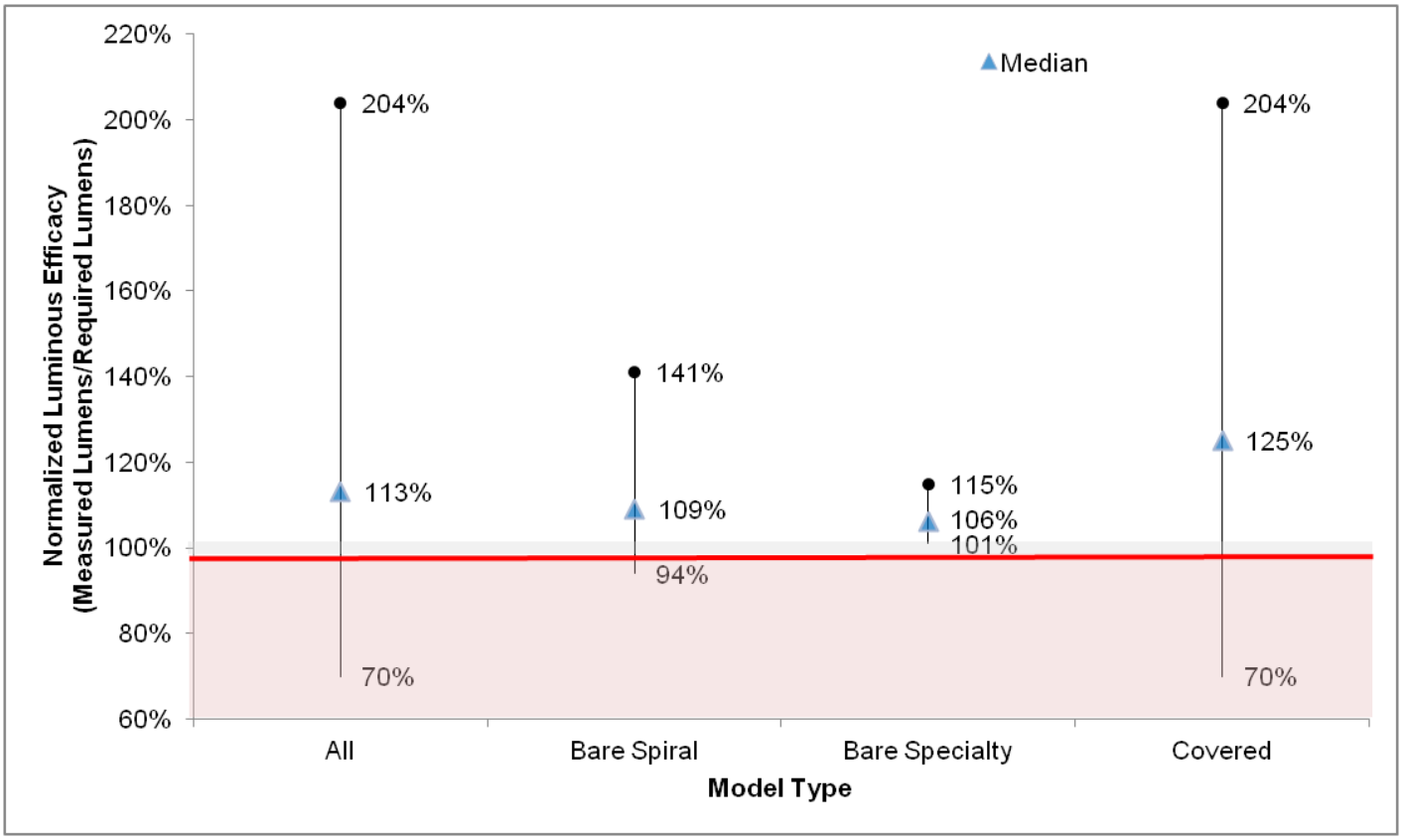


Table 6: Normalized Luminous Efficacy Test Results

	Number of Models Tested	% of Models				
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean	Median
All Models	184	97.5%	0.5%	2%	1.18	1.13
Bare Spiral	105	98%	1%	1%	1.12	1.09
Bare Specialty	10	100%	0%	0%	1.07	1.06
Covered	69	97%	0%	3%	1.29	1.25

STARTING TIME

Starting time is the time needed after switching a CFL on for it to start fully and remain lit. Models with start-up time measurements of <1,000 milliseconds pass the test. The red-shaded region of Figure 8 indicates the range of results that would be considered a failure.

RESULTS: Every model in Batch 4 passed this test.

Figure 8: Starting Test Results by Product Type

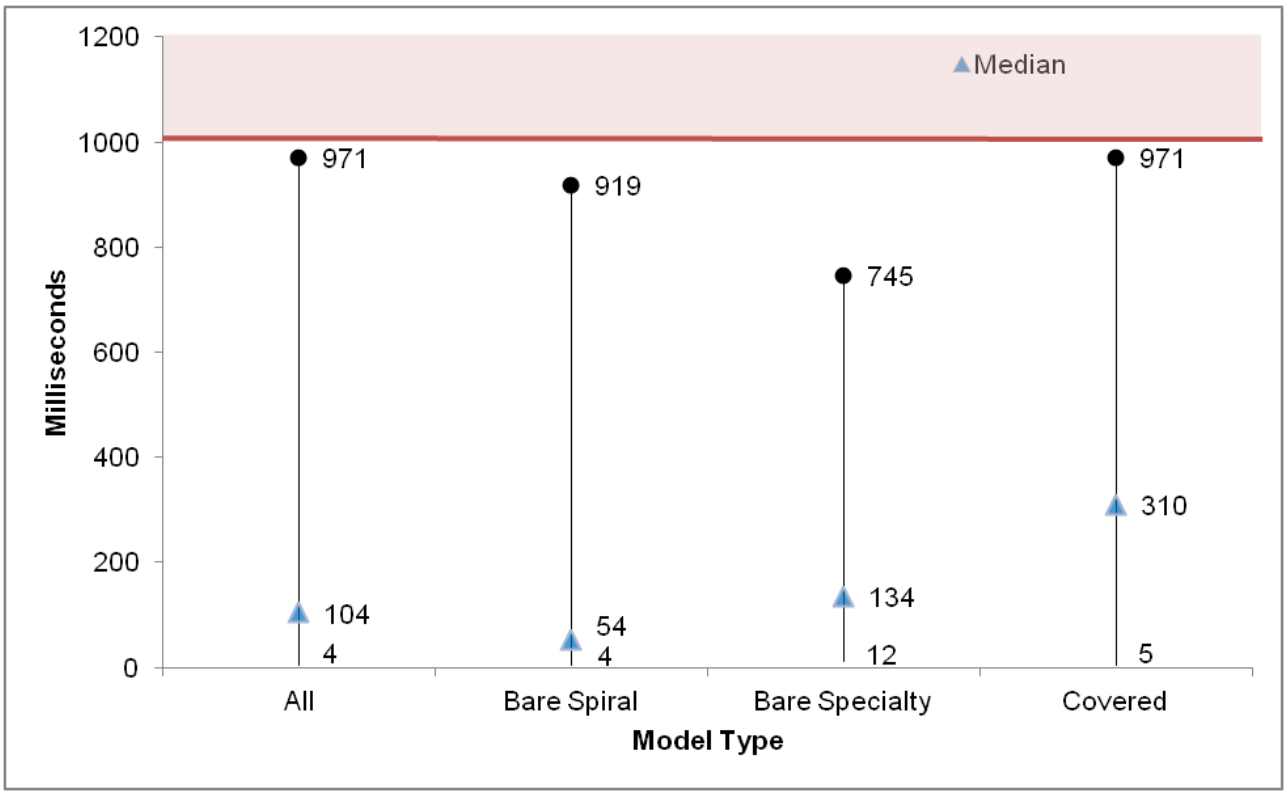


Table 7: Starting Time Test Results

	Number of Models Tested	% of Models				
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean (milliseconds)	Median (milliseconds)
All Models	184	100%	0%	0%	261	104
Bare Spiral	105	100%	0%	0%	170	54
Bare Specialty	10	100%	0%	0%	240	134
Covered	69	100%	0%	0%	401	310

RUN-UP TIME

Run-up time is the time it takes a CFL to reach full brightness. Bare and bare specialty amalgam mercury models with run-up times of <180 seconds and non-amalgam mercury models with run-up times of <60 seconds pass the test. Amalgam and non-amalgam mercury covered models with run-up times of <180 seconds pass the test. The red-shaded regions of Figures 9 and 10 indicate test failure.

RESULTS:

- Among the 153 amalgam models, only 6 failed, all of which were covered models.
- Among the 31 non-amalgam models, only 2 failed, all of which were bare spiral models.
- All bare specialty models passed this test.

Figure 9: Run-Up Time Test Results by Product Type: Amalgam

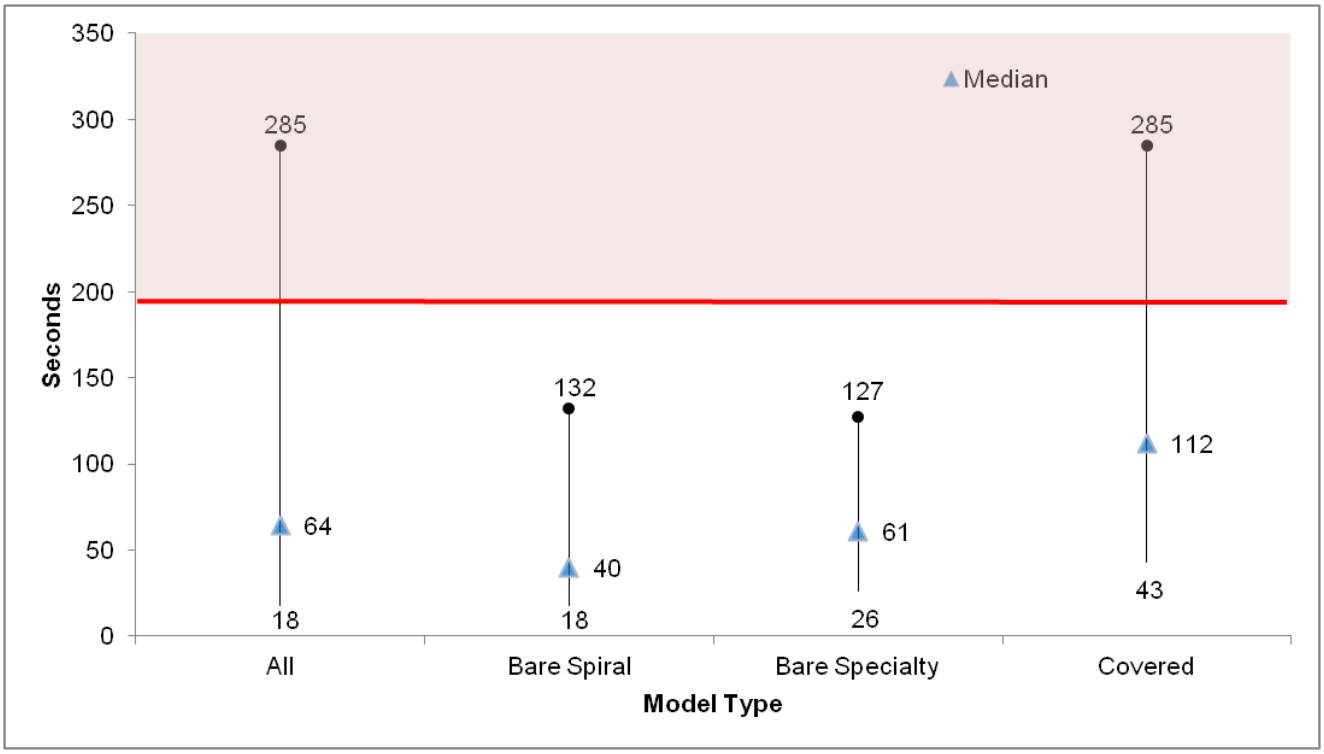


Figure 10: Run-Up Time Test Results by Product Type: Non-Amalgam[9]

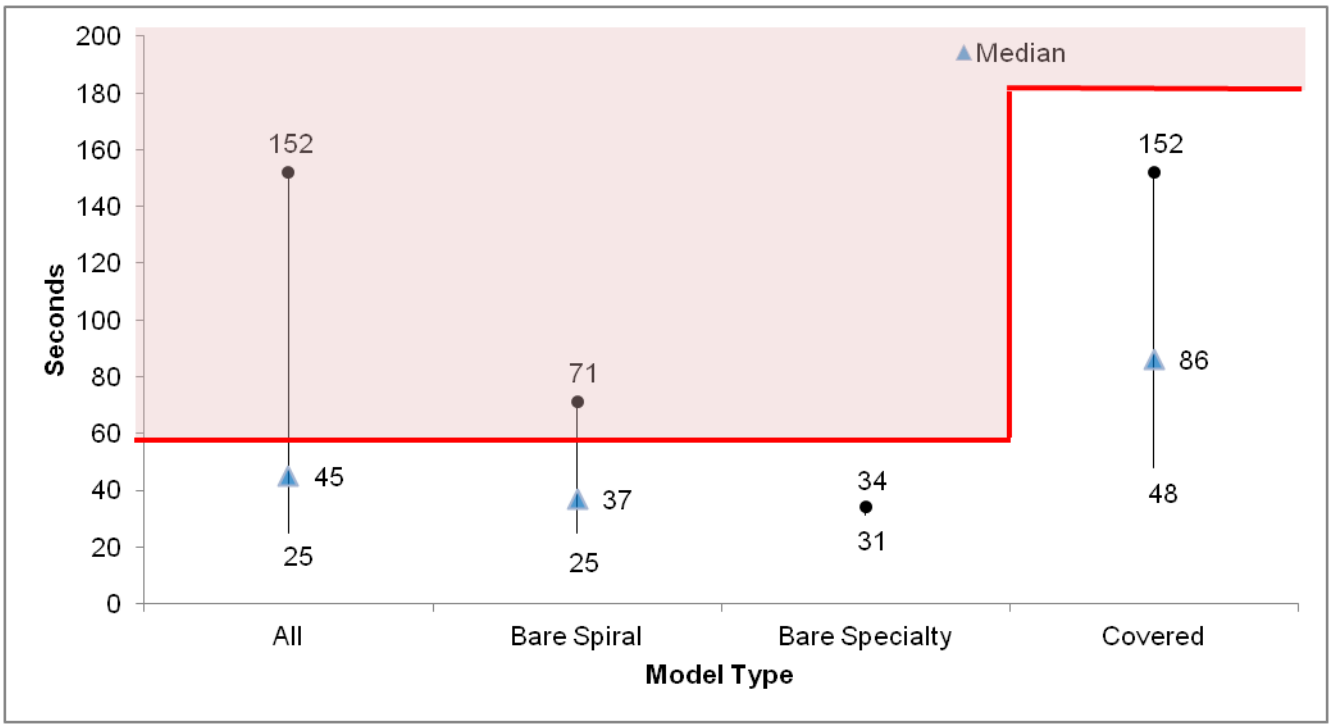


Table 8: Run-Up Time Test Results: Amalgam

	Number of Models Tested	% of Models				
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean (seconds)	Median (seconds)
All Models	153	96%	0%	4%	77	64
Bare Spiral	84	100%	0%	0%	48	40
Bare Specialty	8	100%	0%	0%	70	61
Covered	61	90%	0%	10%	119	112

[9] The 60-second maximum for non-amalgam products applies only to bare spiral and bare specialty products. The maximum for non-amalgam covered products is 180 seconds.

Table 9: Run-Up Time Test Results: Non-Amalgam

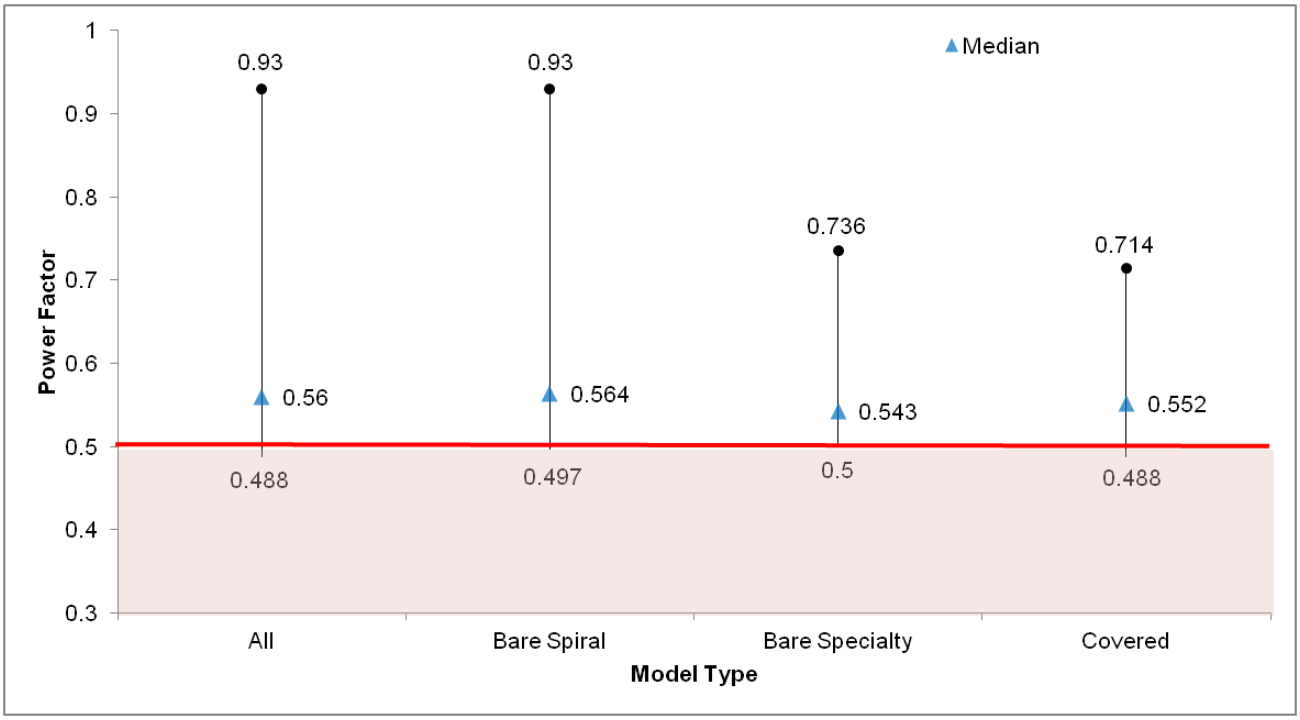
	Number of Models Tested	% of Models				
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean (seconds)	Median (seconds)
All Models	31	94%	0%	6%	54	45
Bare Spiral	21	91%	0%	9%	40	37
Bare Specialty	2	100%	0%	0%	32	N/A[10]
Covered	8	100%	0%	0%	96	86

POWER FACTOR

Power factor is the active power of the CFL divided by the apparent power. Models with a power factor of >0.5 pass the test. The red-shaded region of Figure 11 indicates test failure.

RESULTS: One bare spiral model and one covered model failed the Power Factor Test.

Figure 11: Power Factor Test Results by Product Type



[10] No median was calculated for this lamp type because only 2 models were tested.

Table 10: Power Factor Test Results

	Number of Models Tested	% of Models				
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean (Power Factor)	Median (Power Factor)
All Models	184	99%	0%	1%	0.569	0.560
Bare Spiral	105	99%	0%	1%	0.573	0.564
Bare Specialty	10	100%	0%	0%	0.557	0.543
Covered	69	99%	0%	1%	0.566	0.552

COLOR RENDERING INDEX

The Color Rendering Index (CRI) is a measure of a light source's ability to accurately render the color of illuminated objects; this is the effect of the CFL on the color appearance of the objects it illuminates. The CRI is defined according to the Commission Internationale de l'Eclairage's Publication No.13.3 1995. Models that have an average CRI >80 across the 10 samples tested and have no more than 3 samples with a CRI of <77 pass the test. The red-shaded region in Figure 12 indicates test failure.

RESULTS: One bare spiral product and one covered product failed this test.

Figure 12: Color Rendering Index Test Results by Product Type

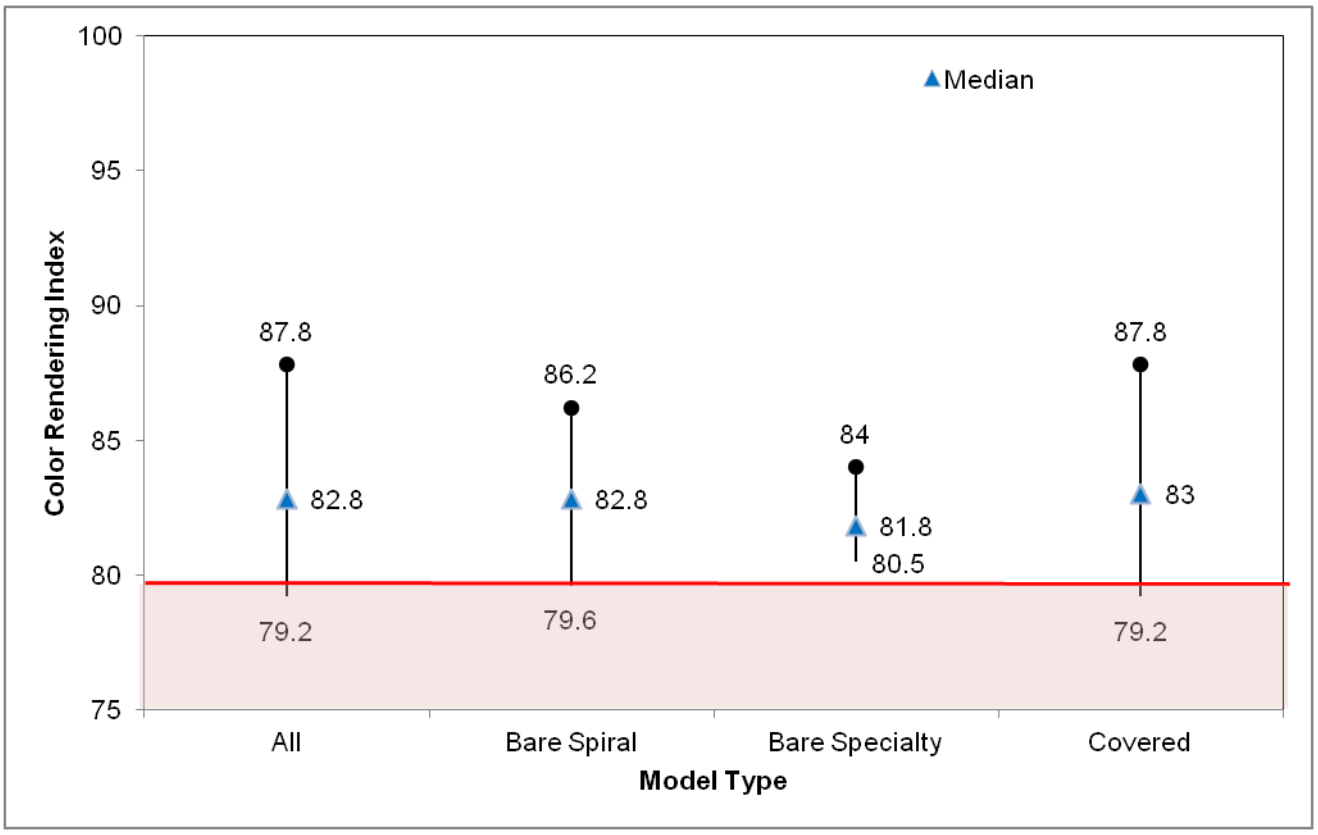


Table 11: Color Rendering Index Test Results

	Number of Models Tested	% of Models				
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean (CRI)	Median (CRI)
All Models	184	99%	0%	1%	82.9	82.8
Bare Spiral	105	99%	0%	1%	82.8	82.8
Bare Specialty	10	100%	0%	0%	81.9	81.8
Covered	69	99%	0%	1%	83.2	83.0

CHROMATICITY

Chromaticity, or correlated color temperature (CCT), is a measure of the color appearance of a CFL measured in Kelvin. CCT is scored based on the American National Standards Institute (ANSI) ellipse for the manufacturer's specified color temperature. Models with 9 or 10 samples (or at least 17, for double sample sizes) falling within the ANSI ellipse pass the test. Models with exactly 8 samples falling within the ANSI ellipse are marginal failures, indicated by the gray-shaded regions in Figures 13 and 14. There is no marginal failure for the double sample size option. The red-shaded regions in these figures indicate test failure.

RESULTS:

- Only 60% of bare specialty models passed this test, which could indicate a performance issue with these products. However, the small sample size makes drawing widespread conclusions difficult.
- Bare spiral models performed well in this test, with a passing rate of 96%.
- Covered models had moderately good performance, with a passing rate of 91%.
- The overall marginal failure rate was 0.5%.

Figure 13: Chromaticity Test Results for Single Sample Size Option (10 Samples)

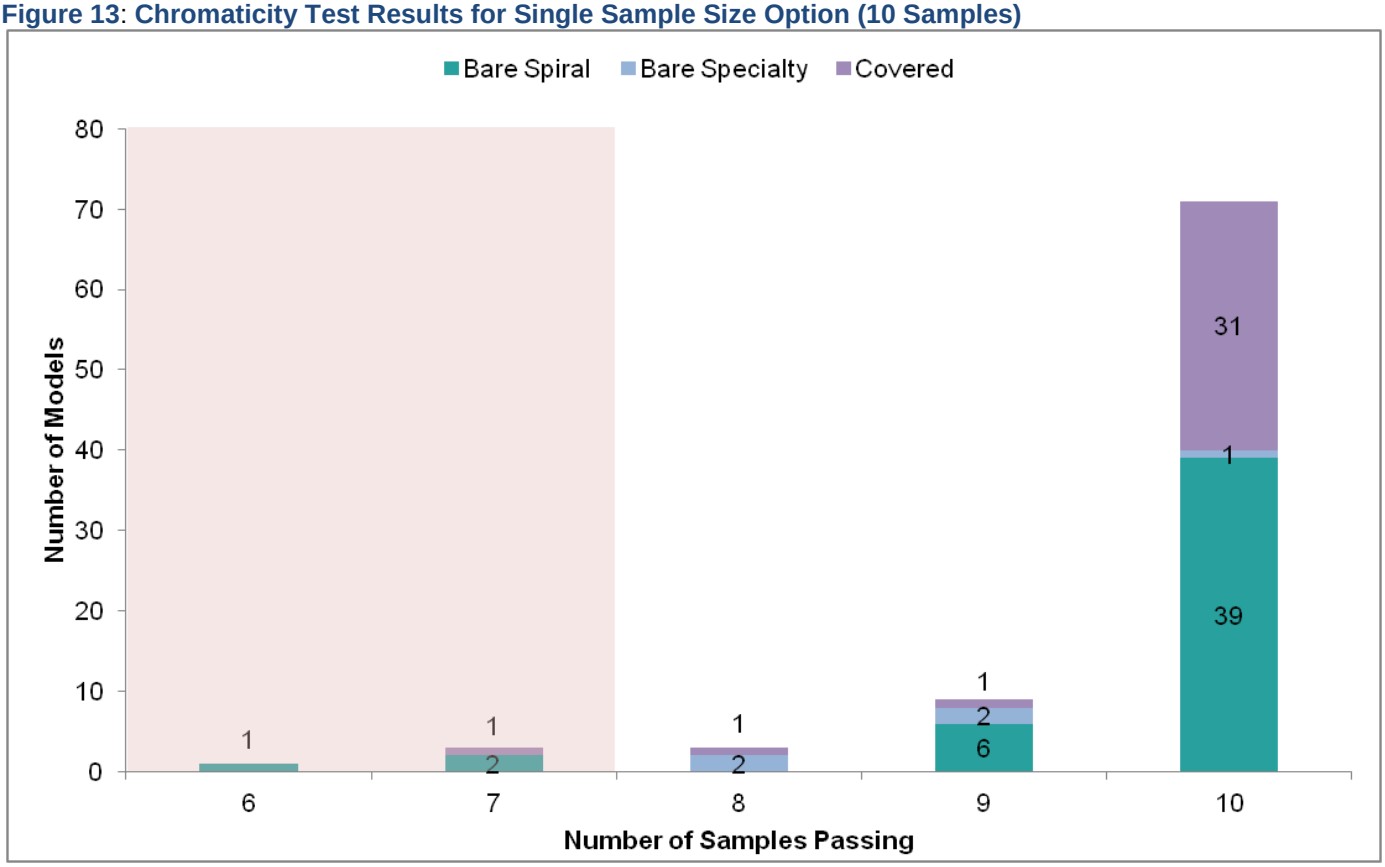


Figure 14: Chromaticity Test Results for Double Sample Size Option (20 Samples)

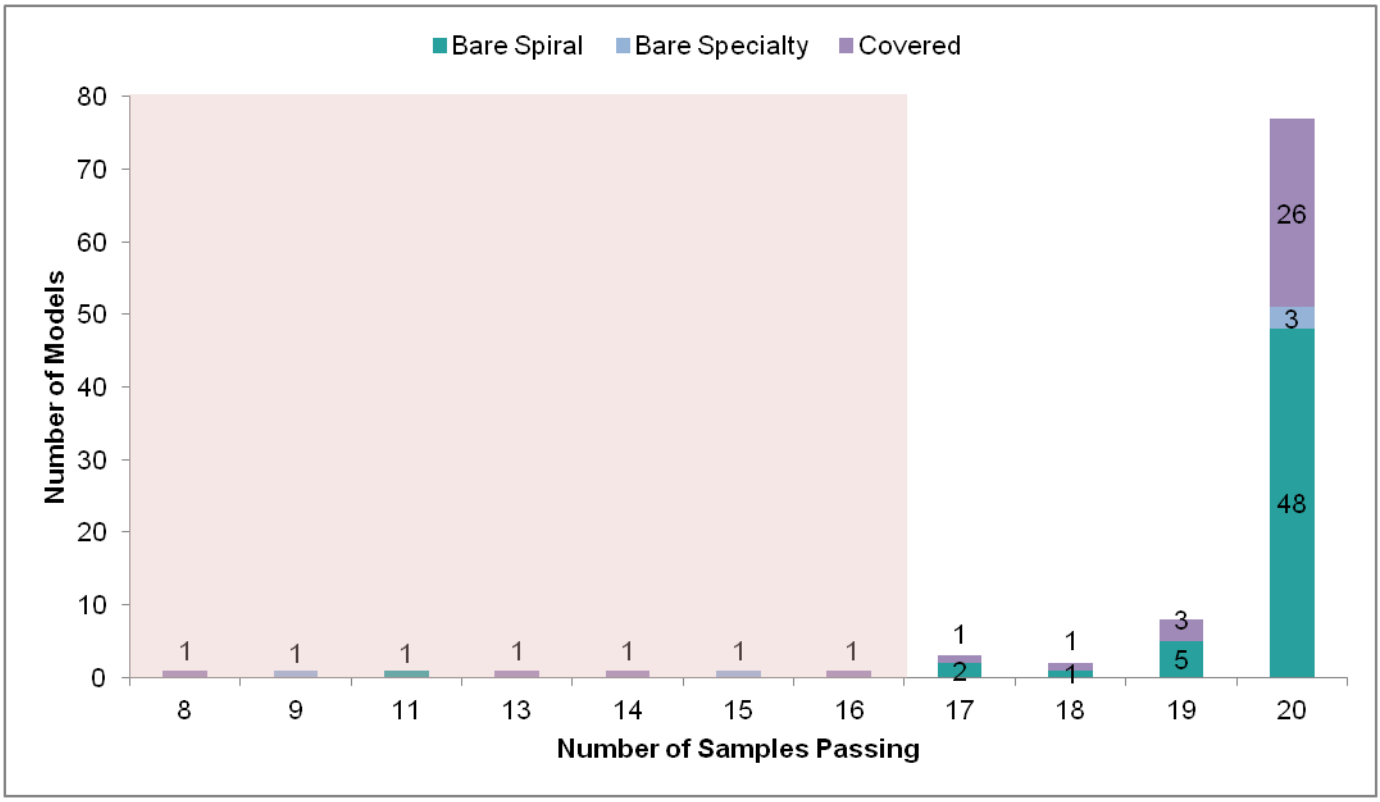


Table 12: Chromaticity Test Results

	Number of Models Tested	% of Models		
		Passed Initial Test	Marginal Failure (Retest)	Full Failure
All Models	184	92.5%	0.5%	7%
Bare Spiral	105	96%	0%	4%
Bare Specialty	10	60%	10%	30%
Covered	69	91%	0%	9%

1,000-HOUR LUMEN MAINTENANCE

The 1,000-Hour Lumen Maintenance Test is an initial measurement of how well a product maintains its light output level over time. Models with light output at 1,000 hours that is greater than 90% of the 100-hour measurement (with a tolerance of 3%) and no more than 3 individual samples (6 individual samples for a double sample size) with lumen output less than 85% pass the test. The red-shaded region of Figure 15 indicates a test failure, and the gray-shaded region indicates the 3% tolerance.

RESULTS:

- Of the 11 tests, the 1,000-Hour Lumen Maintenance Test had the third-highest failure rate, with 19 models (10%) failing.
- Of the 69 covered models, 41 (72%) passed.
- All bare specialty and bare spiral models passed this test in full or within the 3% tolerance.

Figure 15: 1,000-Hour Lumen Maintenance Test Results

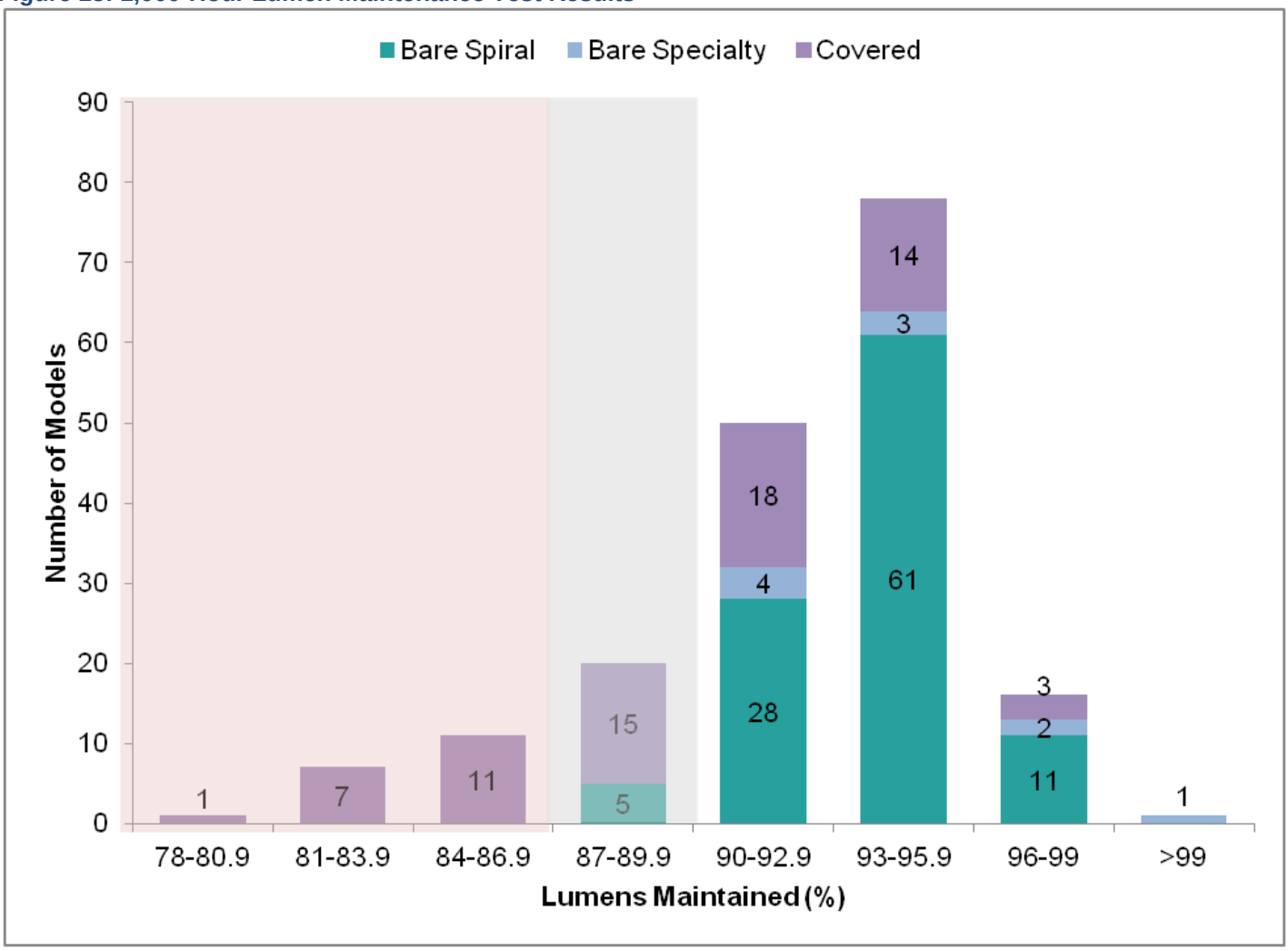


Table 13: 1,000-Hour Lumen Maintenance Test Results

	Number of Models Tested	% of Models				
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean (Percent of Lumens Maintained)	Median (Percent of Lumens Maintained)
All Models	184	90%	0%	10%	92%	93%
Bare Spiral	105	100%	0%	0%	94%	94%
Bare Specialty	10	100%	0%	0%	94%	94%
Covered	69	72%	0%	28%	89%	90%

RAPID CYCLE STRESS TEST

The Rapid Cycle Stress Test tests how many on/off cycles a product can endure without failing. Models that have five or six samples (or at least nine, for double sample sizes) endure the test for a number of cycles equivalent to half the product's rated life pass the test. If exactly four samples survive, the product scores as a marginal failure. There is no marginal failure for the double sample size option. The red-shaded regions of Figures 16 and 17 indicate test failure, and the gray-shaded regions indicate marginal failure (single sample size only).

RESULTS:

- All product types performed well in this test.
- All bare specialty and covered models and 97%[11] of bare spiral models passed this test.

[11] One bare spiral model was a marginal failure. The manufacturer declined a retest; therefore, the product has been counted as a failure.

Figure 16: Rapid Cycle Stress Test Results for Single Sample Size Option (6 Samples)

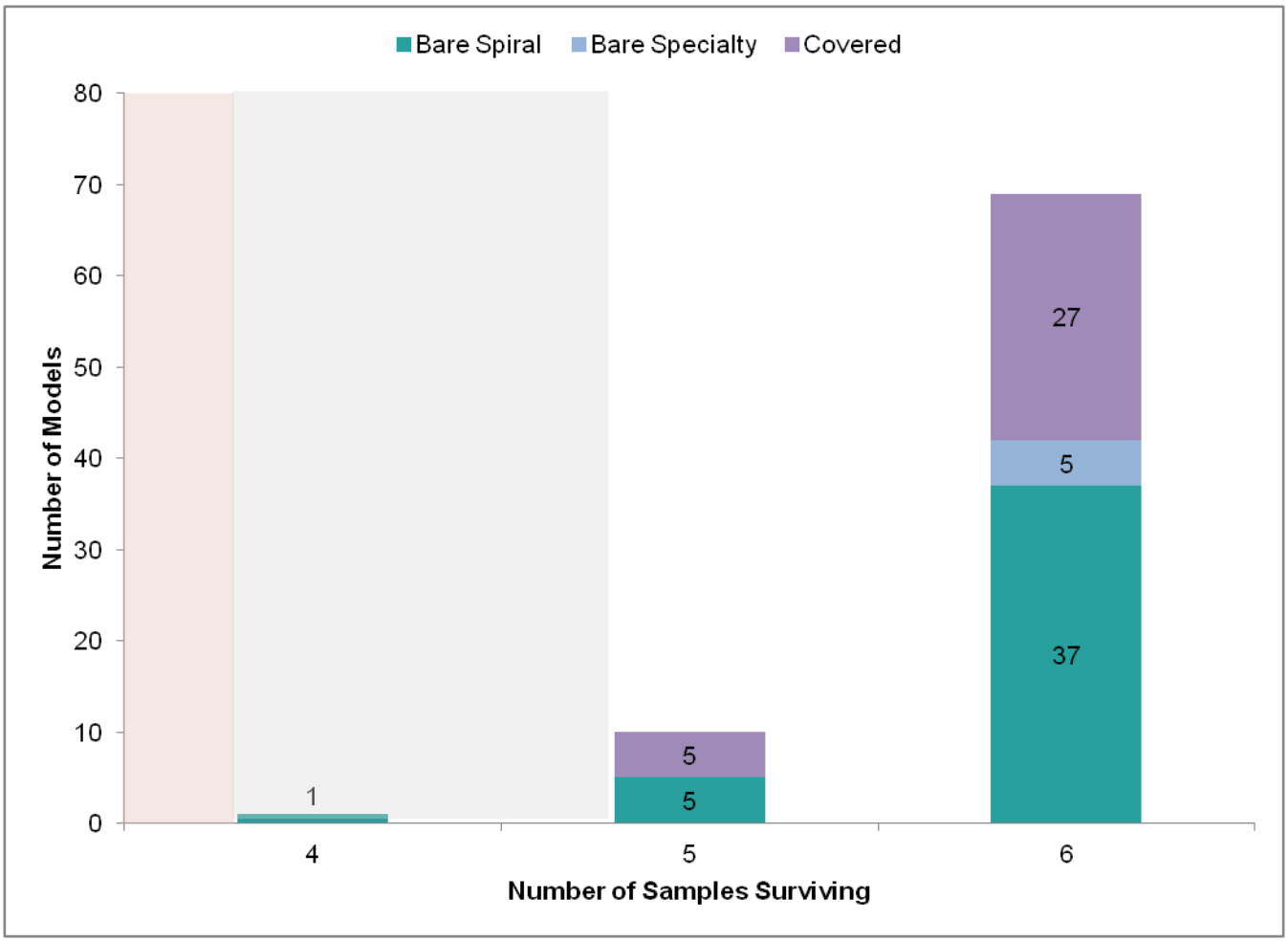


Figure 17: Rapid Cycle Stress Test Results for Double Sample Size Option (12 Samples)

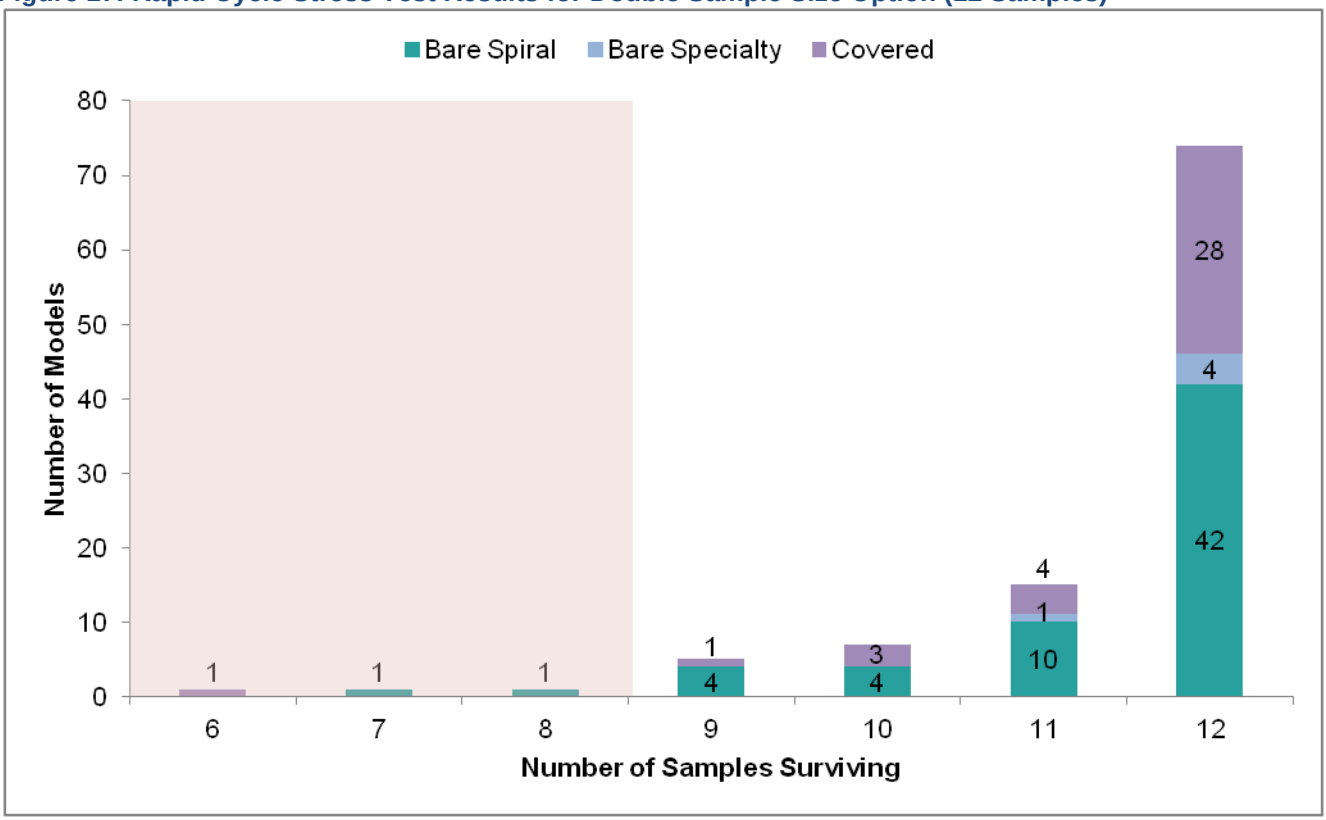


Table 14: Rapid Cycle Stress Test Results

	Number of Models Tested	% of Models		
		Passed Initial Test	Marginal Failure (Retest)	Full Failure
All Models	184	98%	0%	2%
Bare Spiral	105	97%	0%	3%
Bare Specialty	10	100%	0%	0%
Covered	69	100%	0%	0%

LUMEN MAINTENANCE AT 40% OF RATED LIFE

The 40% of Rated Life Lumen Maintenance Test is a secondary measurement of how well a product maintains its light output over time. Models with light output at 40% of their rated life greater than 80% of their light output at 100 hours (with a tolerance of 3%) and with no more than three samples with light output less than 75% of light output at 100 hours pass the test. The lowest-scoring unit's results are not considered. A product is listed as a marginal failure if the average of the remaining units is less than 80% (with a 3% tolerance) and no more than four (seven for a double sample size) have a lumen output measurement of less than 75%. Table 15 shows the results of the 40% Lumen Maintenance Test. The red-shaded region of Figure 18 indicates test failure, and the gray-shaded region indicates the 3% tolerance.

RESULTS:

- This test had the second-highest failure rate, with 22 models (12%) failing.
- Bare specialty and bare spirals performed relatively well, with only 1 and 2 failures, respectively.
- Covered lamps had the most trouble with this test; 19 models failed, and no models marginally failed.

Figure 18: 40% Lumen Maintenance Test Results

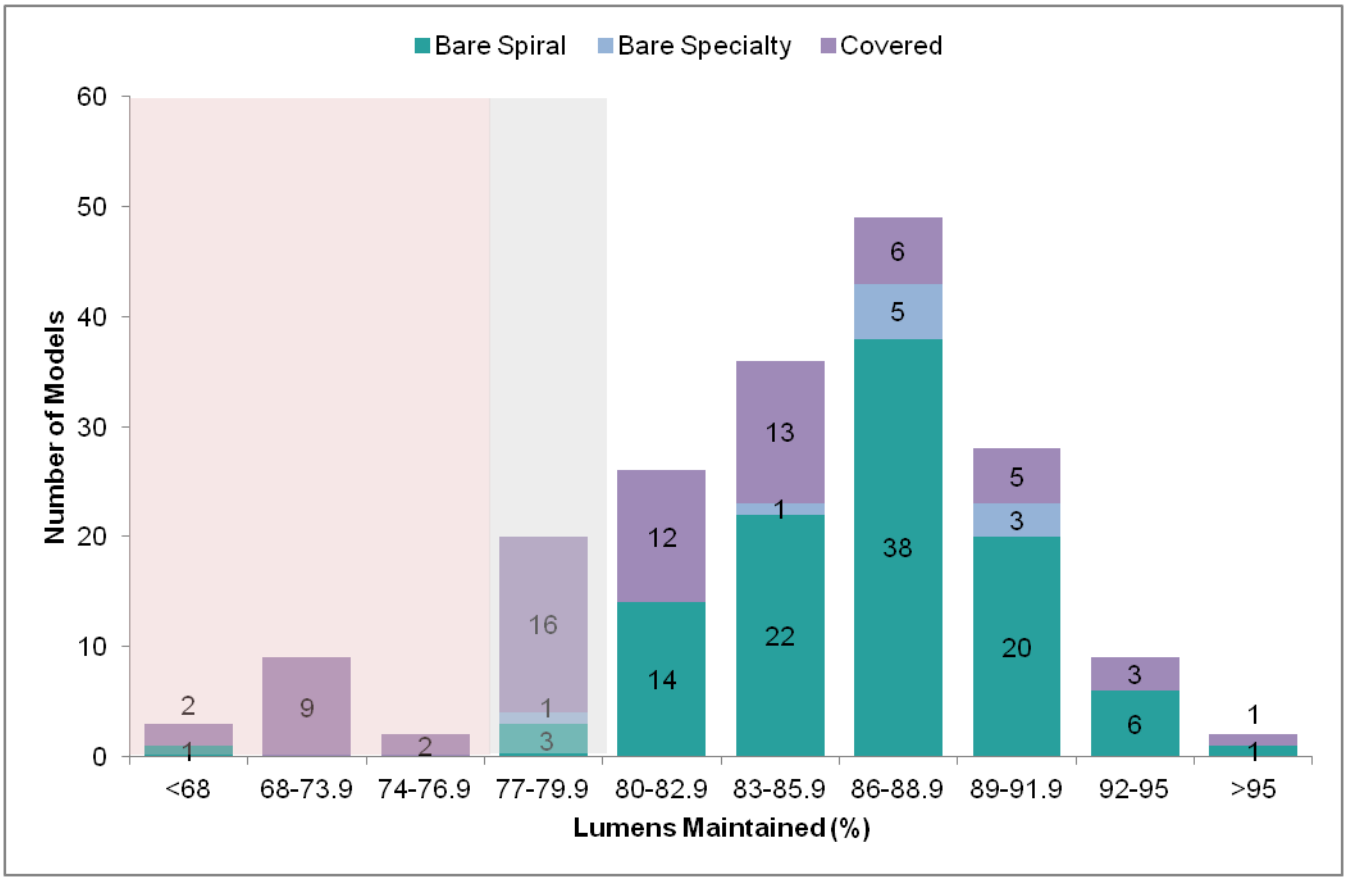


Table 15: 40% Lumen Maintenance Test Results

	Number of Models Tested	% of Models				
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean (% Lumens Maintained at 40% of Rated Life)	Median (% Lumens Maintained at 40% of Rated Life)
All Models	184	89%	0%	11%	84%	86%
Bare Spiral	105	98%	0%	2%	86%	87%
Bare Specialty	10	90%	0%	10%	87%	88%
Covered	69	74%	0%	26%	81%	81%

INTERIM LIFE TEST

The Interim Life Test measures how many of the 10 samples are still lit at 40% of the CFL's rated life. Models with 9 or 10 samples (or at least 17, for double sample sizes) still lit at 40% of rated life pass the test. If exactly 8 samples stay lit, the product is recorded as a marginal failure. There is no marginal failure for the double sample size option. The red-shaded regions of Figures 19 and 20 indicate a full test failure, and the gray-shaded regions indicate a marginal failure.

RESULTS:

- This test had the highest failure rate, with 23 models (12%) failing. Covered models were the worst performers, with only 81% of models passing.
- Bare spiral and bare specialty models had pass rates of 90% and 100%, respectively.

Figure 19: Interim Life Test Results for Single Sample Size Option (10 Samples)

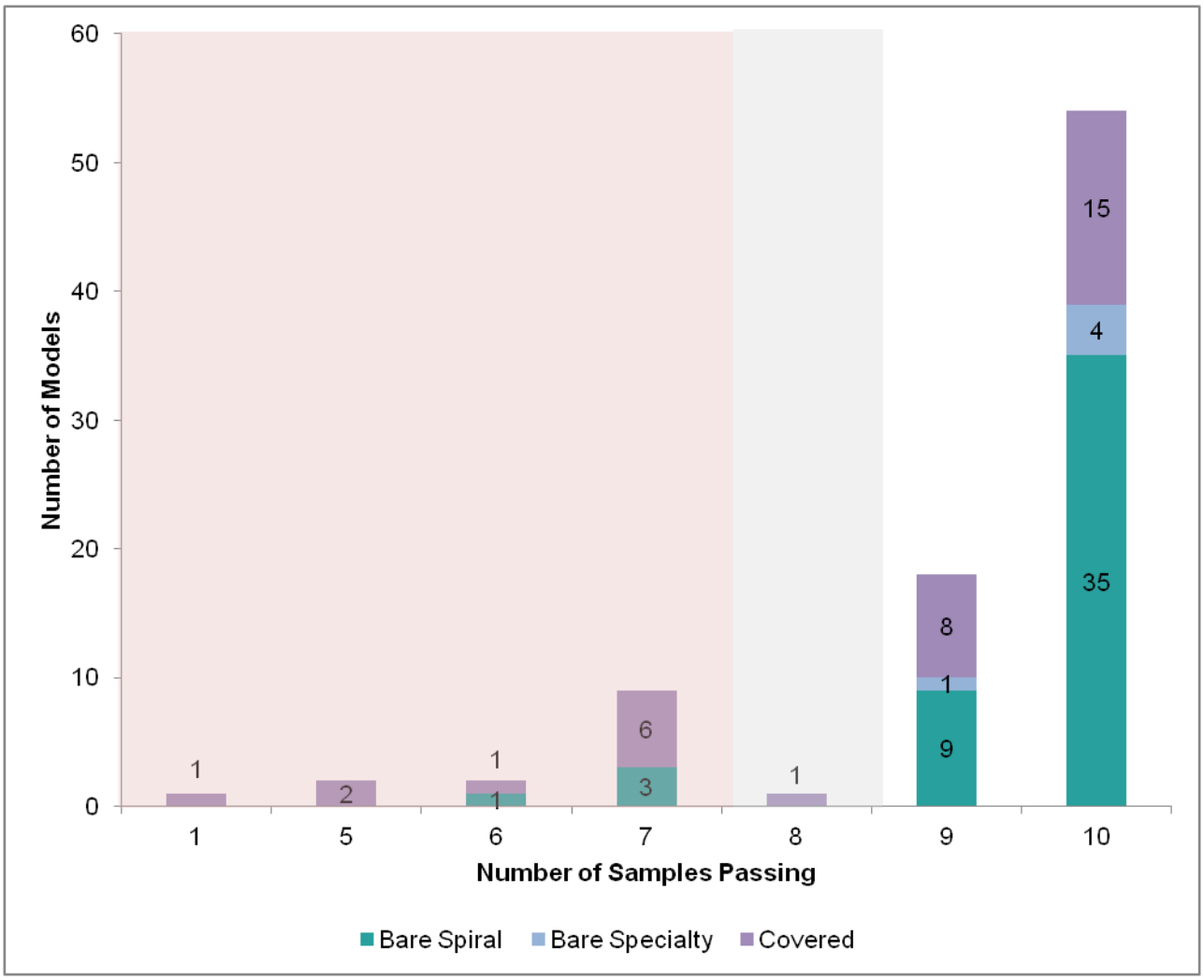


Figure 20: Interim Life Test Results for Double Sample Size Option (20 Samples)

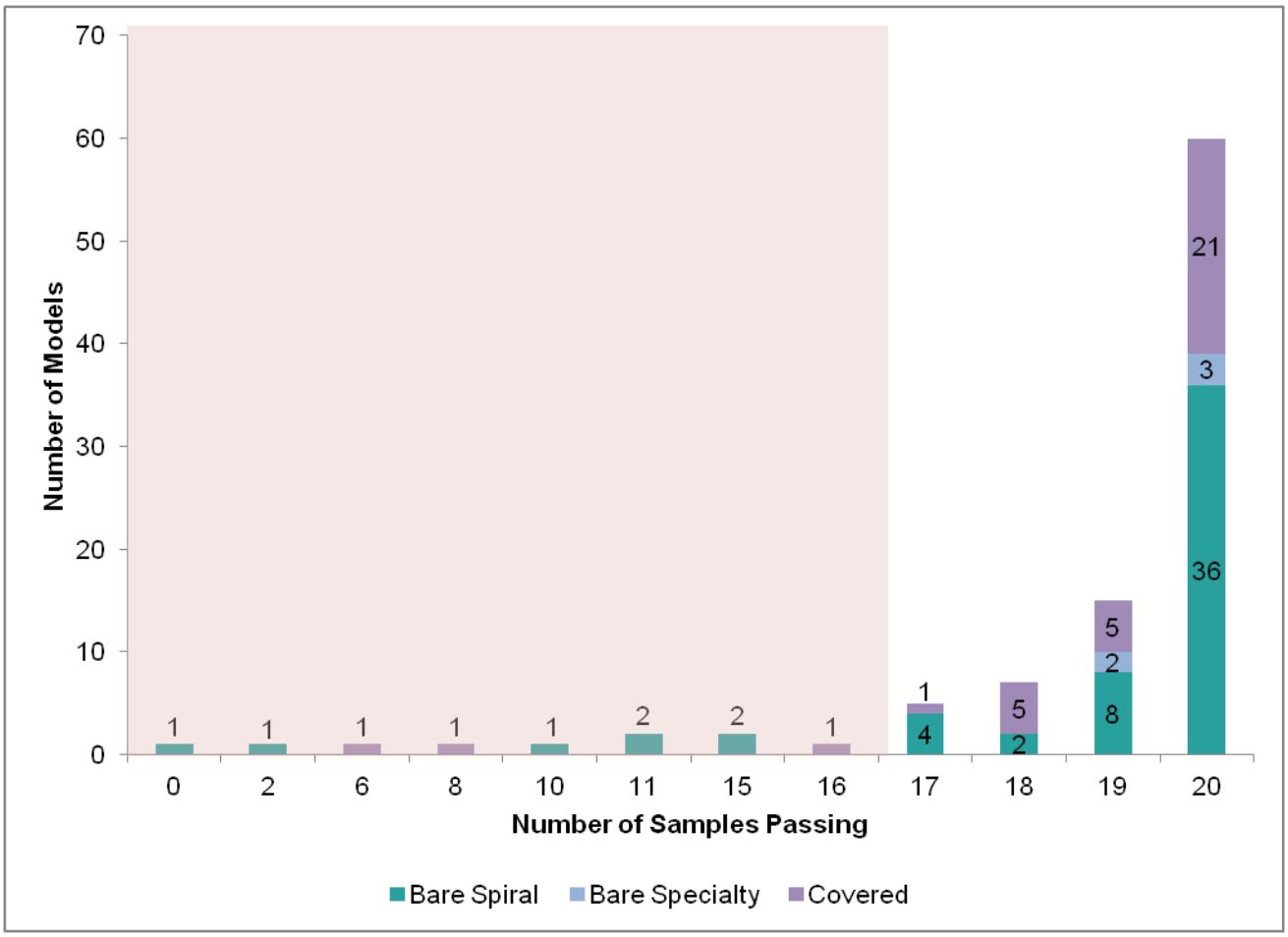


Table 16: Interim Life Test Results

	Number of Models Tested	% of Models		
		Passed Initial Test	Marginal Failure (Retest)	Full Failure
All Models	184	87.5 %	0%	12.5%
Bare Spiral	105	90.5%	0%	9.5%
Bare Specialty	10	100%	0%	0%
Covered	69	80%	0%	20%

INITIAL ELEVATED TEMPERATURE OUTPUT RATIO

The Initial Elevated Temperature Output Ratio is a measurement of lumen output; it is conducted only for indoor covered reflector models. The test is performed on only one sample; that sample must attain 90% of its claimed light output to meet ENERGY STAR requirements. The red-shaded region in Figure 21 indicates full test failure. There is no defined marginal failure or 3% tolerance criteria for the Initial Elevated Temperature Output Ratio Test. This test was performed on the 17 models that were identified as indoor covered reflector lamps.

RESULTS:

- Three models failed this test. One test failure was ruled “de minimis” by EPA and the model remained certified, resulting in a pass rate of 88% for this test.

Figure 21: Initial Elevated Temperature Output Ratio

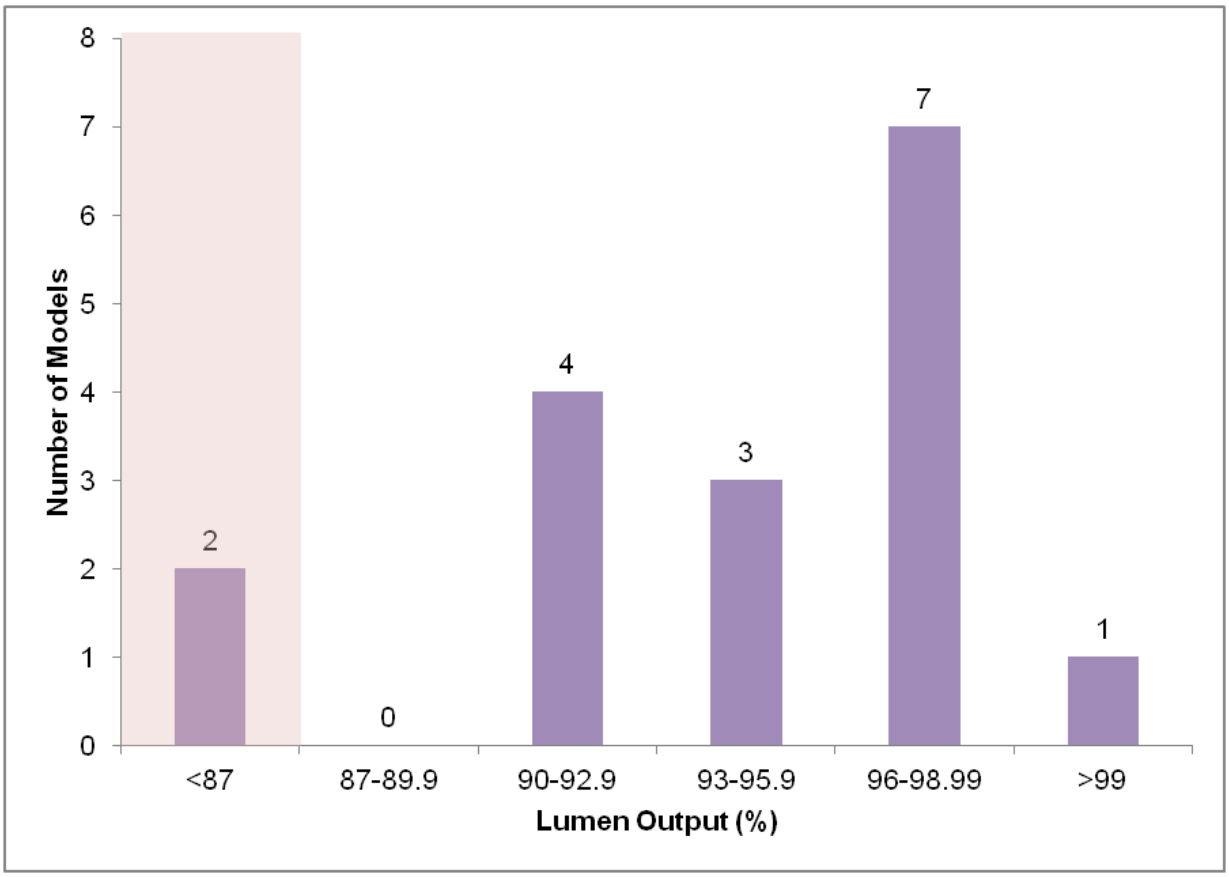


Table 17: Initial Elevated Temperature Output Ratio

	Number of Models Tested	% of Models			
		Passed Initial Test	Full Failure	Mean (% Lumen Output)	Median (% Lumen Output)
Covered	17	88%	12%	94%	95.4%

ALL TESTS

Of the 184 models in Batch 4, 127 (69%) passed all tests, 55 (30%) fully failed at least one test, and the remaining 2 (1%) had at least one marginal failure — but no full failures.

Table 18 presents results for all tests.

KEY FINDINGS:

- All tested models passed the Start-Up Time Test.
- The 1,000-Hour Lumen Maintenance, 40% Lumen Maintenance, and Interim Life Tests had the highest failure rates, with 10%, 11%, and 12% of models failing, respectively.
- Overall, 96% of all failures were full failures and 4% were marginal failures.
- The Initial Elevated Temperature Output Ratio Test had a failure rate of 12%. One product originally failed, but was changed to a pass following a successful dispute.

Table 18: Detailed Results for All Tests

Summary	Efficacy	Starting Time	Run-Up Time	Power Factor	1,000-Hour Lumen Maint-enance	40% Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test	Initial Elevated Temperature Output Ratio	Total Tests	Total Mod-els
Passing Criteria	Minimum 33-60, depending on wattage and model type	<1,000 ms	<60 sec (non-amalgam), <180 sec (amalgam)	>0.5	>90%	>80% of 100-hour lumen average	>80	9/10 coordinates must fall inside ellipse	5/6 must meet rated life	9/10 must last 40% of rated life	>90%		
All												**1857**	**184**
Mean	**61.1**	**261**	**73.5**	**0.569**	**92.2**	**84.3**	**82.9**	**14.7**	**9**	**14.2**	**94.4**		
Median	**63.6**	**104**	**54.8**	**0.560**	**93**	**85.7**	**82.8**	**15**	**10**	**15**	**95.4**		
Test Data for Failures													
Full Failures	3	0	8	2	19	21	2	12	3	23	2	95	55
Bare Spiral Models	1	0	2	1	0	2	1	4	3	10	0	24	19
Bare Specialty Models	0	0	0	0	0	1	0	3	0	0	0	4	3
Covered Models	2	0	6	1	19	18	1	5	0	13	2	67	33
% Failing Test	2%	0%	4%	1%	10%	11%	1%	6%	2%	12%	12%		30%
Test Data for Marginal Failures													

Summary	Efficacy	Starting Time	Run-Up Time	Power Factor	1,000-Hour Lumen Maint-enance	40% Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test	Initial Elevated Temperature Output Ratio	Total Tests	Total Mod-els
Marginal Failures	1	0	0	0	0	0	0	1	0	0	0	2	2
Bare Spiral Models	1	0	0	0	0	0	0	0	0	0	0	1	1
Bare Specialty Models	0	0	0	0	0	0	0	1	0	0	0	1	1
Covered Models	0	0	0	0	0	0	0	0	0	0	0	0	0
% Marginally Failing Test	0.5%	0%	0%	0%	0%	0%	0%	0.5%	0%	0%	0%		1%
Test Data for Passes													
Passing Test	180	184	176	182	165	163	182	171	181	161	15	1760	127
Bare Spiral Models	103	105	103	104	105	103	104	101	102	95	0	1025	85
Bare Specialty Models	10	10	10	10	10	9	10	6	10	10	0	95	6

Summary	Efficacy	Starting Time	Run-Up Time	Power Factor	1,000-Hour Lumen Maint-enance	40% Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test	Initial Elevated Temperature Output Ratio	Total Tests	Total Mod-els
Covered Models	67	69	63	68	50	51	68	64	69	56	15	640	36
% Passing Test	98%	100%	96%	99%	90%	88.5%	99%	93%	98%	87.5%	88%		69%

COMPARISON OF BATCHES 1, 2, 3, AND 4

This section compares the performance of models tested in Batches 1 through 4. Observed trends among the tested models suggest trends in the population of ENERGY STAR certified CFLs at large, because the models included in Batch 4 were generally first qualified as ENERGY STAR models about 4 years later than those in Batch 1, 3 years later than Batch 2, and 2 years later than Batch 3.

Summary of Results by Product Type

A total of 438 models have been tested as of May 31, 2015, with Batch 1 and Batch 2 each containing 68 models, Batch 3 containing 118 models, and Batch 4 containing 184 models. The majority of models tested were bare spiral lamps (60%), 7% were bare specialty lamps, and 33% were covered lamps. Figure 22 presents summary results.

Figure 22: Summary of Results: Aggregate

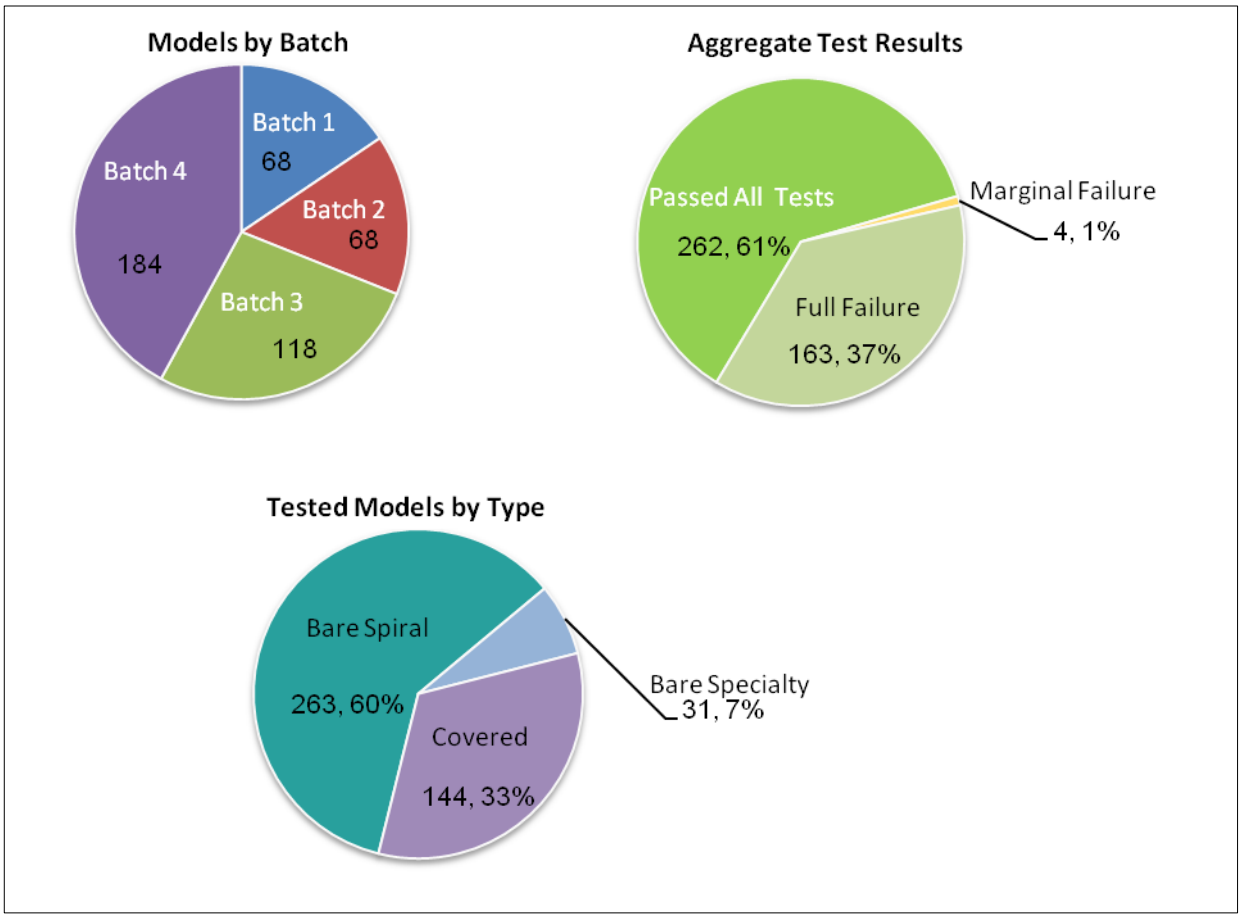


Figure 23: Summary of Models Tested by Batch

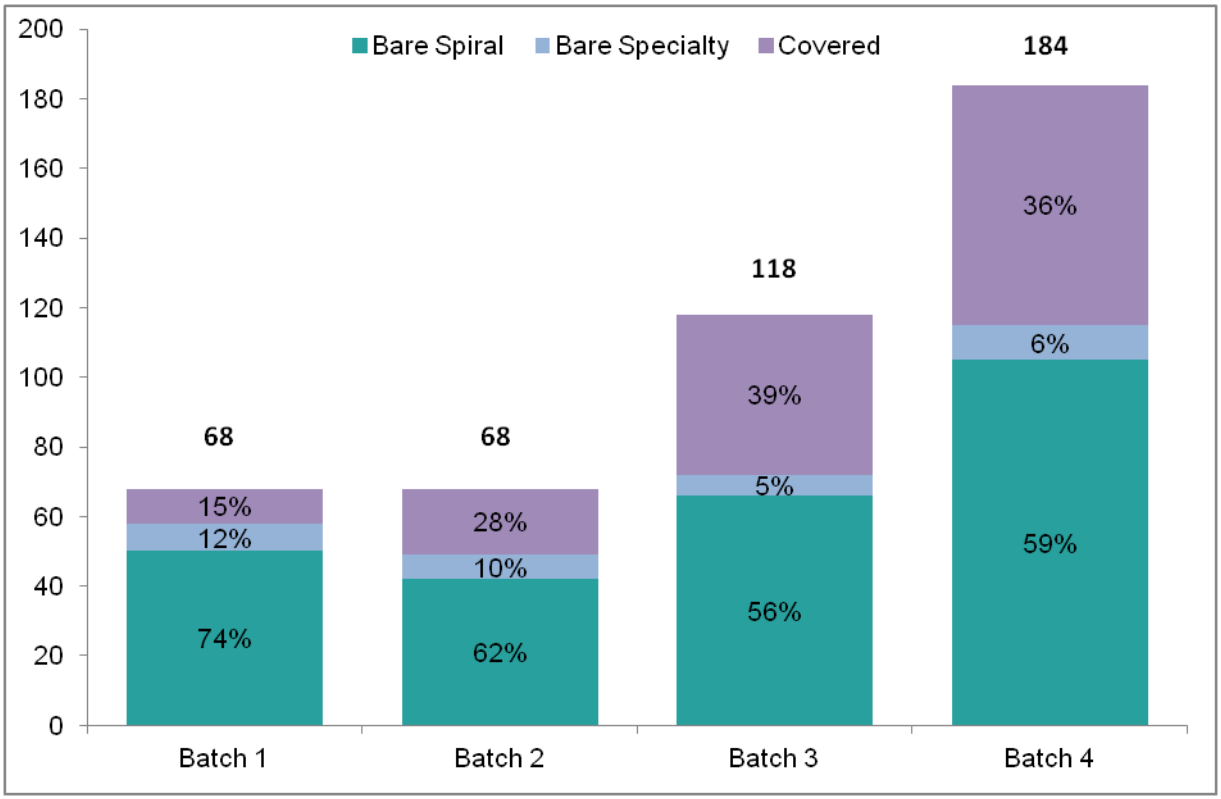
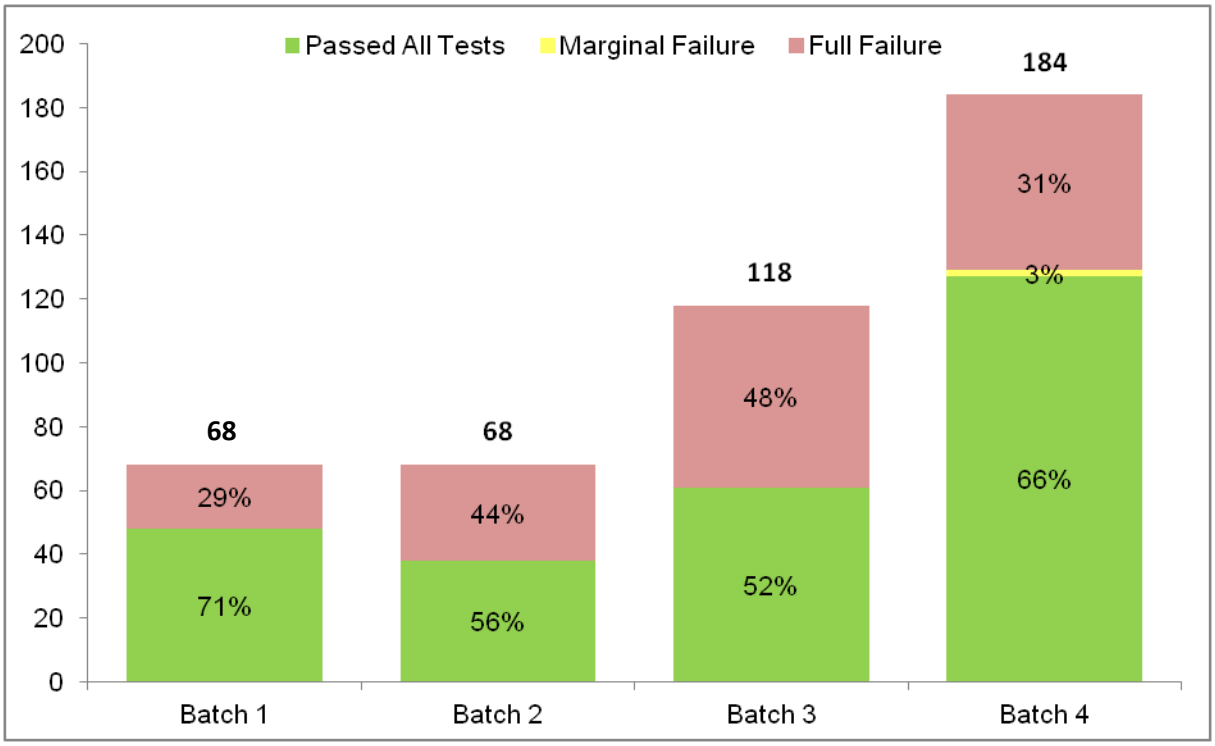
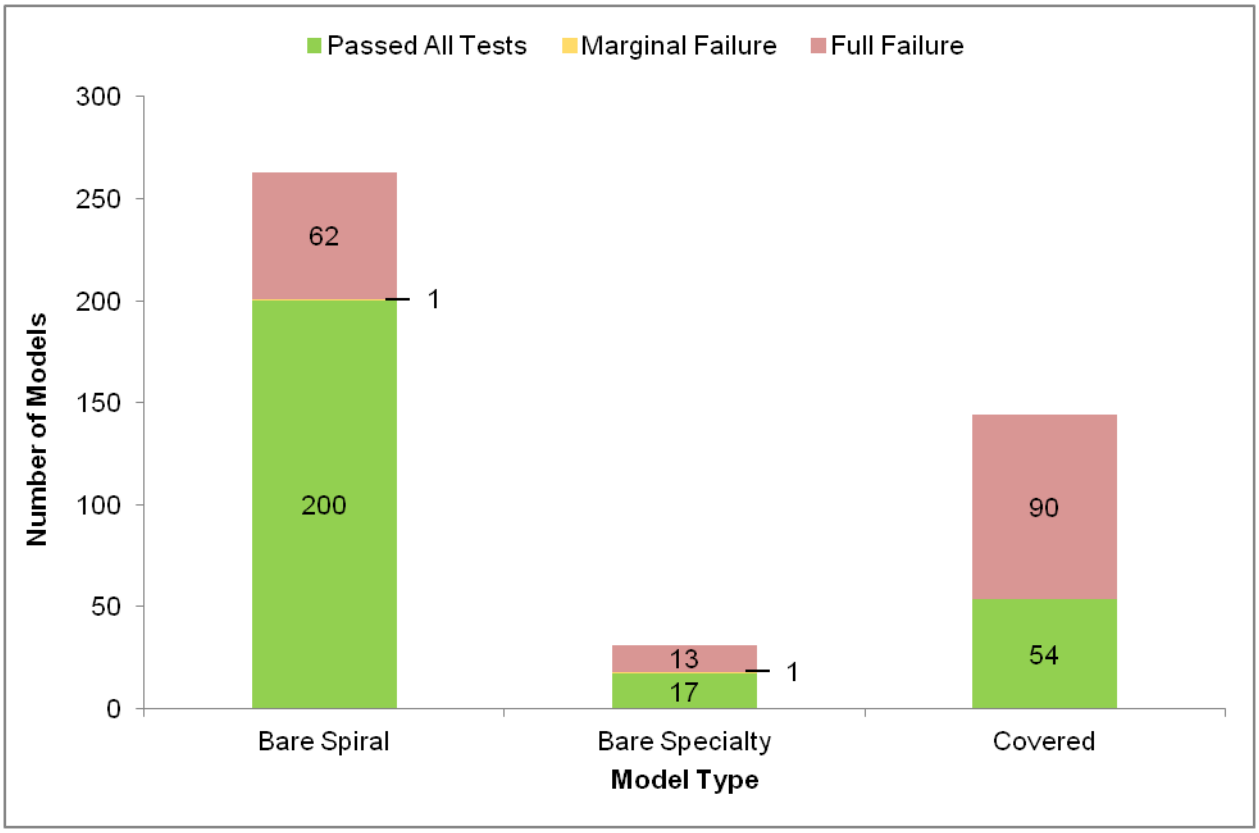


Figure 24: Summary of Results by Batch



Across all four batches, bare spiral models had a 24% failure rate, bare specialty models had a 42% failure rate, and covered models performed worst, with 63% of models failing. See Figure 25.

Figure 25: Results by Model Type: Aggregate



Bare spiral performance has changed little over the four batches, consistently outperforming other lamp types. Bare spiral models performed the best in Batch 4, with 82% of models passing all tests. Performance was fairly consistent in the other three batches, with 76% of models in Batch 1 and Batch 2 and 70% of models in Batch 3 passing all tests. Figure 26 presents bare spiral model test results.

Bare specialty models have undergone limited testing to date, with only 31 models tested across all four batches. They performed poorly in the first two batches, with 50% of models passing in Batch 1 and only 29% passing in Batch 2. Performance in Batch 3 improved, with 83% of models passing, but the small sample size limits the ability to generalize this finding to bare specialty models overall. In Batch 4, 60% of models passed all tests. While the sample size for each batch is too small for results to be conclusive, the results have consistently been worse than desired (55% overall passing rate), indicating an issue with the performance of this category. Figure 27 presents bare specialty model results.

Covered models have consistently had the lowest passing rate of the three lamp types, with 37% of models passing all tests. In Batch 1, covered models had a passing rate of 60%, with, 6 out of 10 models passing all tests. Only 4 of the 19 covered models in Batch 2 (21%) passed all tests. Batch 3 had similar results, with only 22% passing all tests. Covered models performed better in Batch 4, with

52% of models passing all tests. The sample size of covered lamps tested increased over time (10 in Batch 1 compared to 69 in Batch 4), but overall performance continued to be poor. Figure 28 presents covered model results.

Figure 26: Bare Spiral Test Results

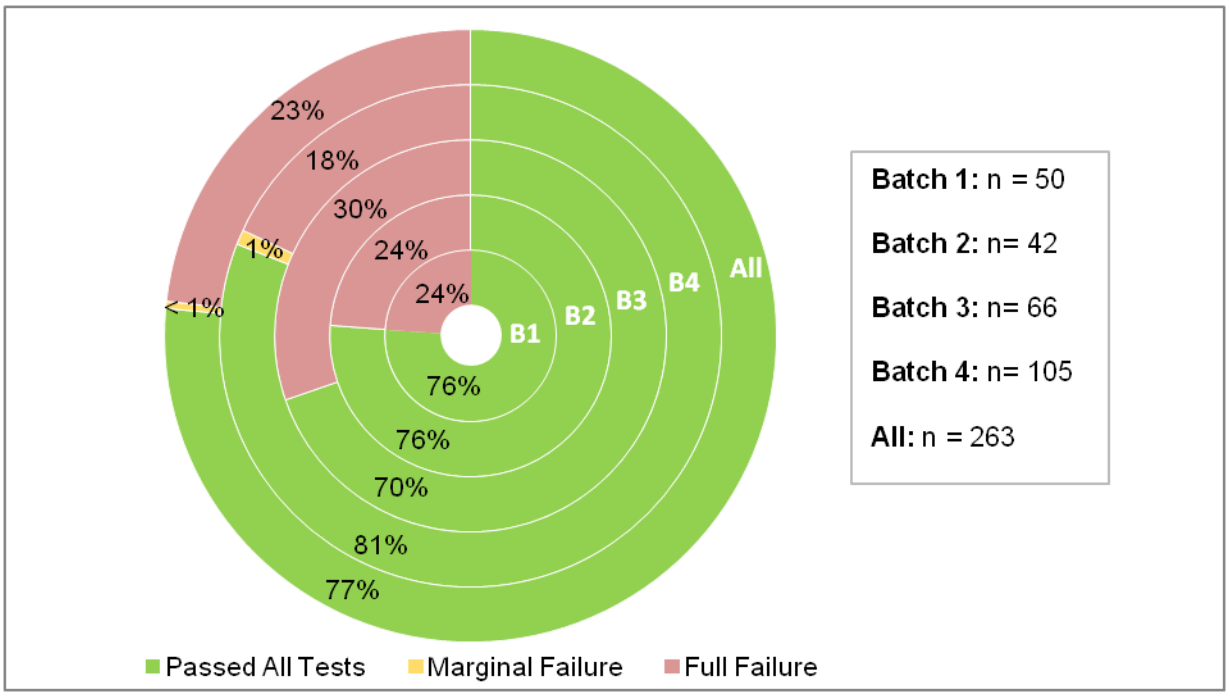


Figure 27: **Bare Specialty Test Results**

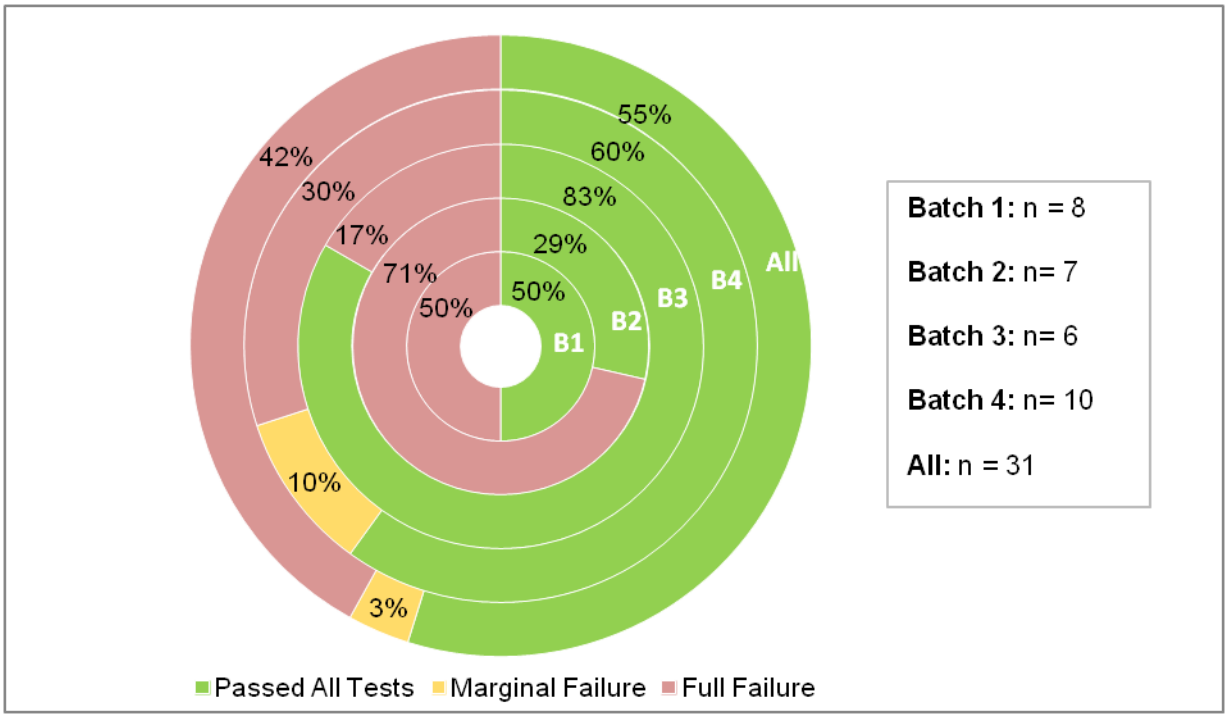
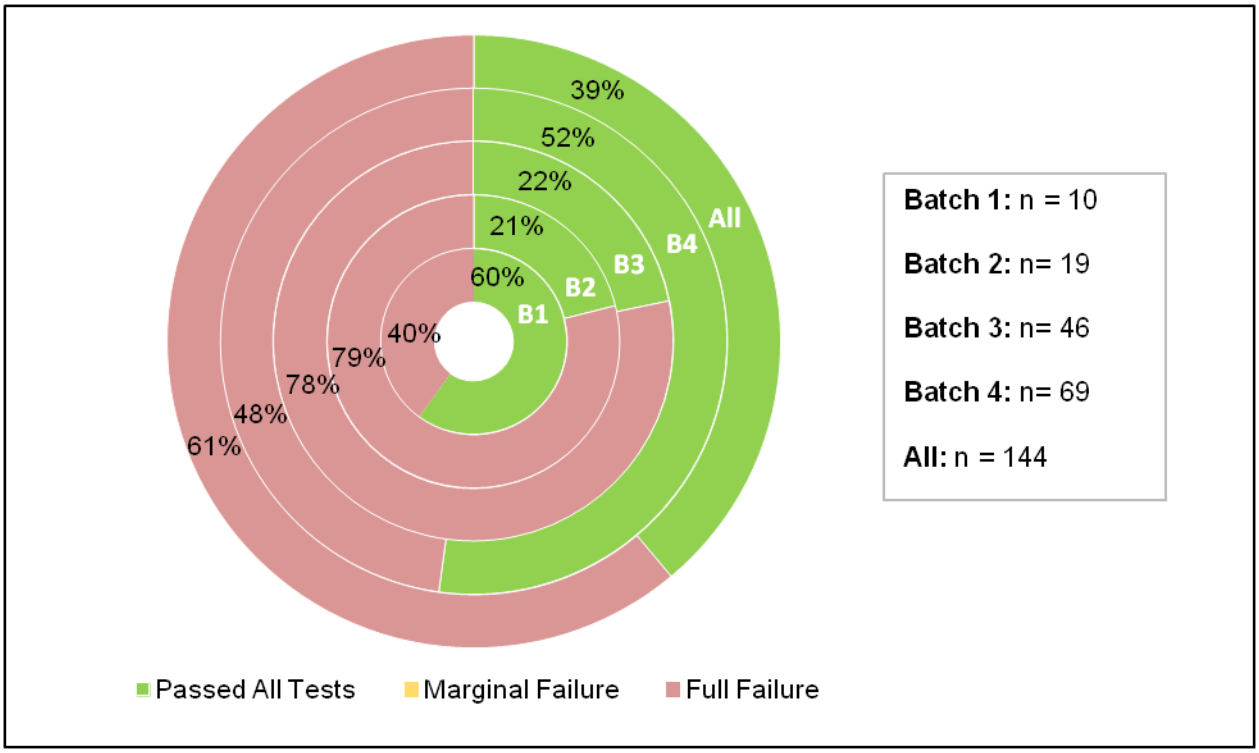


Figure 28: Covered Test Results



Summary of Results by Test

This section compares product performance on each of the 11 tests for the four batches and three product types.

No test maintained a 100% passing rate across all four batches. Figure 29 presents aggregate test results.[12]

- Efficacy, Starting Time, Power Factor, and Color Rendering Index had the highest passing rates, ranging from 98% to 99%.
- Run-Up Time, Chromaticity, and Rapid Cycle Stress Test had acceptable failing rates of 8%-9%.
- 1,000-Hour Lumen Maintenance, 40% Lumen Maintenance, and Interim Life Tests had undesirable failure rates, ranging from 11%-15%
- Of tests that were performed on all products, the Interim Life Test had the lowest passing rate, at 85%.
- The Initial Elevated Temperature Light Output Ratio Test, which was performed on only 32 models across all four batches, had a low passing rate of 88%.

[12] Marginal failures are not included in the failing percentages.

Figure 29: Aggregate Test Results

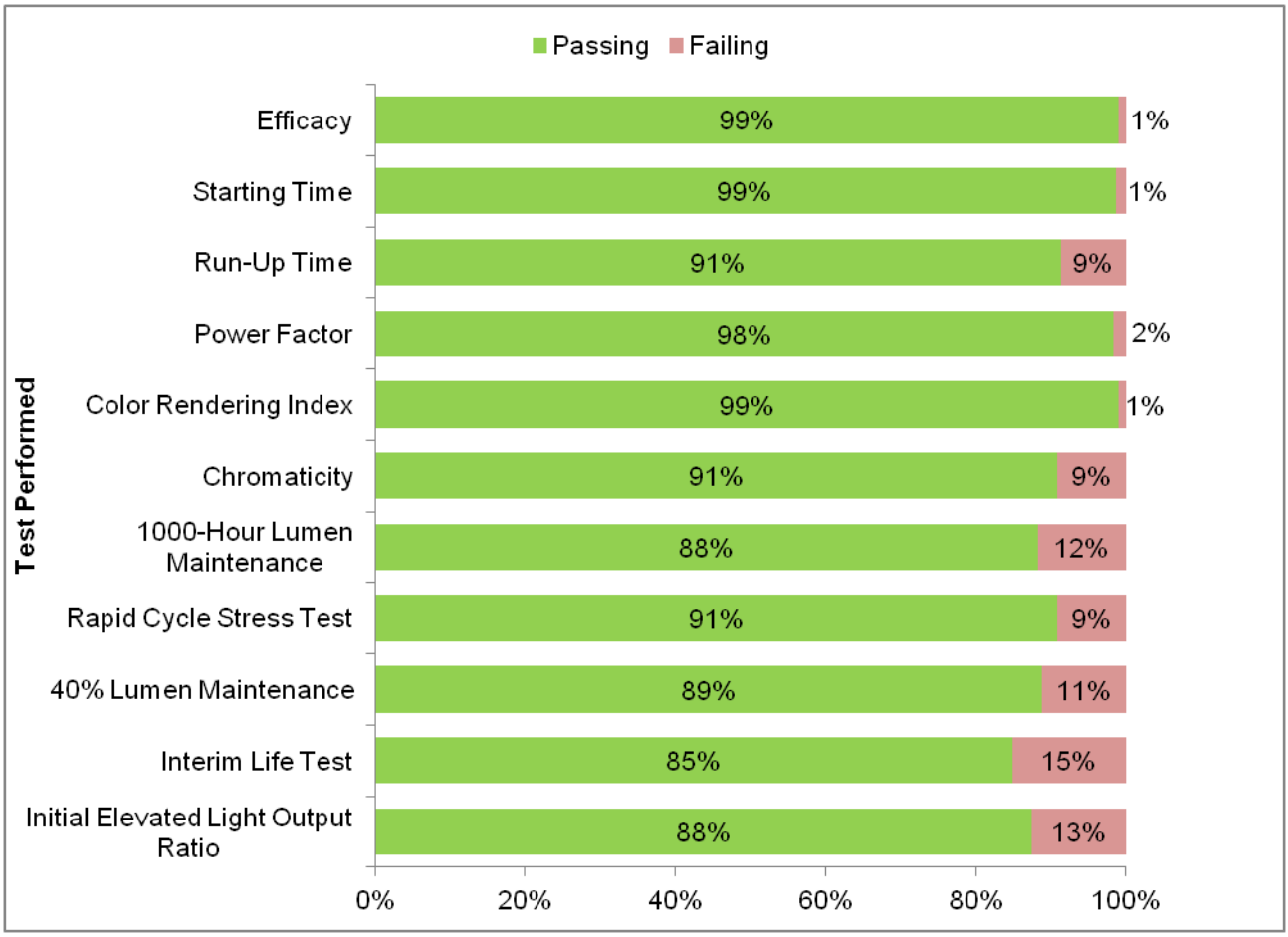


Figure 30[13] shows the distribution of test failures across the 11 tests for each of the three lamp types.

- The Interim Life Test accounts for 26% of the test failures experienced by bare spiral models. More bare spiral models failed this test than any other product type.
- The Rapid Cycle Stress Test accounts for 25% of test failures for bare spirals, compared to 0% for bare specialty and 4% for covered models. This test was primarily an issue for bare spiral lamps.
- The Chromaticity Test accounts for 35% of bare specialty failures, which was by far the highest failure rate for that product type.
- The 1,000-Hour Lumen Maintenance Test and 40% Lumen Maintenance Test had the highest failure rates for covered models; the tests represented 22% and 25% of covered product failures, respectively.

[13] Marginal failures are not included in the test failure totals.

Figure 30: Distribution of Test Failures by Test

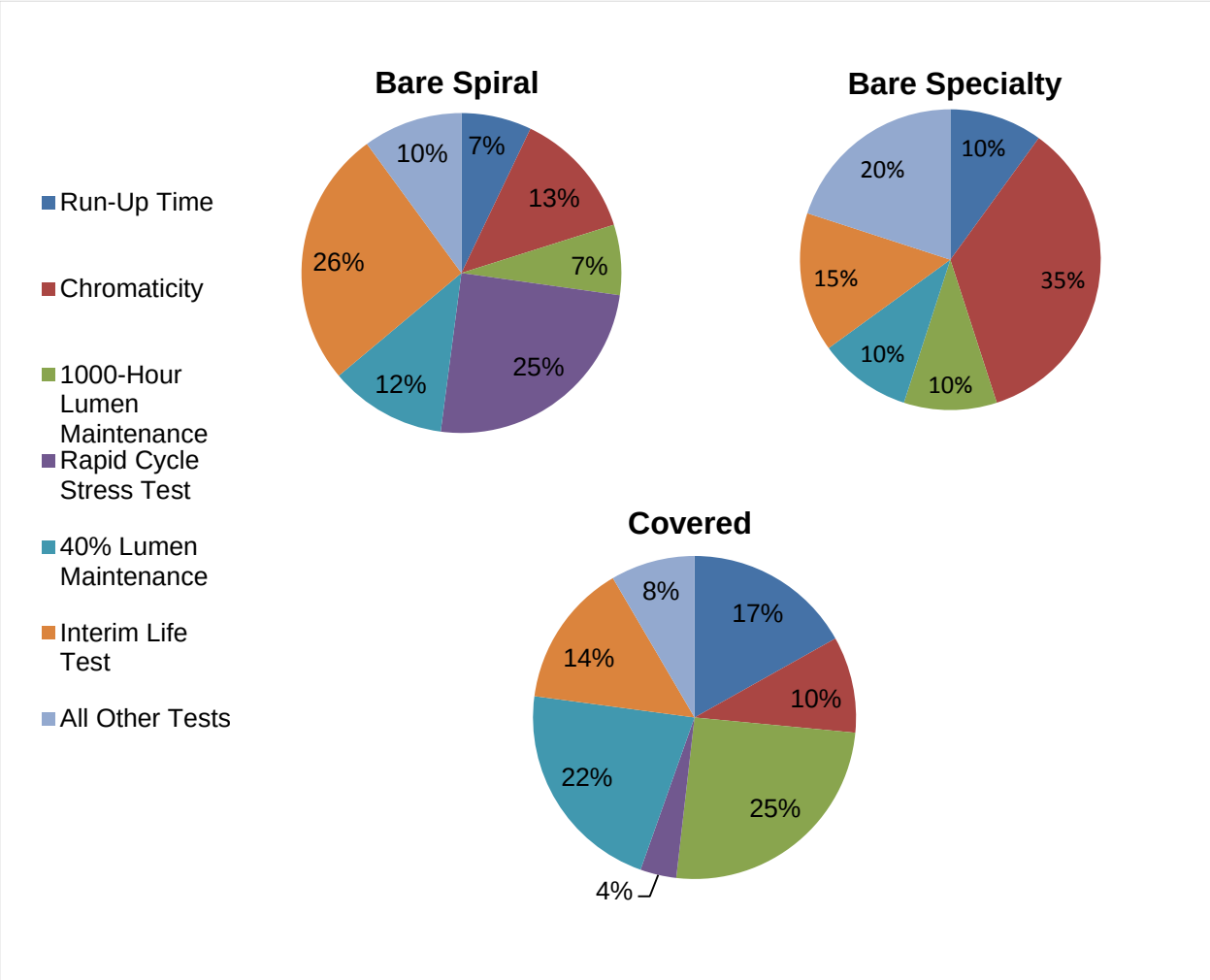
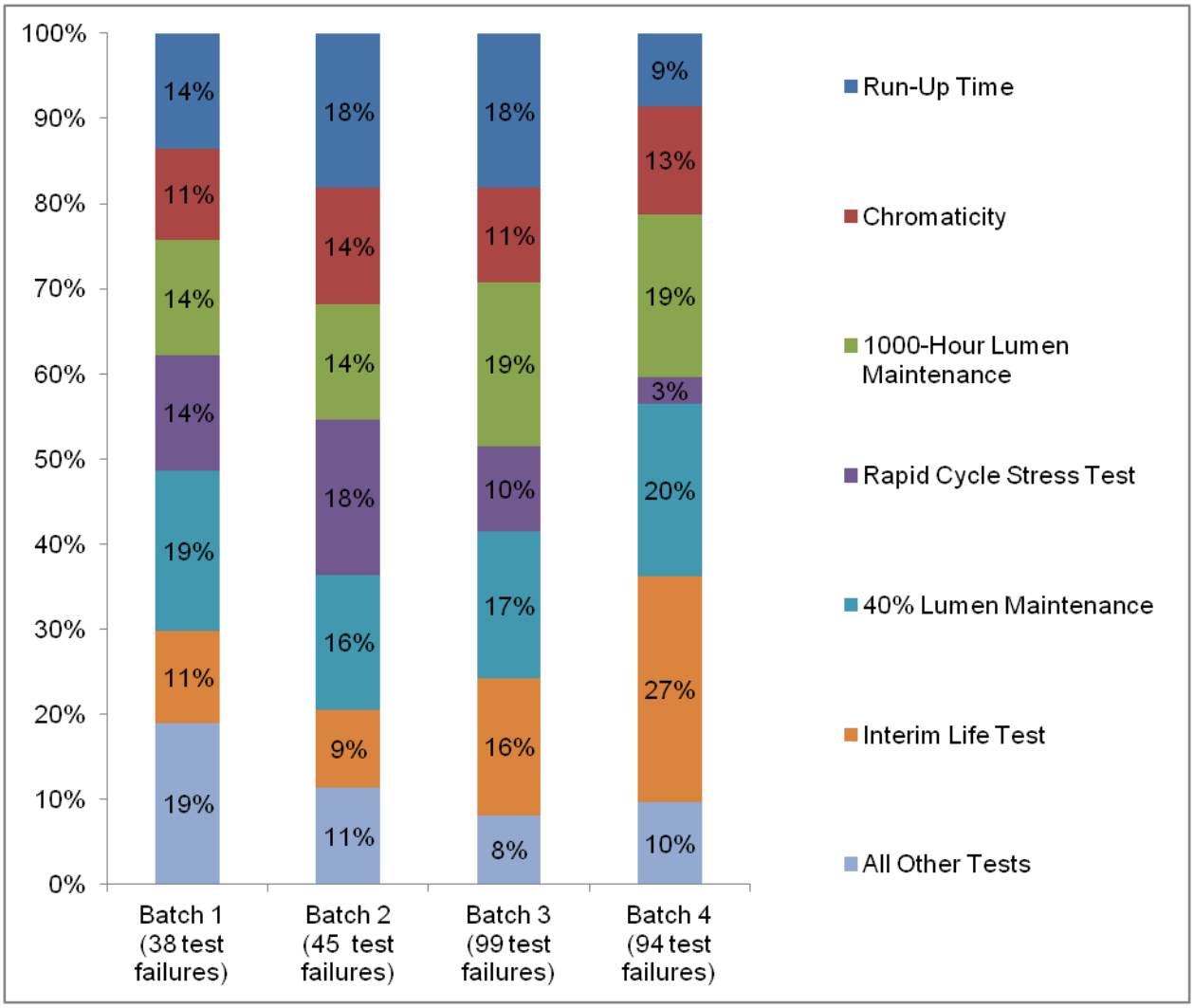


Figure 31 shows the distribution of test failures to date across the 11 tests for each of the four batches. There was little variance in failure rates for any individual test across the first three batches. However, Batch 4 showed noticeable differences in test failures for some tests:

- Run-Up Time and Rapid Cycle Stress Test failures decreased from Batch 3 to Batch 4 by nine percentage points and seven percentage points, respectively. These tests also had a much lower failure rate in Batch 4 than in other batches.
- For the Interim Life Test, test failures increased by eleven percentage points from Batch 3 to Batch 4. Batch 4 experienced significantly more failures for this test than any other batch.
- The 1000-Hour Lumen Maintenance and 40% Lumen Maintenance Tests had high failure rates across all four batches.

Figure 31: Failures by Test, Batches 1 through 4: All Models



Figures 32, 33, and 34 show the distribution of test failures to date across the 11 tests for each of the three lamp types, by batch.

For bare spiral models:

- The Rapid Cycle Stress Test accounted for significant numbers of failures in Batches 1, 2, and 3; failures notably decreased in Batch 4 (see Figure 32).
- The Interim Life Test accounted for 44% of failures in Batch 4 and 17%-21% of failures in Batches 1 through 3.
- There were no 1,000-Hour Lumen Maintenance failures in Batch 4.

For bare specialty models:

- The Run-Up Time, Power Factor, Chromaticity, and Interim Life Tests produced failures in Batches 1 and 2 (see Figure 33).
- The only bare specialty test failures in Batch 4 were in the Chromaticity Test and 40% Lumen Maintenance Test.
- The 1,000-Hour Lumen Maintenance Test, which accounted for 25% of the failures in Batch 1, had no failures in subsequent batches. The Chromaticity Test, which was responsible for just 13% of failures in Batch 1, was responsible for 43% of failures in Batch 2 and 75% of failures in Batch 4.
- There seems to be no consistency in terms of which tests bare specialty lamps fail.

For covered models:

- The Run-Up Time Test and the two lumen maintenance tests produced substantial failures in all four batches (see Figure 34).
- In Batch 4, the two lumen maintenance tests represented 56% of all failures for covered models.
- No covered models in Batch 1 failed the Chromaticity Test, though this test accounted for 25% of the failures in Batch 2. The small sample sizes in Batches 1-2 could account for the inconsistent results.
- The Interim Life Test produced 22% of failures in Batch 4, more than in any of the previous three batches. The larger sample size in Batch 4 makes these results more robust.

Figure 32: Bare Spiral Failures by Test and Batch

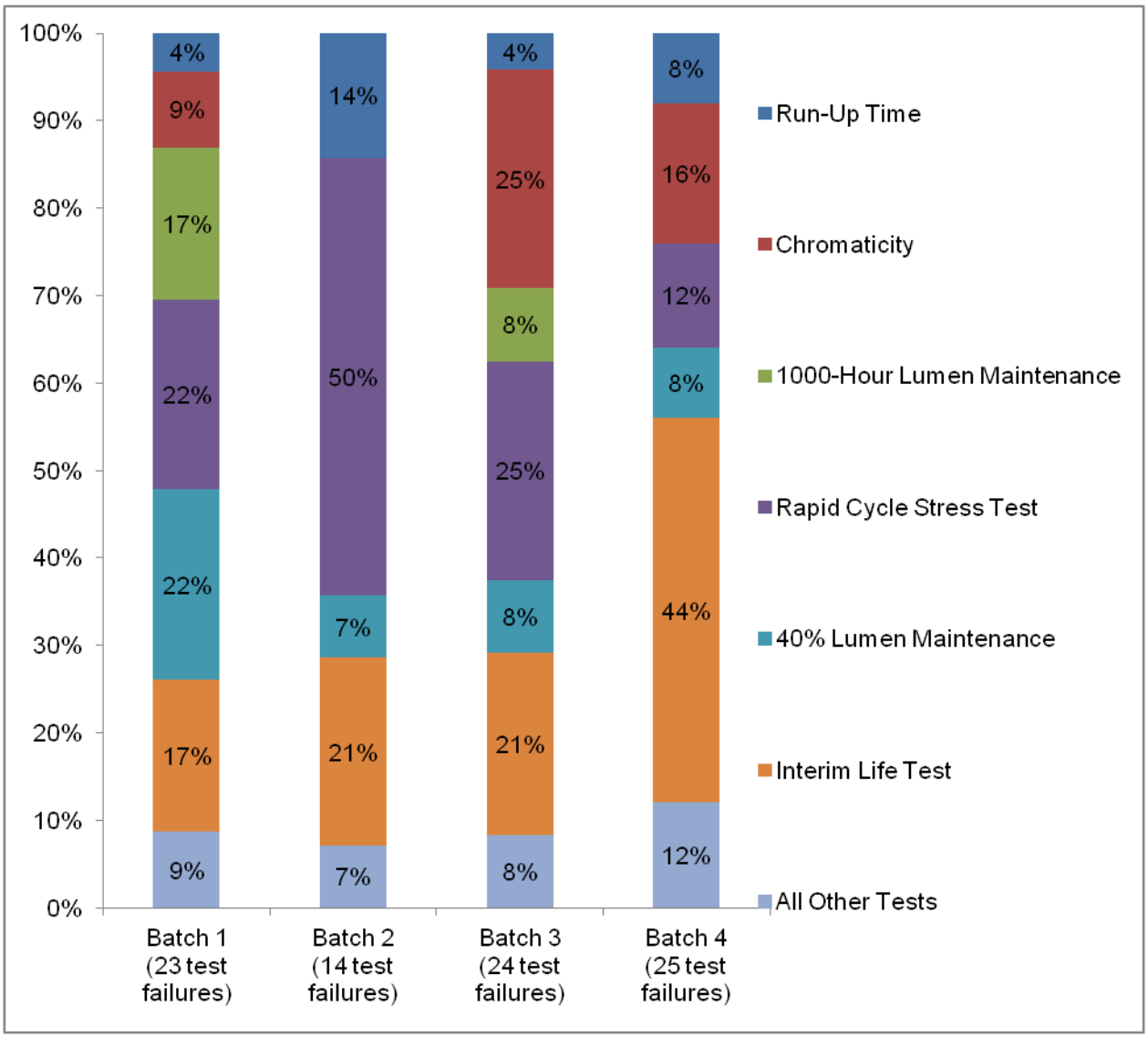


Figure 33: Bare Specialty Failures by Test and Batch

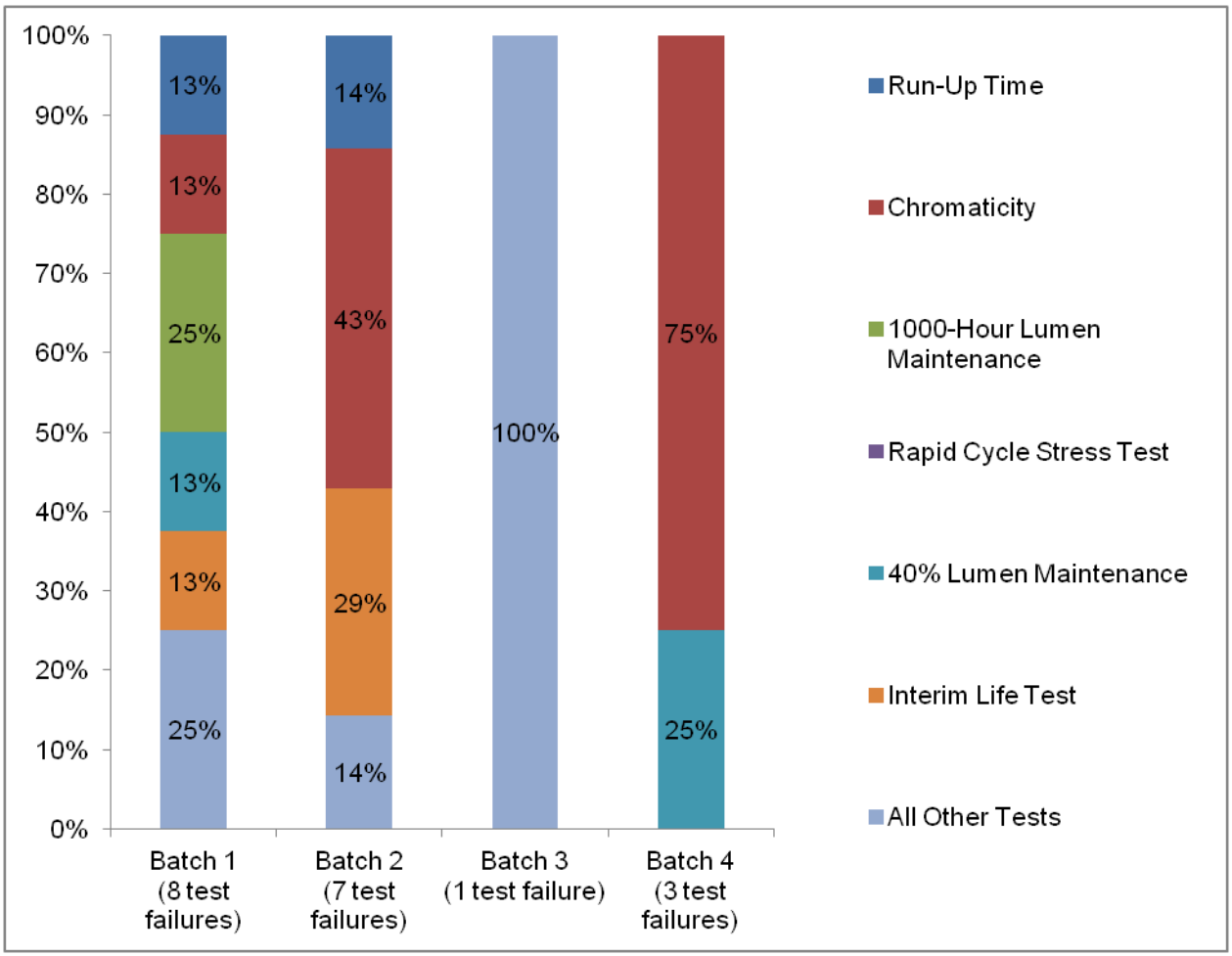


Figure 34: Covered Failures by Test and Batch

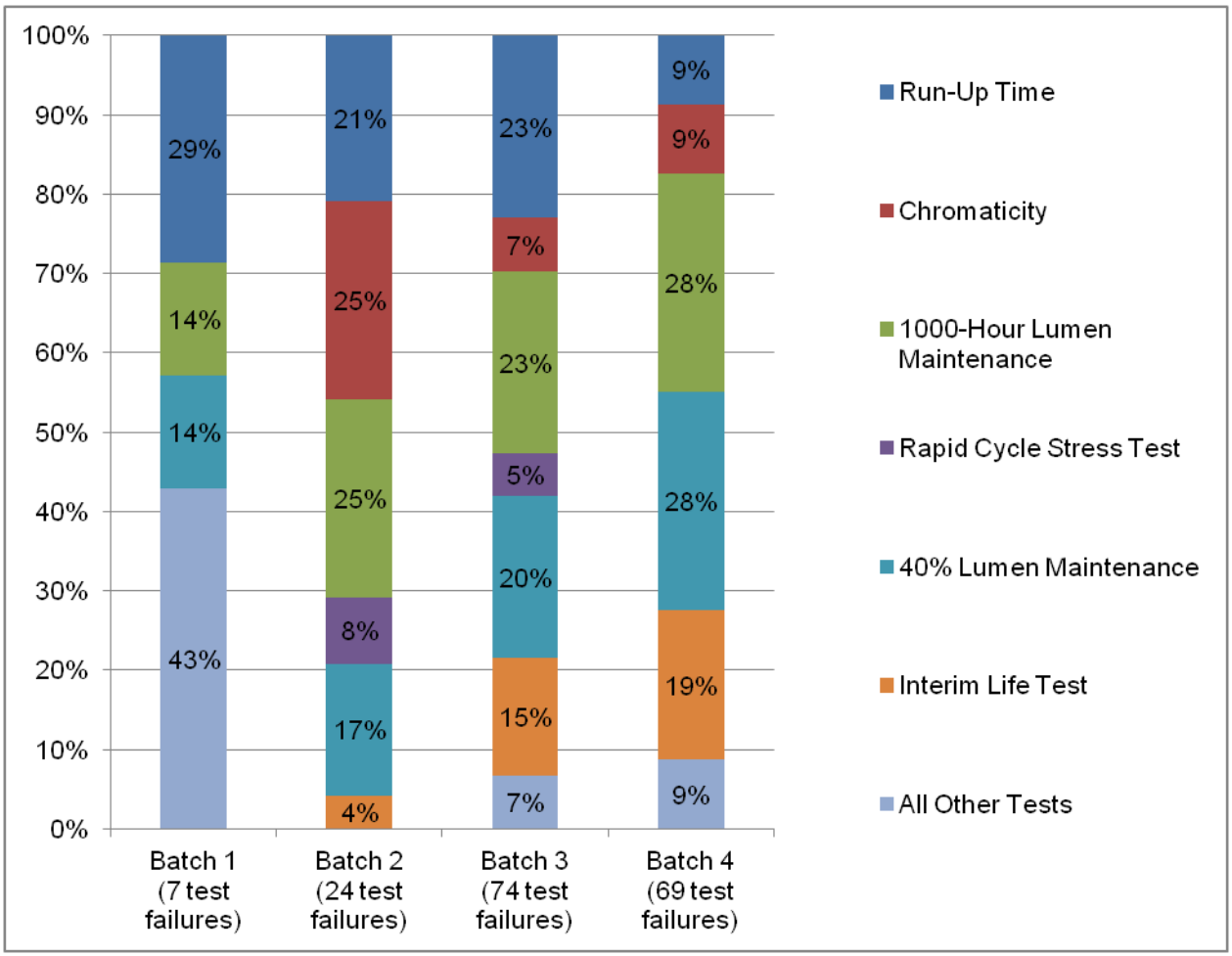


Table 19 presents the mean and median values for all tests in Batches 1 through 4. Results for the Efficacy, Starting Time, and Run-Up Time Tests differed significantly among the batches:

- The mean and median for the Efficacy Test decreased from Batch 1 and Batch 2 to Batch 3 and increased from Batch 3 to Batch 4.
- The mean and median for the Starting Time Test for Batch 4 were significantly lower than for Batch 3.
- The mean and median for the Run-Up Time Test increased from Batch 3 to Batch 4.

Table 19: Comparison of Batches 1 through 4: Mean and Median of Measured Values

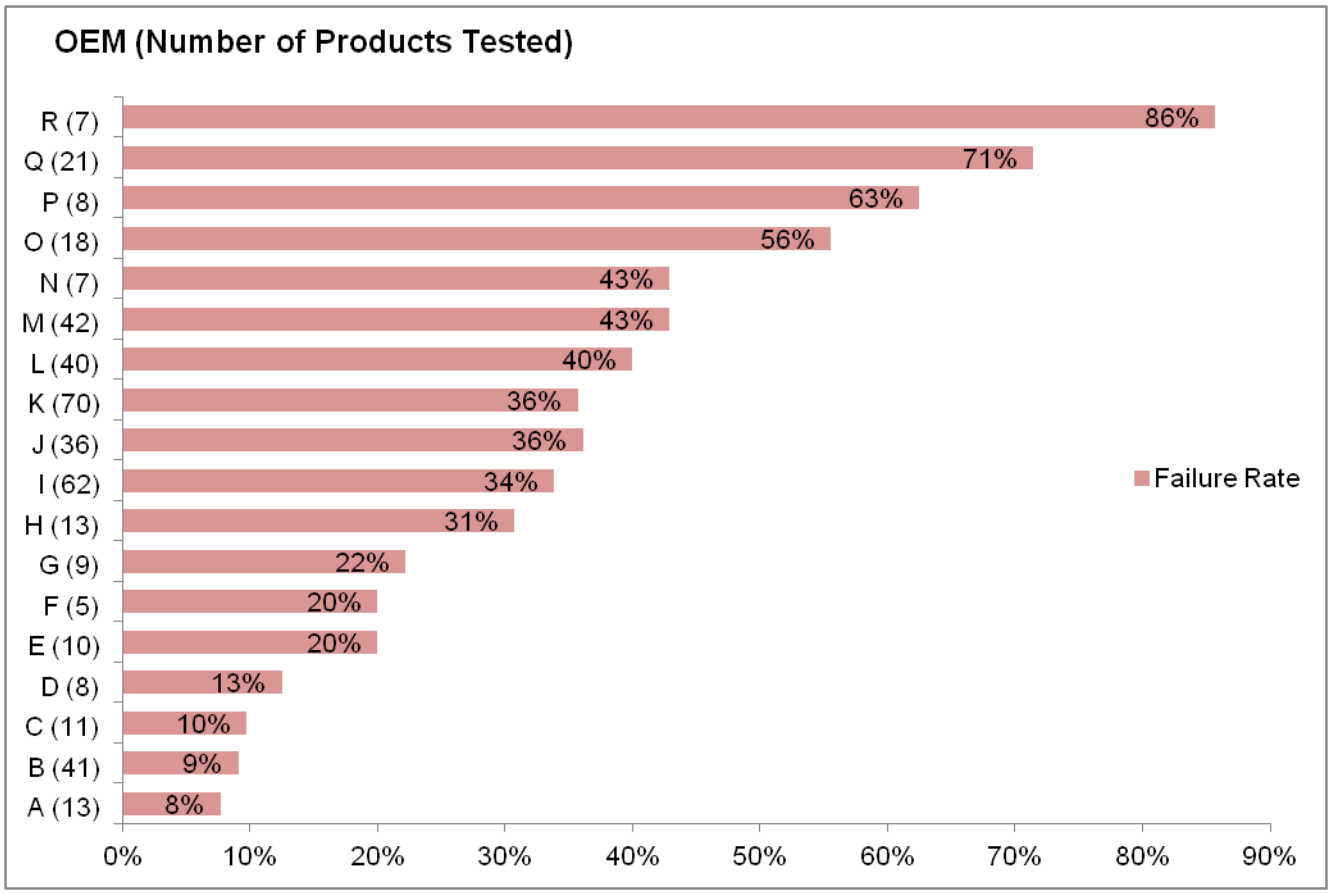
Test	Passing Criteria	Mean				Median			
		Batch 1	Batch 2	Batch 3	Batch 4	Batch 1	Batch 2	Batch 3	Batch 4
Efficacy	Varies by type	65.3	64.7	60.8	61.06	67.8	67.2	62.5	63.7
Starting Time	<1000 milliseconds	360	251	318	260.8	270	170	230	104
Run-Up Time	<60 or <180 seconds	48	68	77	73.4	33	45	48	54.8
Power Factor	>0.5	0.59	0.55	0.58	0.57	0.56	0.55	0.57	0.56
Color Rendering Index	>80	82.7	82.8	82.7	82.9	82.4	82.9	82.4	82.9
Chromaticity	9/10 or 17/20 coordinates inside ellipse	9.5	9.3	12.5	14.7	10	10	10	15
1,000-Hour Lumen Maintenance	>90%	93%	93%	92%	92%	94%	94%	93%	93%
Rapid Cycle Stress Test	5/6 or 9/12 survive to half of rated life	5.4	5.3	7.5	9	6	6	6	10
40% Lumen Maintenance	>80%	85%	85%	84%	84%	86%	85%	84%	86%
Interim Life Test	9/10 or 17/20*survive to 40% of rated life	9.2	9.3	12.4	14.2	10	10	10	15

* Double sample size.

OEM Analysis

Figure 35 compares the overall OEM product failure rates that had at least 5 products tested as of May 31, 2015. Figure 36 compares the failure rates of OEMs that had at least 5 products of each type tested, by product type (bare spiral and other types), as of May 31, 2015

Figure 35: Failure Rate for OEMs with ≥5 Products Tested



CONCLUSION

The performance of the 184 models that completed testing between August 2012 and May 31, 2015 – Batch 4 – was mixed. The most concerning finding is that the three tests with passing rates of less than 90% – 1,000 Hour Lumen Maintenance, 40% Lumen Maintenance, and Interim Life Tests – measure lamp characteristics that CFL consumers are likely to notice.

Of the 184 tested models, 69% passed all of the tests. However, performance varied across product types. Covered lamps and bare specialty models, which include dimmable and 3-way bare lamps, failed at a higher rate than bare spiral models. In Batch 4, 81% of bare spiral models passed all tests, compared with only 60% of bare specialty models and 52% of covered models. Given the low passing rate of the covered models tested, it is likely that a significant proportion of the covered models available in the market and being incentivized through energy efficiency programs are poor performers – a potentially troubling finding for lamp retailers and energy efficiency program sponsors. However, it is encouraging that the pass rate for covered products in Batch 4 improved compared to Batches 1, 2, and 3. Of the bare specialty products that failed a test, all but one failure was for the Chromaticity Test. Across the 4 batches, the pass rate ranged from 29% to 83%, with an average pass rate of 55%, which is very close to the Batch 4 pass rate.

Retailers and energy efficiency program sponsors concerned about the performance of the products they sell or incentivize can take the following steps to improve the market impacts of their products and protect themselves from purchasing and incentivizing models that perform poorly:

- Ask suppliers to provide the results of any verification testing on incentivized models.
- Require that suppliers indicate whether the product has undergone or is currently undergoing verification testing.
- Work with EPA to nominate products for verification testing where performance may be a concern.

OEM performance varied widely in Batch 4, though most OEMs improved their performance in Batch 4 relative to previous batches. Ten OEMs – which represent more than three-quarters of all models tested and more than three-quarters of all model failures – had 5 or more products tested; their overall failure rates ranged from 0% to 50%. Two OEMs had a failure rate above 40%,.

The verification testing program provides EPA with a mechanism for ensuring that ENERGY STAR certified models available in the marketplace perform as promised. The test results also likely reflect consumers' experiences with ENERGY STAR certified CFLs in their homes and businesses. However, care should be exercised when generalizing from the test results described in this report to the entire market of ENERGY STAR certified CFLs, as the sample of models tested is not representative of ENERGY STAR certified CFL shipments for three key reasons.

First, the ENERGY STAR certified product list is highly dynamic. The models tested in Batch 4 were purchased in 2012 and 2013. Many of those models are no longer available, and many new models have been introduced since.

Second, certain subsamples of tested models are quite small. For example, only 31 bare specialty CFL models have been tested to date. This concern is mitigated by the fact that there are currently only 60

bare specialty models on the ENERGY STAR certified product list and anecdotal evidence indicates that these products' sales volumes are small. In addition, the total number of models tested and the amount of data on those models will grow as verification testing under the third party certification program continues.

Third, the sample of models tested is not representative of ENERGY STAR shipments because the CFL models tested were selected by nomination or at random rather than by market share.

APPENDIX

The ENERGY STAR CFL Third Party Testing and Verification Program exists to support the EPA in ensuring that compact fluorescent lamps (CFLs) certified and labeled as ENERGY STAR continue to meet all ENERGY STAR CFL qualification criteria. This report contains the results of all models tested by the program from August 1, 2012 through May 31, 2015.

KEY	
Failed	The product failed testing.
Marginal Failure	The product was a marginal failure, meaning that one less sample than required passed (i.e.., if 9 out of 10 are required, only 8 out of 10 passed).
3% Applied	The product passed the Efficacy and/or Lumen Maintenance Test with performance between 97% and 99.9% of the minimum requirement.
P	The product passed.

Table A. Detailed Results for the 170 Models Included in Batch 4

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Sample Size	Efficacy	Starting Time	Run-Up Time	Power Factor	1,000-Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity	Rapid Cycle Stress Test	Interim Life Test	Initial Elevated Temperature Output Ratio
Spiral	23	1600	10000	6/10	P	P	P	P	89.86	78.97	P	P	P	P	
Spiral	14	900	10000	12/10	P	P	P	P	P	P	P	P	P	P	
Spiral	25	1600	15000	6/10	64.35	P	P	P	P	P	P	P	P	P	
Spiral	20	1115	12000	12/10	P	P	P	P	P	P	P	P	P	P	
Spiral	9	900	10000	12/20	P	P	P	P	P	P	P	P	P	15	
Spiral	19	1200	12000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	20	1350	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	32	1920	8000	6/10	P	P	P	P	P	P	79.6	7	P	P	
Spiral	13	900	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	14	800	8000	6/10	P	P	P	P	87.6	77.6	P	P	P	P	
Covered	9	510	10000	6/10	P	P	254.8	P	83.5	73.5	P	P	P	P	
Spiral	23	1600	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Specialty	15	900	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	23	1600	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	23	1600	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	9	280	8000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	23	1200	8000	6/10	P	P	270	P	P	P	P	P	P	7	
Covered	15	750	10000	6/10	P	P	P	P	86	64.7	P	P	P	7	P
Spiral	13	900	10000	6/10	P	P	P	P	P	P	P	P	P	7	
Spiral	13	900	12000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	23	1600	12000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	13	850	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	10	580	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	11	600	10000	6/10	P	P	P	P	89.4	79.4	P	P	P	P	
Spiral	23	1600	10000	6/10	P	P	P	P	P	P	P	P	P	7	
Spiral	13	800	10000	6/10	P	P	P	P	P	P	P	P	P	7	
Covered	11	555	8000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	23	1600	8000	12/20	P	P	P	P	P	P	P	P	P	P	

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Sample Size	Efficacy	Starting Time	Run-Up Time	Power Factor	1,000-Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity	Rapid Cycle Stress Test	Interim Life Test	Initial Elevated Temperature Output Ratio
Specialty	12/21/32	2400	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	15	800	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	13	900	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	13	900	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	15	720	6000	12/20	P	P	P	P	83.1	P	P	P	P	P	P
Spiral	23	1600	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	7	280	8000	12/20	P	P	P	P	81.92	71.8	P	P	P	P	
Covered	9	520	8000	6/10	41.7	P	P	P	88.4	77.3	P	P	P	P	
Covered	15	720	6000	12/20	P	P	P	P	85.3	P	P	P	P	P	86.2
Covered	15	750	10000	12/20	P	P	P	P	P	79.4	P	P	P	P	
Spiral	23	1600	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	15	800	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	13	800	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	20	1300	12000	12/20	P	P	68	P	88.9	P	P	P	P	P	
Spiral	30	2000	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	13	825	12000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	23	1600	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	15	750	8000	12/20	P	P	P	P	89.6	P	P	P	P	P	
Covered	12	640	8000	12/20	P	P	P	P	84.9	P	P	P	P	8	
Spiral	23	1600	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	18	950	10000	12/20	P	P	P	P	81.5	71.2	P	13	P	6	P
Spiral	14	900	12000	12/20	P	P	P	P	P	0	P	P	P	0	
Spiral	13	870	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	15	950	12000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	11	460	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	9	450	8000	12/20	P	P	P	0.488	P	P	79.2	P	P	P	
Spiral	13	850	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	23	1600	12000	12/20	P	P	P	P	P	P	P	11	P	P	
Covered	11	500	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	15	720	6000	12/20	P	P	P	P	89.4	P	P	P	P	P	

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Sample Size	Efficacy	Starting Time	Run-Up Time	Power Factor	1,000-Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity	Rapid Cycle Stress Test	Interim Life Test	Initial Elevated Temperature Output Ratio
Covered	15	800	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	11	550	10000	12/20	P	P	P	P	85.8	P	P	14	P	P	
Spiral	15	950	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	20	1200	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	15	750	10000	12/20	P	P	P	P	88.3	78.9	P	P	P	P	
Covered	11	450	10000	12/20	P	P	P	P	87.6	77.6	P	P	P	P	
Spiral	10	580	12000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	11	460	10000	12/20	P	P	P	P	86.2	79.4	P	P	P	P	
Covered	11	505	10000	12/20	P	P	P	P	88.4	P	P	P	P	P	
Covered	15	825	10000	12/20	P	P	P	P	85.6	77	P	P	P	P	
Covered	23	1185	10000	12/20	P	P	P	P	85.4	76.1	P	P	P	P	P
Spiral	20	1250	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	10	550	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	26	1600	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	26	1600	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	15	650	10000	12/20	P	P	P	P	85.2	72.2	P	P	P	P	
Covered	26	1300	10000	12/20	P	P	P	P	83.4	69.7	P	P	P	P	
Covered	14	750	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	20	1100	8000	12/20	P	P	P	P	87.4	77.6	P	P	P	P	
Spiral	26	1700	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	26	1750	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	11	500	10000	12/20	P	P	P	P	88.5	78.9	P	P	P	P	
Covered	26	1350	10000	12/20	50.87	P	P	P	81.09	71.9	P	P	P	P	
Covered	11	370	10000	12/20	P	P	P	P	84.1	73.6	P	16	P	16	P
Covered	20	1100	10000	12/20	P	P	P	P	84.5	74.9	P	P	P	P	
Spiral	26	1610	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	42	2700	12000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	13	825	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	10	520	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	26	1650	8000	12/20	P	P	P	P	P	P	P	P	P	P	

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Sample Size	Efficacy	Starting Time	Run-Up Time	Power Factor	1,000-Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity	Rapid Cycle Stress Test	Interim Life Test	Initial Elevated Temperature Output Ratio
Spiral	26	1700	12000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	32	2200	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Specialty	15	900	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Specialty	32	2150	8000	12/20	P	P	P	P	P	P	P	9	P	P	
Spiral	10	520	8000	12/20	P	P	P	P	89.6	P	P	P	P	P	
Spiral	10	490	10000	12/20	P	P	P	P	88.3	77.1	P	P	P	P	
Spiral	10	550	12000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	10	550	12000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	20	1200	12000	12/20	P	P	P	P	P	P	P	P	P	P	
Specialty	26	1750	10000	12/20	P	P	P	P	P	P	P	15	P	P	
Specialty	16/25/32	2150	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	10	580	12000	12/20	P	P	75.1	P	P	P	P	P	P	P	
Spiral	13	870	12000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	15	950	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	13	825	12000	12/20	P	P	P	P	P	P	P	P	P	15	
Spiral	13	870	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	20	1200	10000	12/20	61.9	P	P	P	P	P	P	P	P	2	
Spiral	26	1800	10000	6/10	P	P	P	P	P	P	P	P	4	P	
Covered	9	500	10000	6/10	P	P	P	P	P	79.1	P	P	P	7	
Spiral	18	1200	10000	6/10	63.64	P	P	P	P	P	P	P	P	P	
Spiral	14	800	10000	12/10	P	P	P	P	P	P	P	P	P	P	
Spiral	14	850	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	23	1200	8000	12/20	P	P	209	P	P	P	P	P	P	P	
Spiral	20	1300	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	23	1600	8000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	9	550	8000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	9	550	12000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	26	1700	10000	6/10	P	P	P	P	P	P	P	6	P	P	
Covered	7	450	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	13	900	12000	6/10	P	P	P	P	P	P	P	P	P	11	

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Sample Size	Efficacy	Starting Time	Run-Up Time	Power Factor	1,000-Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity	Rapid Cycle Stress Test	Interim Life Test	Initial Elevated Temperature Output Ratio
Covered	9	450	12000	6/10	P	P	P	P	P	N/A	P	P	P	1	
Spiral	13	850	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	15	750	10000	6/10	P	P	P	P	P	P	P	7	P	5	
Spiral	13	840	10000	12/20	P	P	P	P	89.2	79.1	P	P	P	P	
Covered	15	700	6000	6/10	P	P	P	P	78.8	73.6	P	P	P	5	
Spiral	20	1300	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	9	500	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	14	830	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	20	900	8000	6/10	P	P	P	P	81.46	69.9	P	P	P	P	P
Spiral	23		10000	6/10	P	P	P	P	P	P	P	7	P	6	
Spiral	13	900	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	9	300	8000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	23	1660	12000	6/10	64.82	P	P	P	P	P	P	P	P	P	
Specialty	12/22/33	2245	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	15	775	8000	6/10	P	P	203	P	89.9	P	P	P	P	P	P
Covered	14	800	8000	6/10	P	P	P	P	87.9	77.3	P	8	P	7	
Spiral	18	1170	8000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	12	600	8000	12/20	44.6	P	P	P	P	P	P	P	P	P	
Spiral	13	835	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	23	1600	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Specialty	26	1700	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	9	300	8000	6/10	P	P	P	P	P	P	P	P	P	P	P
Covered	23	1300	10000	6/10	P	P	P	P	P	P	P	P	P	P	P
Specialty	12/22/33	2100	10000	6/10	P	P	P	P	P	P	P	8	P	P	
Spiral	11	690	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	13	800	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Specialty	30	2100	10000	6/10	P	P	P	P	P	77.1	P	8	P	P	
Covered	15	600	8000	6/10	P	P	P	P	P	79.8	P	P	P	6	P
Spiral	31	2100	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	18	1100	8000	6/10	P	P	P	P	89.7	P	P	P	P	P	

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Sample Size	Efficacy	Starting Time	Run-Up Time	Power Factor	1,000-Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity	Rapid Cycle Stress Test	Interim Life Test	Initial Elevated Temperature Output Ratio
Spiral	19	1220	10000	6/10	P	P	P	0.497	P	P	P	P	P	P	
Spiral	13	800	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	23	1600	8000	6/10	63.1	P	P	P	P	P	P	P	P	P	
Spiral	13	880	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	14	800	8000	6/10	P	P	P	P	89.4	79.7	P	P	P	P	
Spiral	30	2000	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	14	800	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	9	475	8000	6/10	P	P	P	P	P	P	P	P	P	7	
Covered	23	1300	10000	12/10	P	P	235.1	P	P	P	P	P	P	P	
Covered	14	800	8000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	18.97	1183.9	10000	6/10	62.02	P	P	P	P	P	P	P	P	P	
Covered	20	900	8000	6/10	P	P	P	P	P	P	P	P	P	P	P
Spiral	34	2200	10000	6/10	64.1	P	P	P	P	P	P	P	P	7	
Spiral	18	1170	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	18	1170	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	32	2000	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	5	280	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	19	1100	10000	12/20	P	P	P	P	P	P	P	P	P	P	
Covered	14	500	8000	6/10	P	P	P	P	P	P	P	P	P	7	
Covered	15	725	8000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	23	1200	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	11	730	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	13	900	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	9	550	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	14	640	8000	6/10	P	P	P	P	P	P	P	P	P	P	86
Spiral	14	850	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	18	1250	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	23	1250	8000	12/20	P	P	285.2	P	P	P	P	8	P	P	P
Spiral	9	540	12000	12/20	P	P	P	P	P	P	P	P	7	11	
Covered	13	500	8000	6/10	P	P	P	P	P	P	P	P	P	P	

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Sample Size	Efficacy	Starting Time	Run-Up Time	Power Factor	1,000-Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity	Rapid Cycle Stress Test	Interim Life Test	Initial Elevated Temperature Output Ratio
Covered	15	700	8000	12/20	P	P	P	P	P	P	P	P	P	P	P
Spiral	23	1600	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Spiral	18	1200	10000	6/10	P	P	P	P	P	P	P	P	P	P	
Covered	15	630	8000	12/20	P	P	P	P	P	P	P	P	P	P	
Spiral	9	570	10000	12/20	P	P	P	P	P	P	P	P	8	P	
Spiral	14	830	10000	12/20	P	P	P	P	P	P	P	P	P	P	