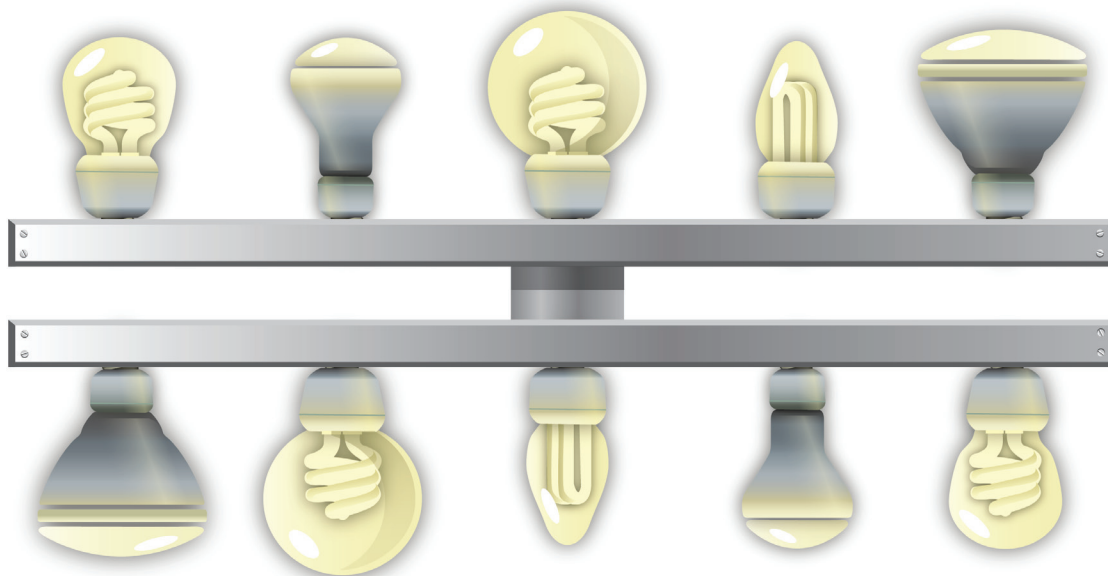


ENERGY STAR[®]

CFL THIRD PARTY TESTING AND VERIFICATION



Off-the-Shelf CFL Performance, Trends, and Implications



February 2012



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ENERGY STAR® CFL THIRD PARTY TESTING AND VERIFICATION

Off-the-Shelf CFL Performance, Trends, and Implications

February 2, 2012

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U.S. Environmental Protection Agency

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EXECUTIVE SUMMARY

As of August 1, 2011, the Independent ENERGY STAR CFL Third Party Testing and Verification Program had tested and verified the performance of 136 base models. These models represent 1,120 or roughly 22 percent of all ENERGY STAR qualified CFL models. Each model was procured “off the shelf” by an independent testing laboratory and subjected to the same ten tests that are required for initial qualification.

No major differences in performance were observed between test results reported in the first report and those that are the focus of this second report. The first report, published in May 2011, covered the 68 models that completed testing by February 5, 2011 (Batch 1), while the current report covers the 68 models that completed testing between February 5 and August 1, 2011 (Batch 2). On average, the models in Batch 2 came on the market nearly two years after those in Batch 1, and thus represent newer models.

Performance on individual tests was mixed. Every model in Batch 2 passed the Efficacy, Starting Time, and Color Rendering Index Tests. The proportion of models that passed each of the remaining seven tests ranged from 79 percent on the Rapid Cycle Stress Test to 97 percent on the Power Factor Test.

Specialty and covered lamps failed at a higher rate than bare spiral models. While 62 percent of the bare spiral models tested passed all initial tests, only 29 percent of bare specialty models and 21 percent of covered models passed all initial tests.

Of the 29 lamps in Batch 2 that failed one or more tests, 20 failed just one test, but nine failed two or more tests. Of these nine, one was bare spiral, two were bare specialty, and six were covered models. Further, 21 of the failed models significantly underperformed on at least one of the failed tests, meaning the model's measured performance was more than two standard deviations away from the mean value. Similar results were observed among Batch 1 models.

A minority of manufacturers with models in Batch 2 had all their tested models pass all ten tests. Among the six manufacturers that had five or more models tested, two had only one failure, three had about half of their tested models fail, and one had four of its five tested models fail. This variation among manufacturers is consistent with the findings of the Program for the Evaluation and Analysis of Residential Lighting (PEARL).

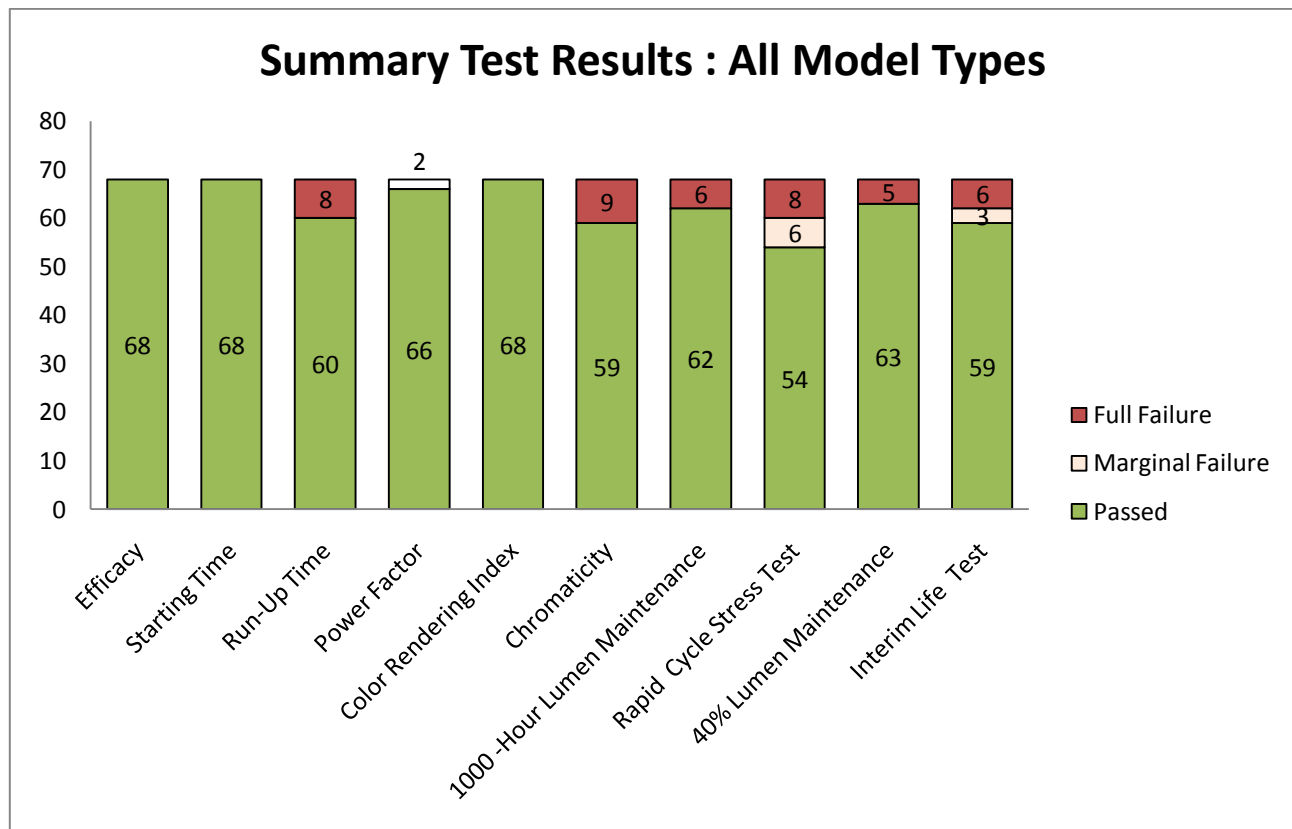
Use care when generalizing from the test results described in this report to the entire market of ENERGY STAR qualified CFLs. The sample of models tested is not representative of ENERGY STAR shipments nor is it perfectly representative of the current list of ENERGY STAR qualified models. Nevertheless, the test results are the best data available on the performance of ENERGY STAR qualified CFLs sold at retail.

SUMMARY RESULTS

This is a summary of the results of verification testing completed between April 2010 and August 2011 (Batch 2). Batch 2 contains a total of 68 ENERGY STAR qualified models: 42 bare spiral models, 7 bare specialty models, and 19 covered models.¹ The results of verification testing completed before April 2010 (Batch 1) are presented in the first report, which was first published in June 2011 and updated in July 2011.² Results from the two batches are compared in the final section of this report.

Every model included in Batch 2 passed the Efficacy, Starting Time, and Color Rendering Index Tests. Two models failed the Power Factor Test. Between five and nine models failed each of the remaining six tests. See Figure 1.

Figure 1



Note: A marginal failure is defined as a tested model with one less sample passing a test than required. For example, a model 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 re-test.

¹ Bare specialty lamps include those that are dimmable and 3-way; lamps in the "covered" category are also considered specialty lamps and include all lamps that are covered.

² D&R International, "ENERGY STAR CFL Third Party Testing and Verification Cycle 1: Results," May 2011. (www.energystar.gov/ia/partners/downloads/Cycle_1_Final_Report_Public_7-18-11.pdf)

There was some variation in the results among different lamp types. The Rapid Cycle Stress Test proved the most challenging test for bare spiral models (14% failed) and was similarly challenging for covered models (11% failed). A large proportion of bare specialty models failed the Chromaticity Test (43% failed) and the Interim Life Test (29% failed). Nearly a third of covered models failed the Run-Up Time, Chromaticity, and 1,000-Hour Lumen Maintenance Tests (32% failed each). See Figure 2, 3, and 4 and Table 1.

Figure 2

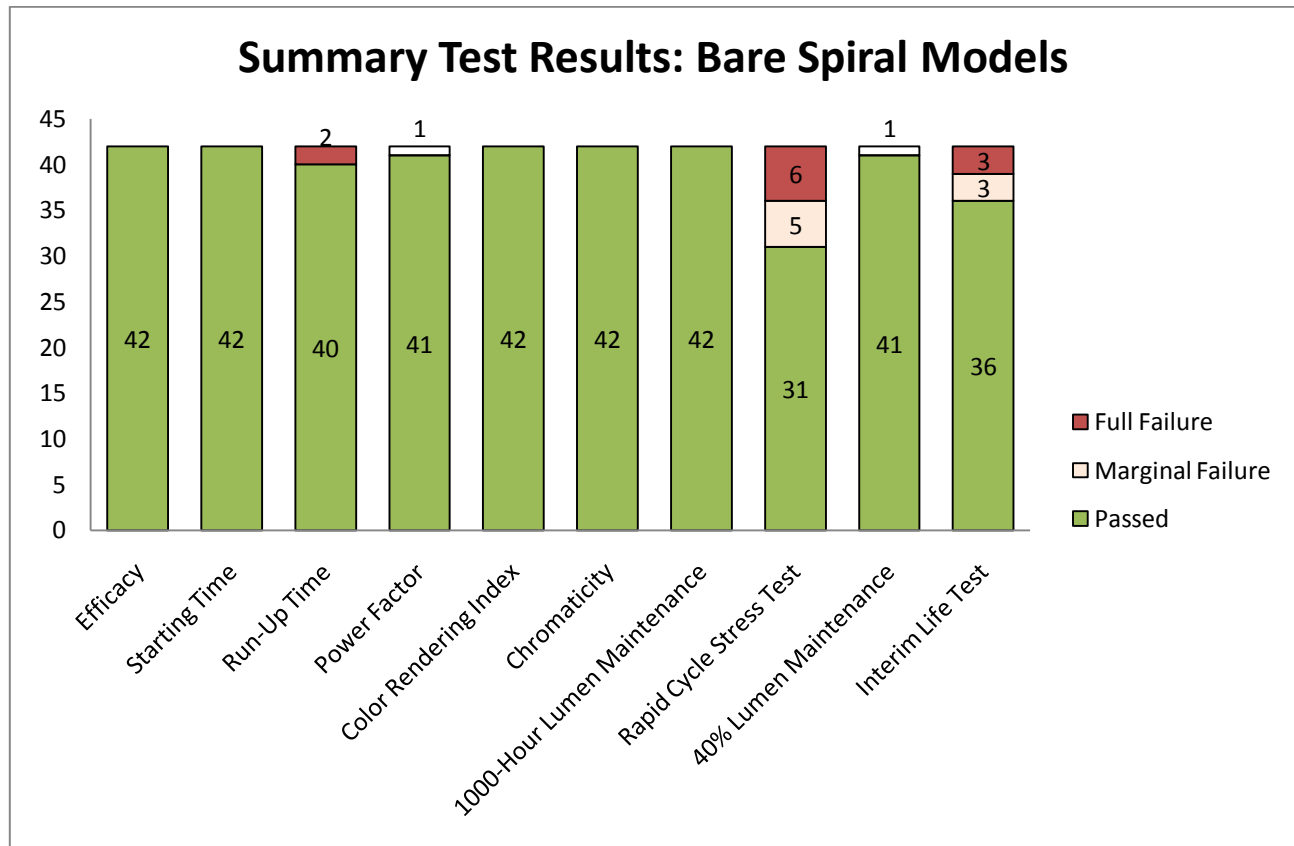


Figure 3

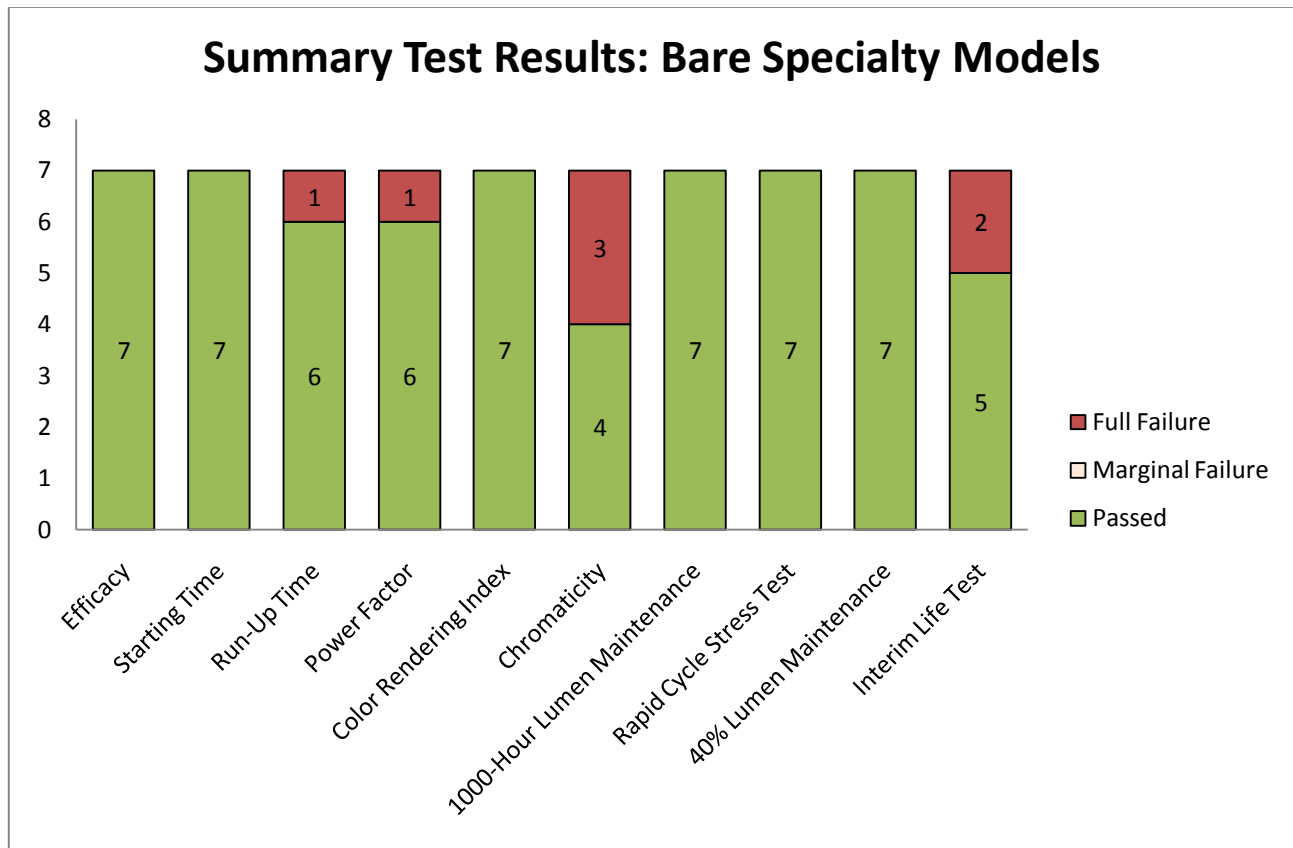


Figure 4

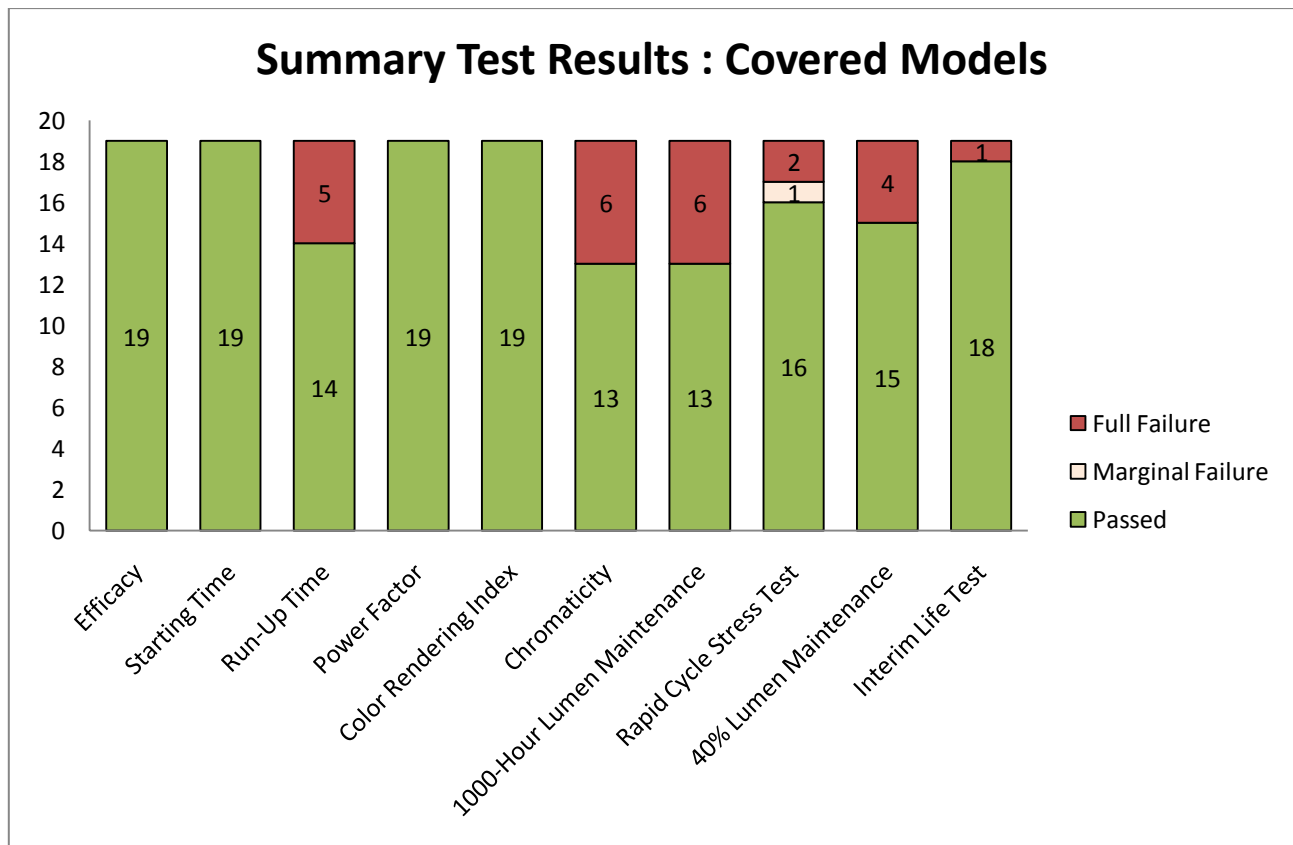


Table 1. Mean, Median, and Percent Passing and Failing Each Test by Lamp Type

Test	Model Type	Mean	Median	Passing Criteria	Percent Passed	% Failed (% Marginally Failed)
Efficacy	All Types	64.7	67.2	Varies by model type	100%	0%
	Bare Spiral	69	70.2		100%	0%
	Bare Specialty	69.2	69.8		100%	0%
	Covered	52.9	54.2		100%	0%
Starting Time	All Types	251	170	< 1000 milliseconds	100%	0%
	Bare Spiral	179	143		100%	0%
	Bare Specialty	540	504		100%	0%
	Covered	316	188		100%	0%
Run-Up Time	All Types	68	45	< 60 or <180 seconds	87%	13%
	Bare Spiral	44	34		93%	7%
	Bare Specialty	64	57		100%	0%
	Covered	126	114		68%	32%
Power Factor	All Types	0.553	0.547	> 0.5	97%	3%
	Bare Spiral	0.553	0.547		98%	2%
	Bare Specialty	0.583	0.558		86%	14%
	Covered	0.541	0.545		100%	0%
Color Rendering Index	All Types	82.8	82.9	> 80	100%	0%
	Bare Spiral	82.8	82.6		100%	0%
	Bare Specialty	82.5	83.1		100%	0%
	Covered	82.8	83		100%	0%
Chromaticity	All Types	9.3	10	9/10 coordinates inside ellipse	87%	13%
	Bare Spiral	9.9	10		98%	2%
	Bare Specialty	7.9	10		57%	43%
	Covered	8.6	10		68%	32%
1,000-Hour Lumen Maintenance	All Types	93%	94%	>90%	91%	9%
	Bare Spiral	94%	94%		100%	0%
	Bare Specialty	94%	94%		100%	0%
	Covered	89%	90%		68%	32%
Rapid Cycle Stress Test	All Types	5.3	6	5/6 survive to half of rated life	79%	12% (9%)
	Bare Spiral	5.1	6		74%	14% (12%)
	Bare Specialty	5.9	6		100%	0%
	Covered	5.4	6		84%	11% (5%)
40% Lumen Maintenance	All Types	85%	85%	>80%	93%	7%
	Bare Spiral	85%	85%		98%	2%
	Bare Specialty	90%	91%		100%	0%
	Covered	81%	81%		79%	21%
Interim Life Test	All Types	9.3	10	9/10 survive to 40% of rated life	87%	9% (4%)
	Bare Spiral	9.3	10		86%	7% (7%)
	Bare Specialty	8.6	10		71%	29%
	Covered	9.7	10		95%	5%

There were 47 instances of full failure across all 68 models and 10 tests. Of these 47 failures, 29 significantly underperformed as defined below. All of the models that failed the Rapid Cycle Stress Test or the Interim Life Test significantly underperformed on the test they failed. Six of the ten models that failed the Chromaticity Test significantly underperformed on that test. On the other hand, only three of the ten models that failed the Run-Up Time Test significantly underperformed. See Table 2 below.

Table 2. Summary of Test Failures for All Models Tested

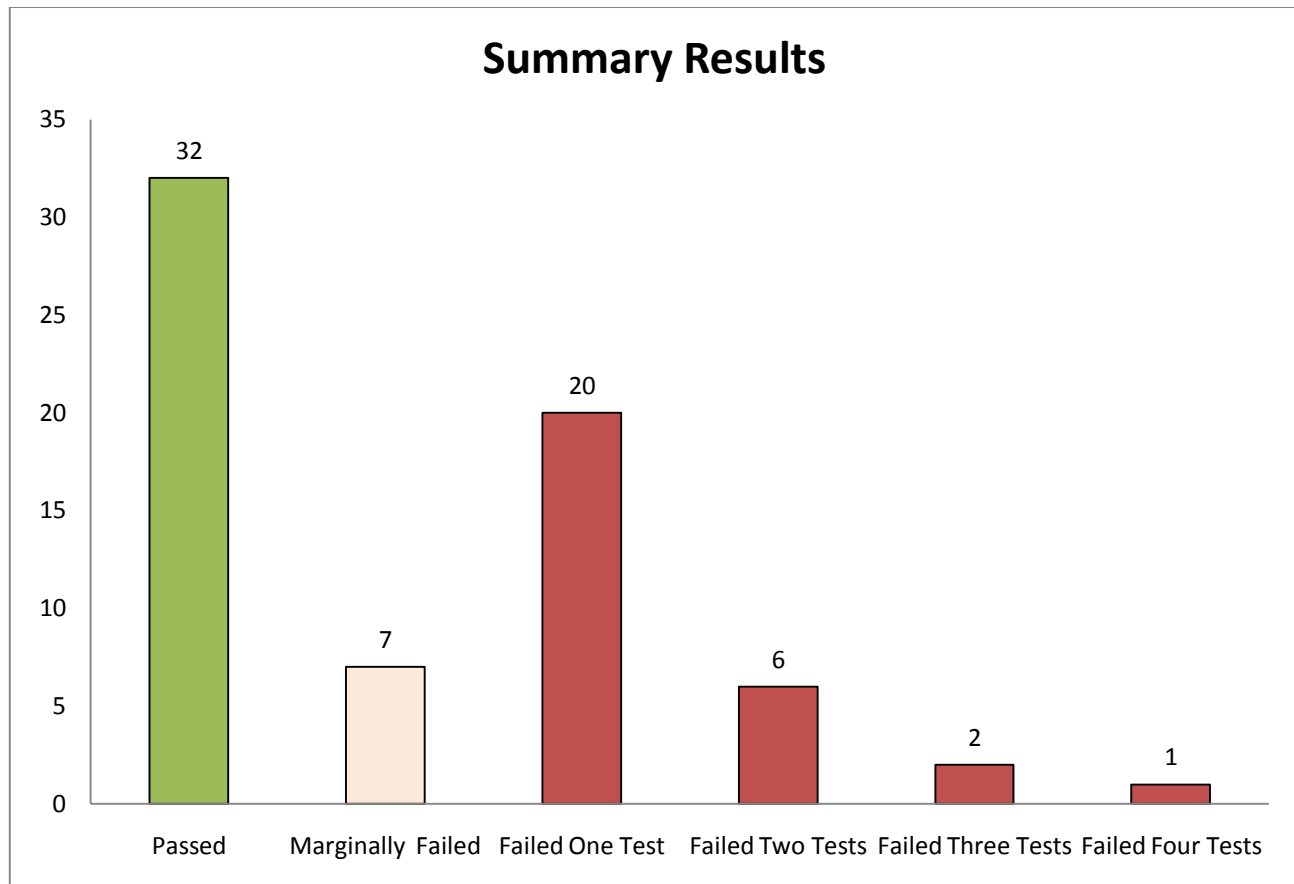
	All Models	Full Failures		Significantly Underperforming Failures*		
	Mean	Failure Criteria	No. of Failures	Criteria	No. of Failures	% of Full Failures
Efficacy	64.7	Varies	0	Varies	0	0%
Starting Time	251	> 1000 ms	0	> 732 ms	0	0%
Run Up Time	52/83	> 60/180 seconds	10	> 112 / > 205 seconds	3	30%
Power Factor	0.553	< 0.50	2	< 0.453	0	0%
Color Rendering Index	82.8	≤ 80.0	0	< 77.9	0	0%
Chromaticity	9.3	≤ 7 samples	10	≤ 6 samples	6	60%
1,000 Hour Lumen Maintenance	93%	≤ 90%	6	< 86%	3	50%
Rapid Cycle Stress Test	5.3	≤ 4 samples	8	≤ 3 samples	8	100%
40% Lumen Maintenance	85%	< 80%	5	< 86%	3	60%
Interim Life Test	9.3	≤ 7 samples	6	≤ 6 samples	6	100%
All Tests	n/a	n/a	47	n/a	29	62%

* Significant underperformance is defined here as having results more than two standard deviations away from the mean. Note that on the Starting Time Test, the distribution of performance was such that two standard deviations greater than the mean was still within the passing range and thus a significantly underperforming failure on this test would have been impossible.

Of the 68 models tested, 32 passed all tests performed, 29 fully failed at least one test, and the remaining 7 marginally failed one or two tests but had no full failures. See Figure 5.

Models that marginally failed a test were subsequently retested. The results of those retests are not presented here because they were not available at the time this report was prepared.

Figure 5



Overall, only 47 percent of models tested passed all initial tests. Failure rates were much higher among bare specialty and covered models than among bare spiral models. While 62 percent of the bare spiral models tested passed all initial tests, only 29 percent of bare specialty models and 21 percent of covered models passed all initial tests.

Of the 29 models that fully failed at least one test, 21 significantly underperformed on at least one test, meaning that their measured value was more than two standard deviations away from the mean measured across all 68 models for that test. Bare specialty and covered models were more likely than bare spiral models to be significant underperformers. See Table 3.

Table 3. Failures for All Models Tested

	All Lamp Types		Bare Spiral		Bare Specialty		Covered	
Results	#	%	#	%	#	%	#	%
Passed All Initial Tests	32	47%	26	62%	2	29%	4	21%
Marginally Failed	7	10%	7	17%	0	0%	0	0%
Failed at Least 1 Test	29	44%	9	21%	5	71%	15	79%
Failed 1 Test	20	31%	8	19%	3	43%	9	47%
Failed 2 Tests	6	7%	0	0%	2	29%	4	21%
Failed 3 Tests	2	1%	1	2%	0	0%	1	5%
Failed 4 Tests	1	1%	0	0%	0	0%	1	5%
Significantly Underperformed on One or More Tests*	21	31%	8	19%	3	43%	10	53%
Total Models Tested	68	100%	42	100%	7	100%	19	100%

* Significant underperformance is defined here as having results more than two standard deviations away from the mean.

Though less than half of models passed all initial tests, more than 79 percent of models passed each individual test. This is because different models failed different tests; some failed the first test, some failed the second test, and so on.

Table 4 lists those Original Equipment Manufacturer (OEM) partners that have CFL models included in Batch 2. Their names have been omitted due to the confidential nature of this information.

Table 4. OEM Partners with Models in Batch 2

OEM Partner Name	No. of Tested Models	No. of Models Failed	Failure Rate of Tested Models (%)
<25 Qualified Models			
A	1	0	0%
B	1	0	0%
C	2	1	50%
D	2	2	100%
E	1	0	0%
F	1	1	100%
G	2	0	0%
25 – 75 Qualified Models			
H	1	0	0%
I	2	0	0%
J	1	0	0%
K	2	0	0%
L	2	2	100%
M	6	3	50%
N	1	1	100%
O	9	5	56%
>75 Qualified Models			
P	5	1	20%
Q	10	5	50%
R	1	0	0%
S	1	1	100%
T	12	1	8%
U	5	4	80%

METHODOLOGY

PRODUCT SELECTION

Models were selected for testing in accordance with version 4.2 of the ENERGY STAR CFL Program Requirements, published on March 7, 2008 and effective December 2, 2008.³ These requirements specify that the program shall "target to test 20 percent of the total number of current [distinct ENERGY STAR] qualified models 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)."

Product selection for Cycle 2 was conducted in December 2009; 100 models were selected. The current (Batch 2) report presents results for the 68 models selected in Cycle 2 that completed testing by August 1, 2011. See Table 5 for the breakdown of randomly selected vs. nominated models for each model type.

Table 5. Models Included in this Report (Batch 2)

Model Type	Nominated Models	Randomly Selected Models	Total
Bare Spiral	11	31	42
Bare Specialty	4	3	7
Covered	5	14	19
All Types	20	48	68

Many models are privately labeled and sold under multiple brand names. The 68 base models in Batch 2 represent 445 qualified models, 13.4 percent of the qualified models list.

PRODUCT PROCUREMENT

For each CFL model number selected, the lab purchased 18 samples.⁴

- 6 samples for the Rapid Cycle Stress Test (RCST)
- 10 samples for the other nine tests
- 2 samples as backups in case of breakage

³ The ENERGY STAR CFL Program Requirements can be downloaded from the ENERGY STAR website: www.energystar.gov/ia/partners/product_specs/program_reqs/Compact_Fluorescent_Lamps_Program_Requirements.pdf

⁴ Larger sample size options became available in later testing cycles.

The laboratory sought to purchase each model from four states and three different retail locations as required by the CFL 4.2 Criteria, but in some cases, a model could be procured from only two locations. Procurement for Cycle 2 began in February 2010.

PRODUCT TESTING

The tests performed on each model are listed in Table 6. Six samples of each model were used for the Rapid Cycle Stress Test and ten samples of each model were used for all other tests. For full details on model testing requirements, see the CFL 4.2 Criteria.

The laboratory began testing Batch 2 models in March 2010. At the conclusion of each test, the laboratory sent the completed test report to the ENERGY STAR Partner and to D&R International.

Table 6. Tests Required for ENERGY STAR Qualification and Verification

	Bare, Covered, or Outdoor Reflector Models	Reflector CFLs for Recessed Downlights/ Indoor Use (Reflectors)⁵	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
7	1,000-Hour Lumen Maintenance	<i>Elevated Temperature</i> 1,000-Hour Lumen Maintenance	Photometric	> 90%
8	Rapid Cycle Stress Test (RCST)	Rapid Cycle Stress Test (RCST)	Lifetime Performance	5/6 samples
9	Lumen Maintenance at 40% of Rated Life	<i>Elevated Temperature</i> Lumen Maintenance at 40% of Rated Life	Lifetime Performance	> 80%
10	Interim Life Test	<i>Elevated Temperature</i> Interim Life Test	Lifetime Performance	9/10 samples

⁵ Results from the Initial Elevated Temperature Light Output Ratio Test (indoor reflectors only) are not presented in this report, but they serve as a baseline for the two Elevated Temperature Lumen Maintenance Tests for these products (measurements at 1,000 hours and at 40% of rated life).

DETAILED RESULTS

This section of the report presents detailed results of ENERGY STAR CFL verification testing completed between April 2010 and August 2011. The results of verification testing completed before December 2010 (Batch 1) are presented in the first report, which was first published in June 2011 and updated in July 2011.⁶ Results from the two batches are compared in the final section of this report.

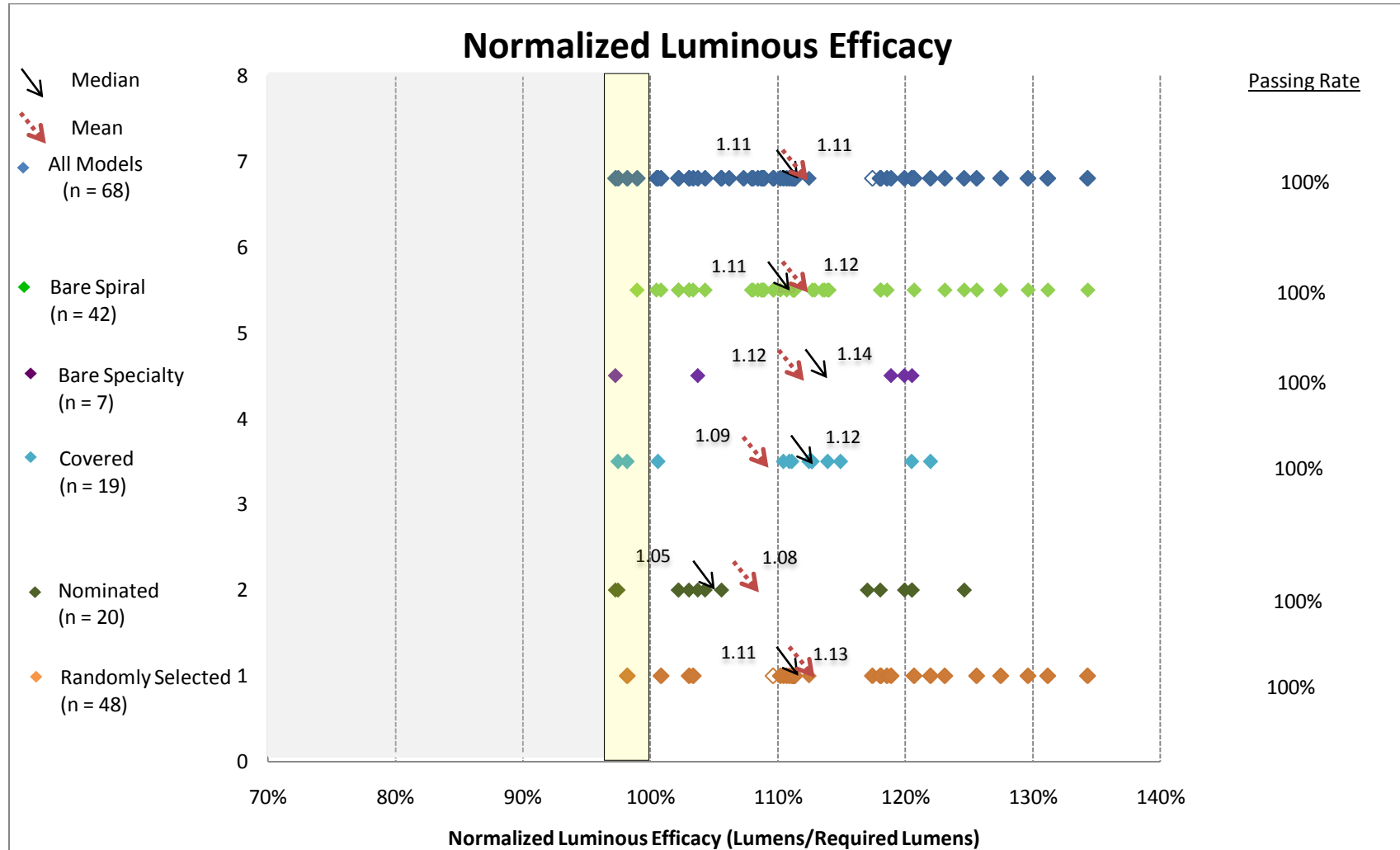
For each of the 10 tests, results are shown for all lamp types, for each of the three lamp types—bare spiral, bare specialty, and covered—separately, and for nominated and randomly selected models separately.

⁶ D&R International, "ENERGY STAR CFL Third Party Testing and Verification Cycle 1: Results," May 2011. (www.energystar.gov/ia/partners/downloads/Cycle_1_Final_Report_Public_7-18-11.pdf)

LUMINOUS EFFICACY

Efficacy is light output divided by power and is measured in lumens per watt. Models with a measured efficacy greater than or equal to the ENERGY STAR efficacy requirement for that model type (with a tolerance of 3 percent) pass the test. Normalized results are presented for this test because normalizing the data points by dividing the measured efficacy by the required efficacy shows how far each model is from its required result. The gray shaded region of Figure 6 indicates a test failure, and the cream colored region indicates the 3% tolerance. All models passed this test.

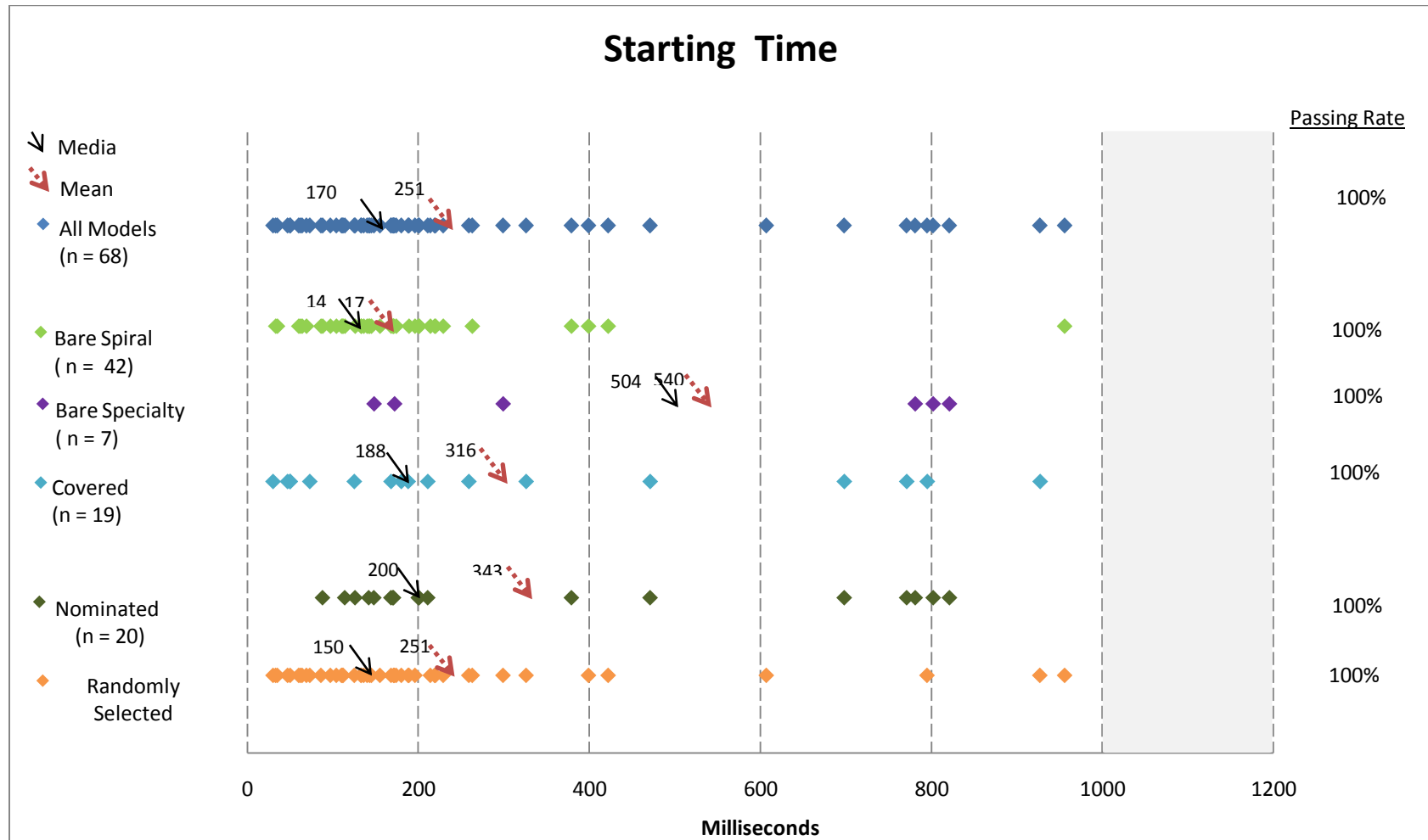
Figure 6



STARTING TIME

Starting time is the time needed after switching the CFL on for it to start fully and remain lighted. Models with start-up time measurements of < 1,000 milliseconds pass the test. The gray shaded region of Figure 7 indicates a test failure. All models passed this test.

Figure 7



RUN-UP TIME

Run-up time is the time it takes the CFL to reach full brightness. Amalgam mercury models with run-up times less than 180 seconds and non-amalgam mercury models with run-up times less than 60 seconds pass the test. The gray shaded regions of Figures 8 and 9 indicate a test failure. Among the amalgam models, only covered models failed this test. Among the non-amalgam models, all three covered models, one of the four bare specialty models, and three of the 21 bare spiral models failed this test.

Figure 8

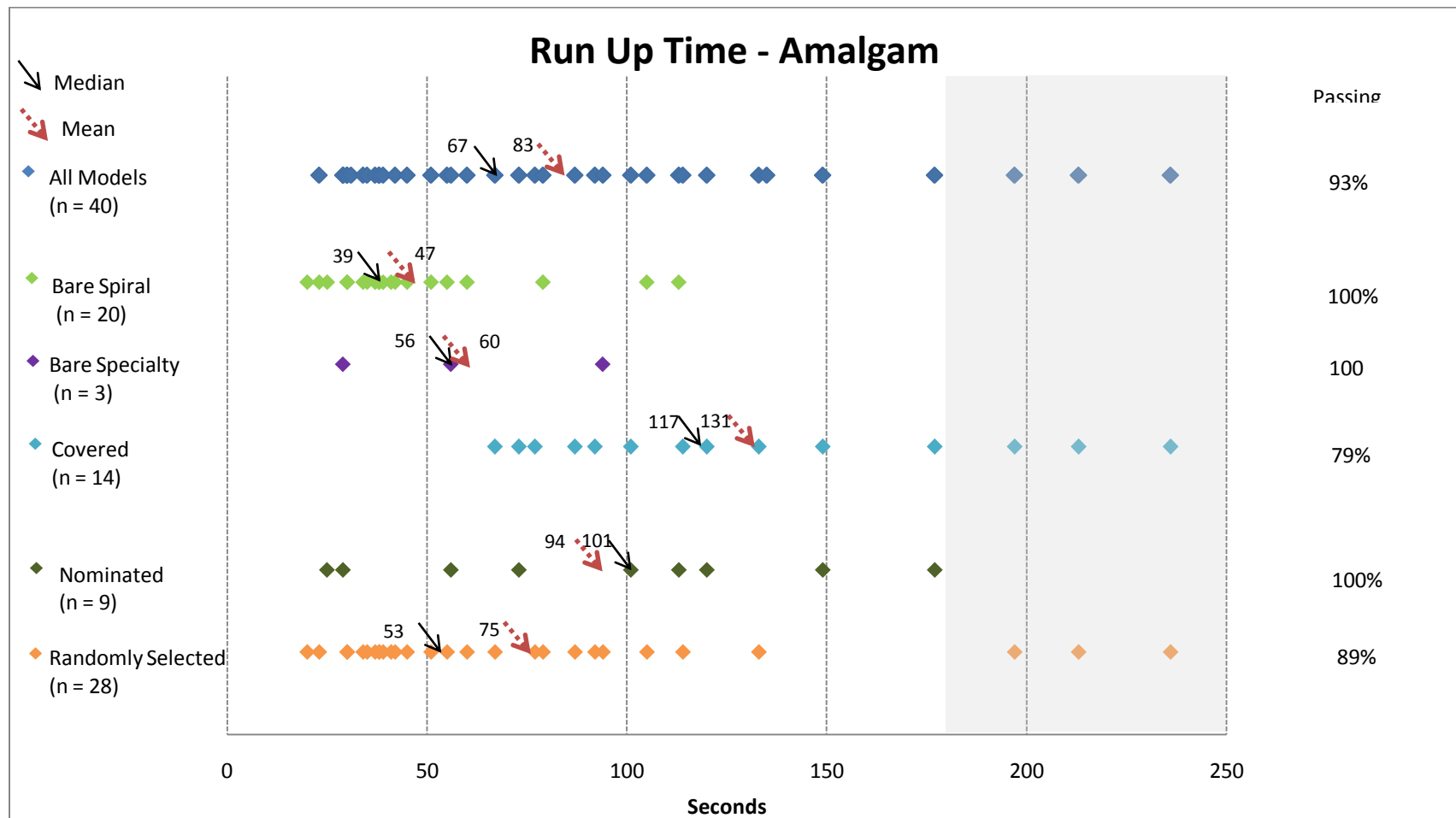
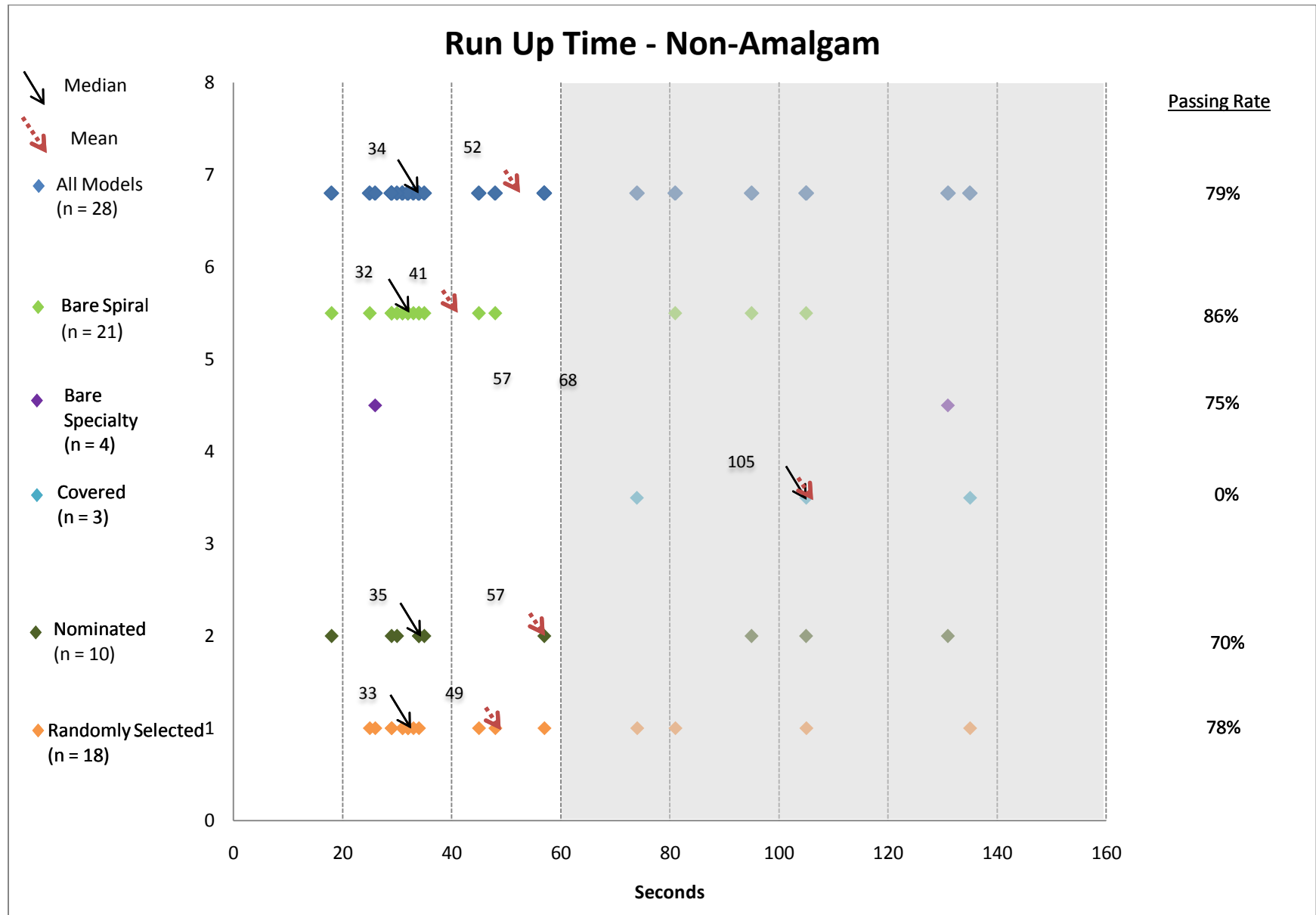


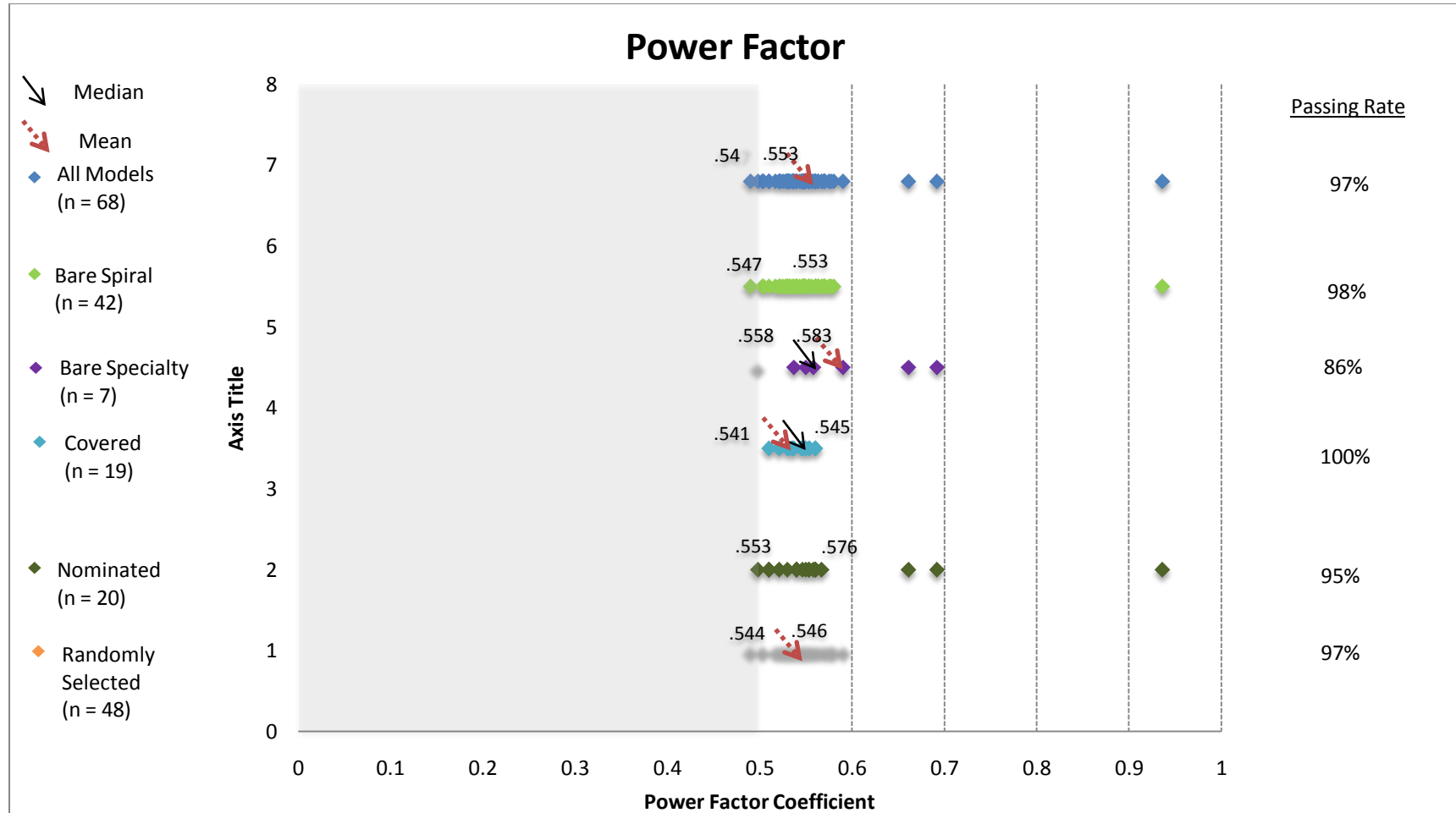
Figure 9



POWER FACTOR

Power factor is the active power of the CFL divided by the apparent power. Models with a power factor > 0.5 pass the test. The gray shaded region of Figure 10 indicates a test failure.

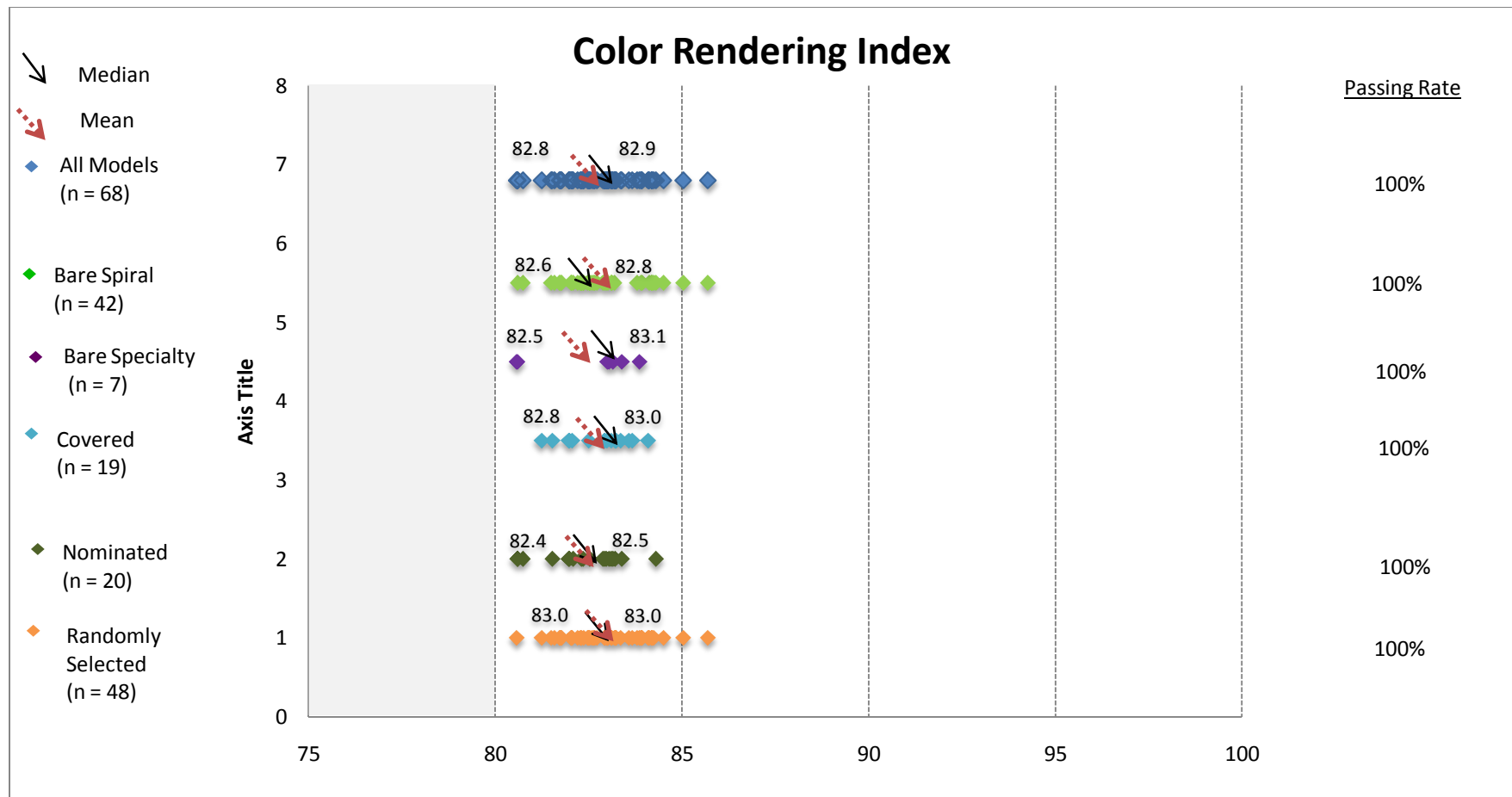
Figure 10



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, which is the effect the CFL has 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 < 77 pass the test. The gray shaded region in Figure 11 indicates a test failure. All models passed this test.

Figure 11



CHROMATICITY

Chromaticity (Correlated Color Temperature) is a measure of the color appearance of a CFL, measured in Kelvin. Chromaticity is scored based on the American National Standards Institute (ANSI) ellipse for the manufacturer's specified color temperature. Models with nine or ten samples falling within the ANSI ellipse pass the test. Models with exactly eight samples falling within the ANSI ellipse score as marginal failures and are indicated by the light gray shaded regions in Figure 12 and Figure 13. The gray shaded region in Figure 12 indicates a test failure.

While 98% of bare spiral models passed this test, only 57% of bare specialty and 68% of covered models passed this test. There were no marginal failures.

Figure 12

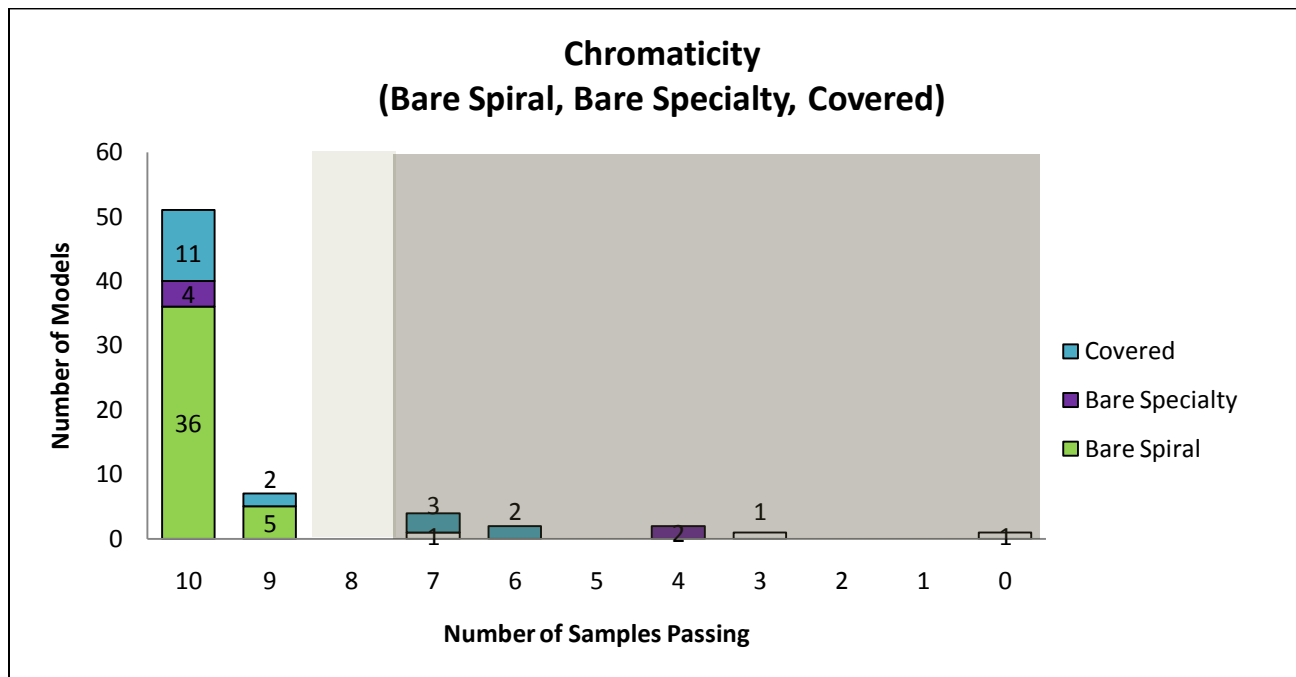


Figure 13

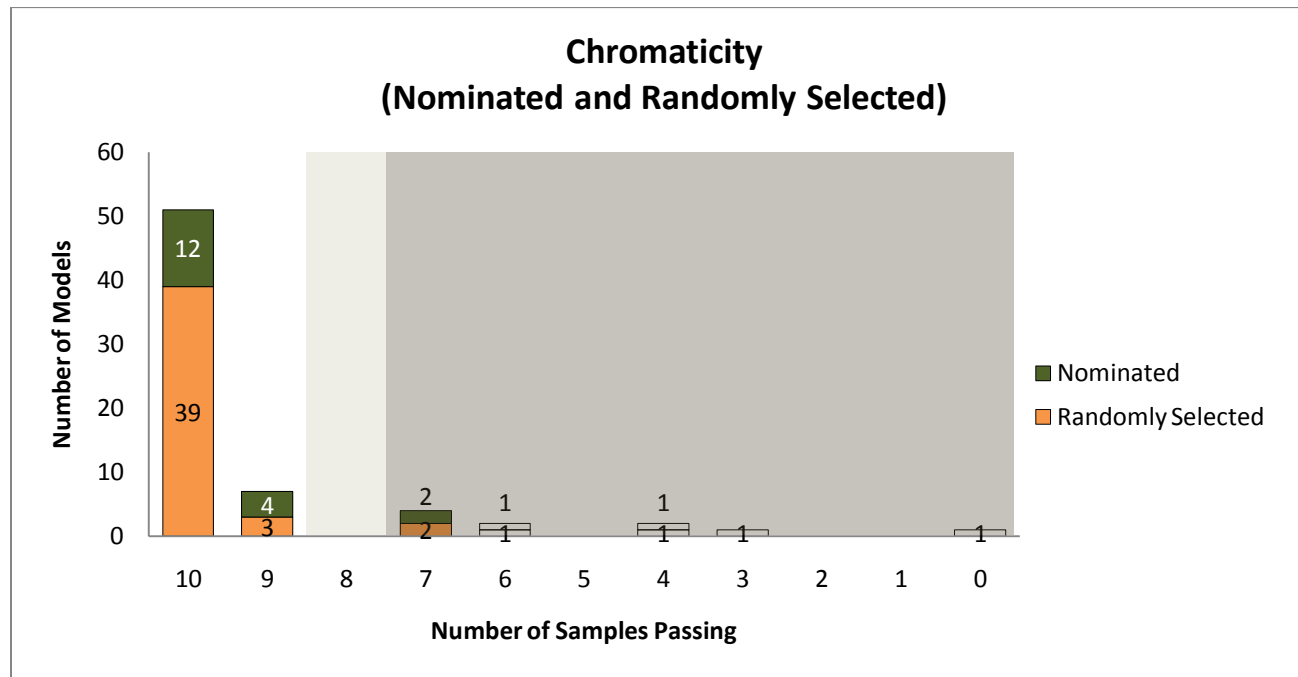


Table 7. Chromaticity Results

	Number of Models Tested	Percent of Models			Number of Samples Passed Initial Test	
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean	Median
All Models	68	85%	0%	15%	9.3	10
Bare Spiral	42	98%	0%	2%	9.9	10
Bare Specialty	7	57%	0%	43%	7.9	10
Covered	19	68%	0%	32%	8.6	10
Nominated	20	80%	0%	20%	8.9	10
Randomly Selected	48	88%	0%	12%	9.2	10

1,000-HOUR LUMEN MAINTENANCE

The 1,000-Hour Lumen Maintenance Test is an initial measurement of how well a model maintains its light output level over time. Model that have a light output at 1,000 hours that is greater than 90 percent of the 100-hour measurement (with a tolerance of 3 percent) and that have no more than 3 individual samples with lumen output less than 85 percent pass the test. The gray shaded regions of Figures 14, 15, and 16 indicate test failure, and the cream shaded regions indicate the 3% tolerance.

All bare spiral and bare specialty models passed this test in full or with a 3% tolerance. Of the 19 covered models, 13 (68%) passed; the remaining six failed this test.

Histograms were included for this test to better illustrate the densely clustered data points for passing models.

Figure 14

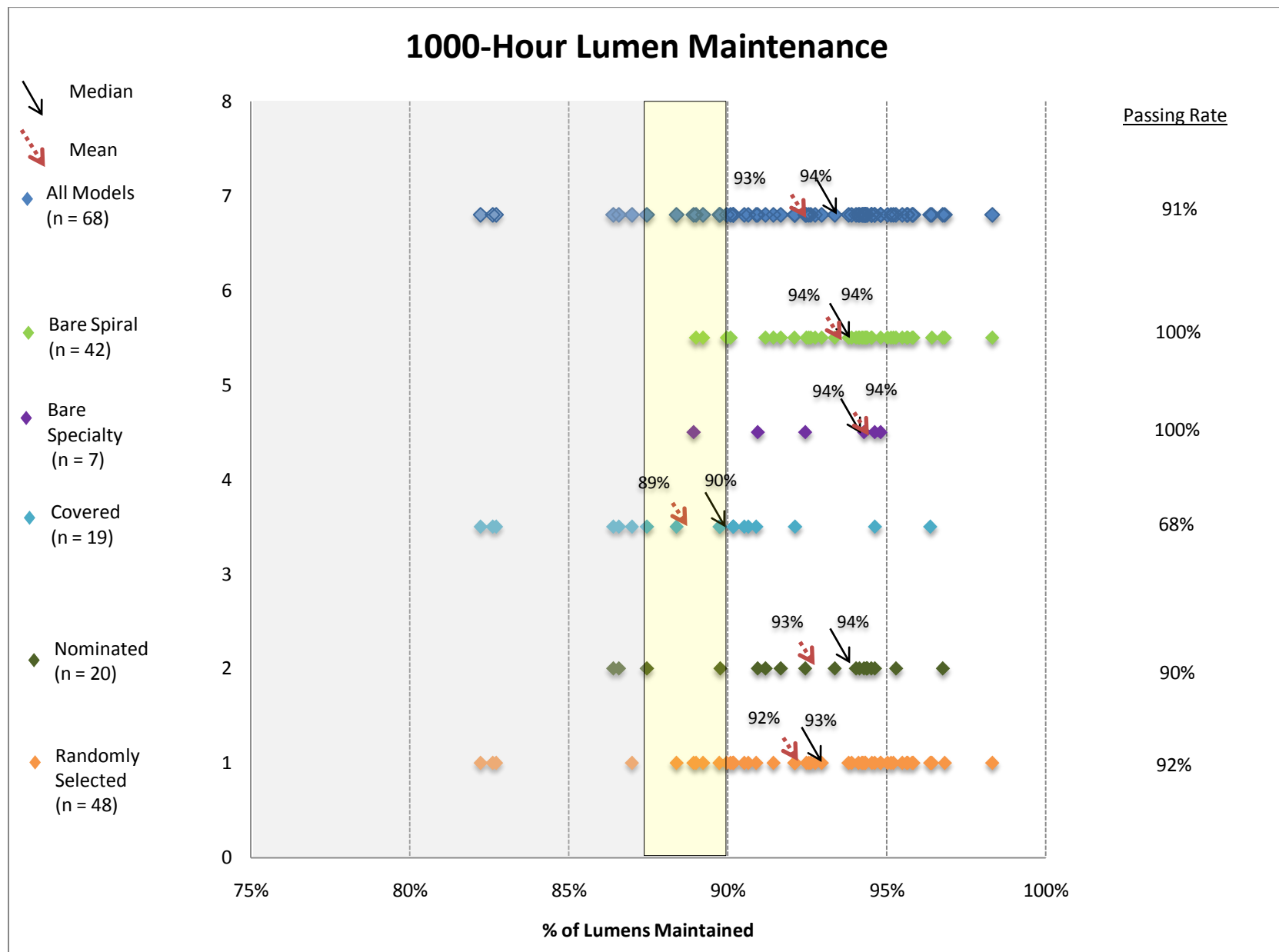


Figure 15

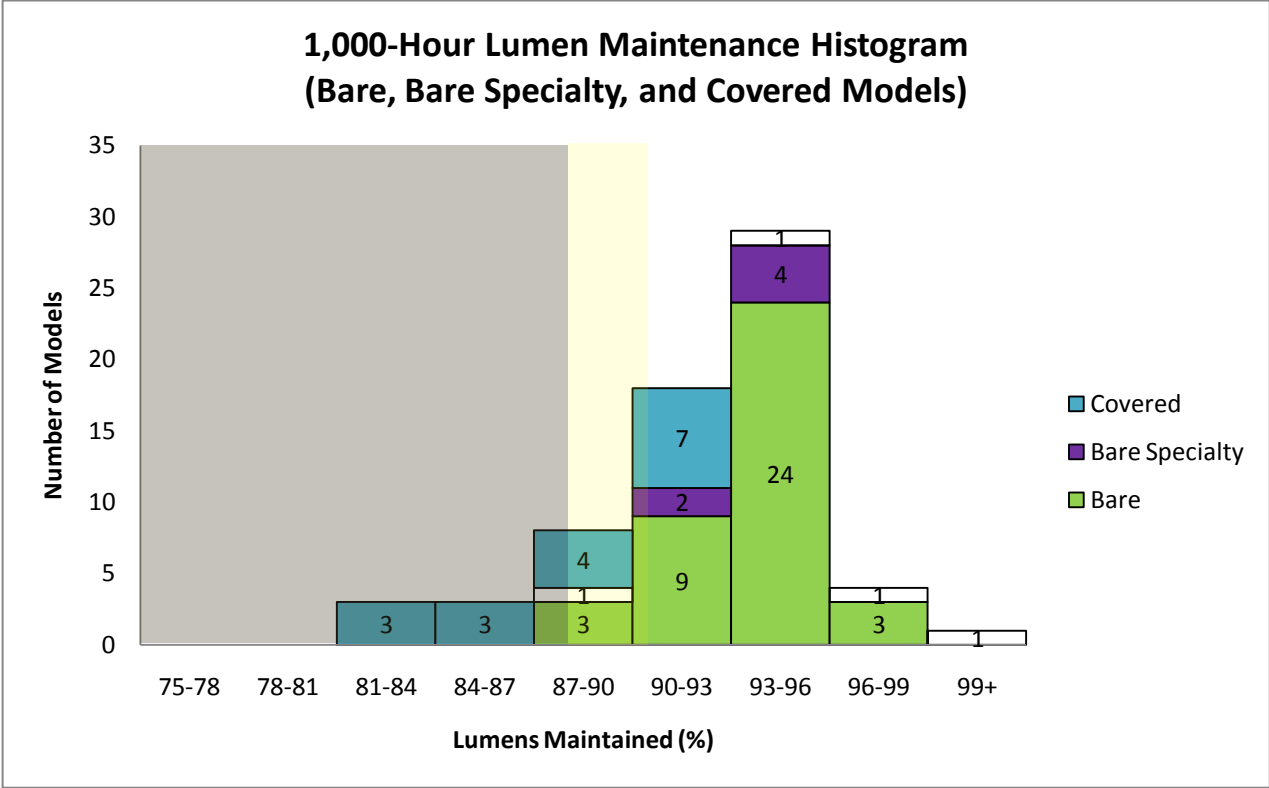
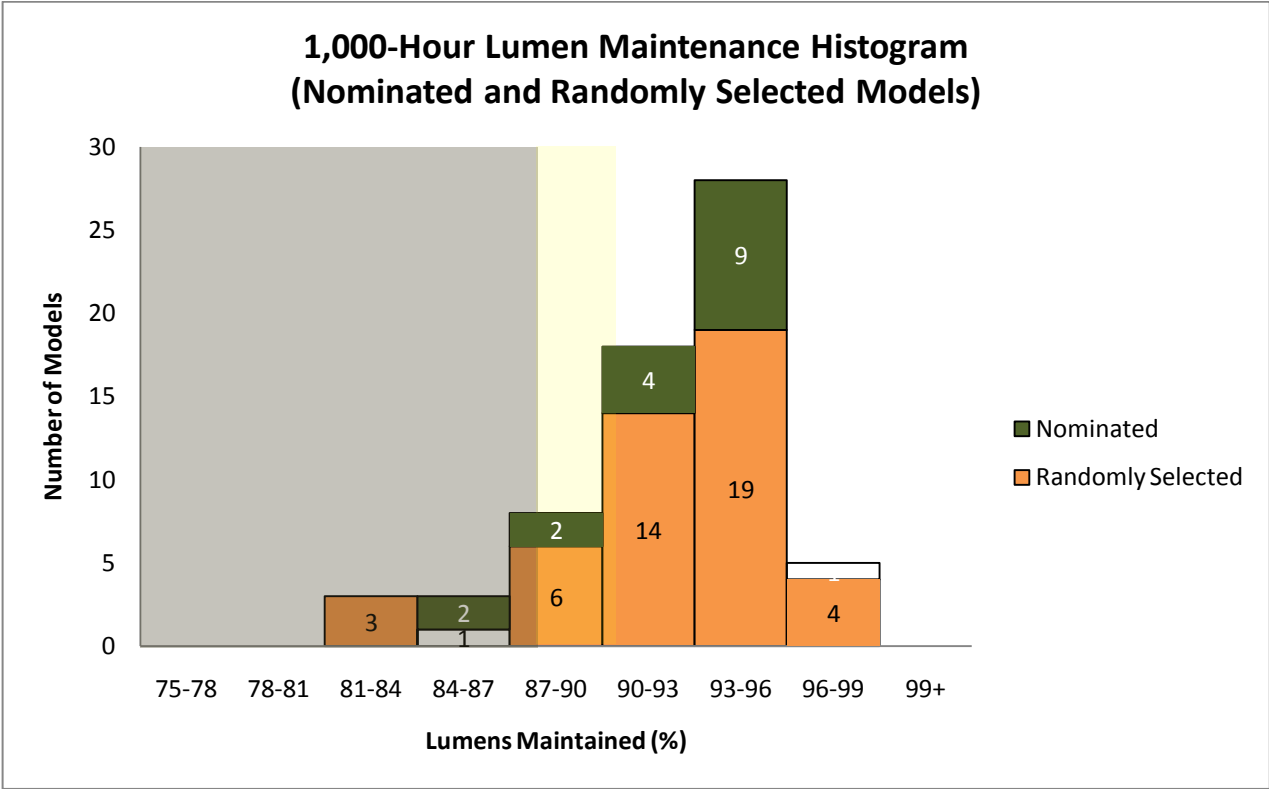


Figure 16



RAPID CYCLE STRESS TEST

The Rapid Cycle Stress Test (RCST) tests how many on/off cycles a model can endure without failing. Models that have five or six samples endure the test for a number of cycles equivalent to half the model's rated life pass the test. If exactly four samples survive, the model scores as a marginal failure. The grey shaded region of Figure 17 indicates a test failure, and the cream shaded region indicates a marginal failure.

All bare specialty models, 84% of covered models, and 74% of bare spiral models passed this test. There were six marginal failures: five bare spiral models and one covered model.

Figure 17

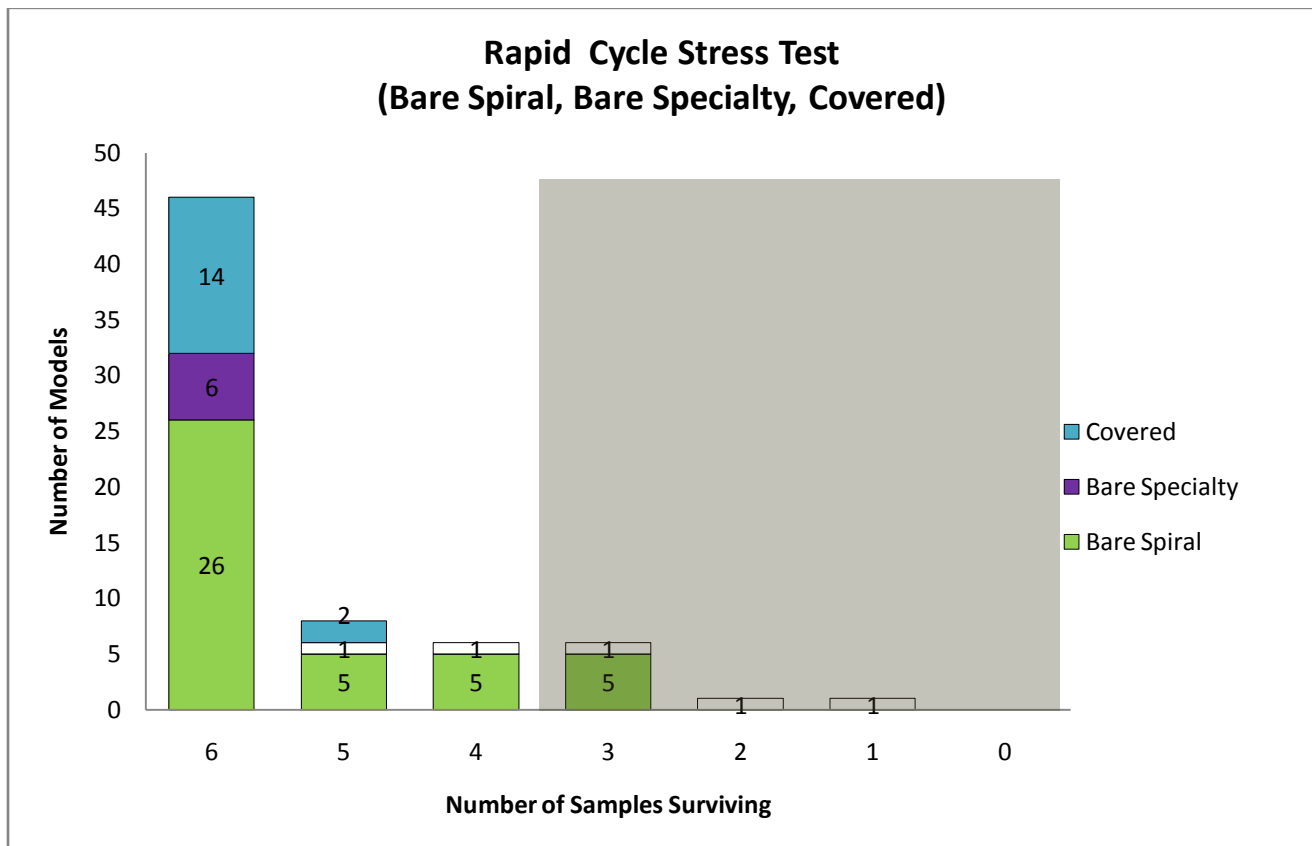


Figure 18

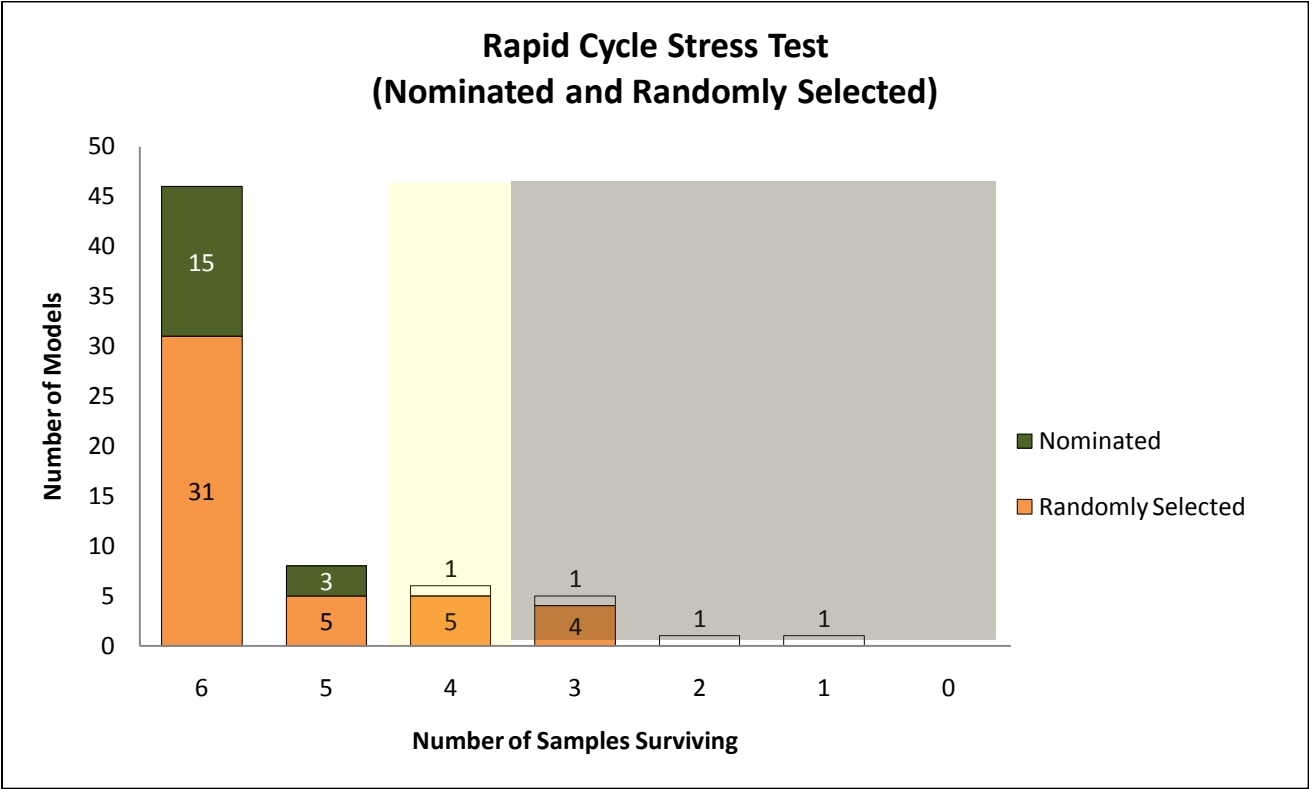


Table 8. Rapid Cycle Stress Test Results

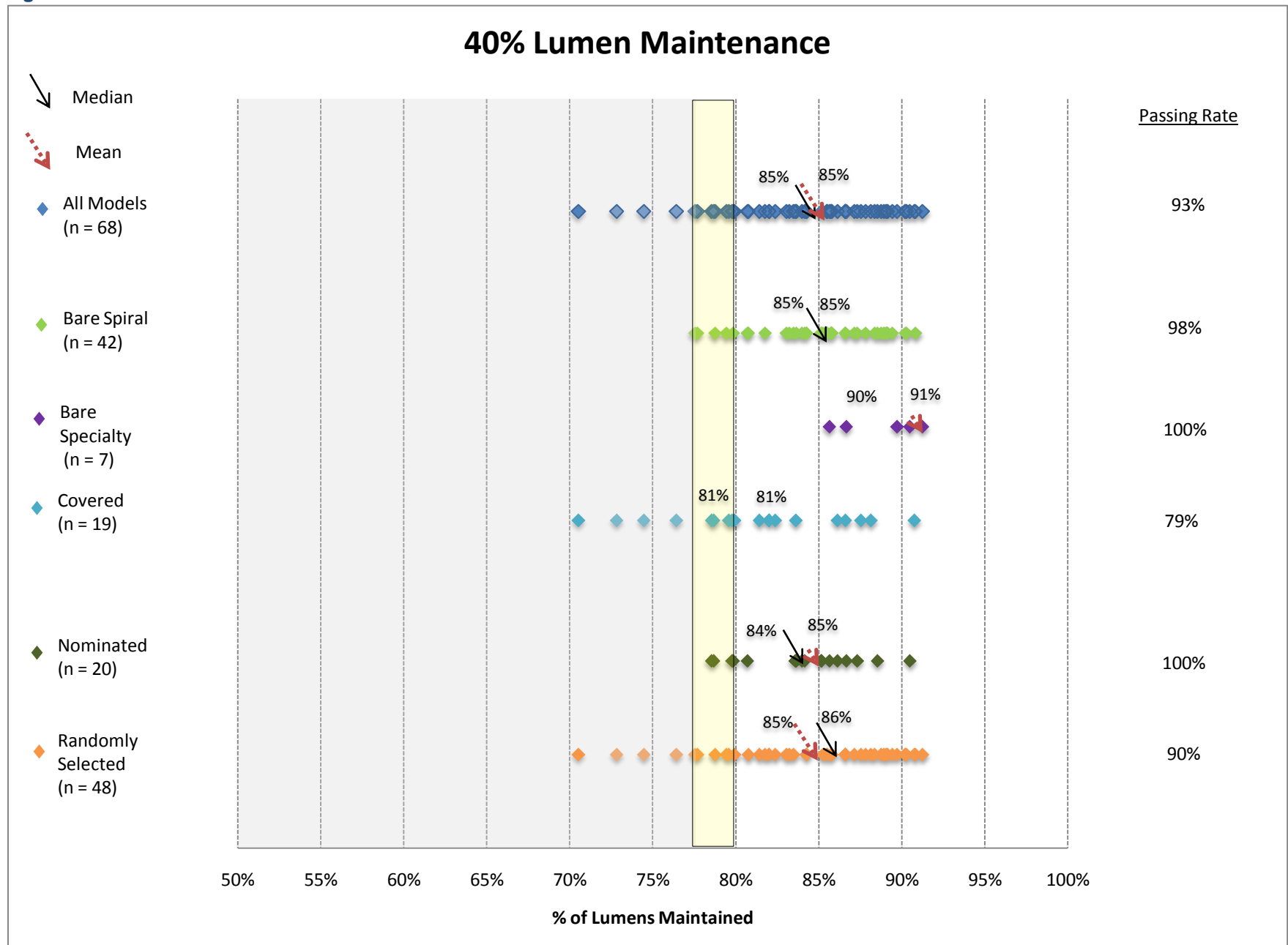
	Number of Models Tested	Percent of Models			Number of Samples Passed Initial Test	
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean	Median
All Models	68	79%	9%	12%	5.3	6
Bare Spiral	42	74%	12%	14%	5.1	6
Bare Specialty	7	100%	0%	0%	5.9	6
Covered	19	84%	5%	11%	5.4	6
Nominated	20	90%	5%	5%	5.6	6
Randomly Selected	48	77%	8%	15%	5.2	6

LUMEN MAINTENANCE AT 40 PERCENT OF RATED LIFE

The 40% of Rated Life Lumen Maintenance Test is a secondary measurement of how well a model maintains its light output level over time. Models with light output at 40 percent of their rated life greater than 80 percent of their light output at 100 hours (with a tolerance of 3 percent) and with no more than 3 samples with light output less than 75 percent of light output at 100 hours pass the test. The grey shaded regions of Figures 19 through 21 indicate test failure, and the cream shaded region indicates the 3 percent tolerance.

One bare spiral and four covered models failed this test, while all bare specialty models passed. All five of the models that failed this test were among those randomly selected for testing.

Figure 19



Histograms were included for this test to better illustrate the densely clustered data points for passing models.

Figure 20

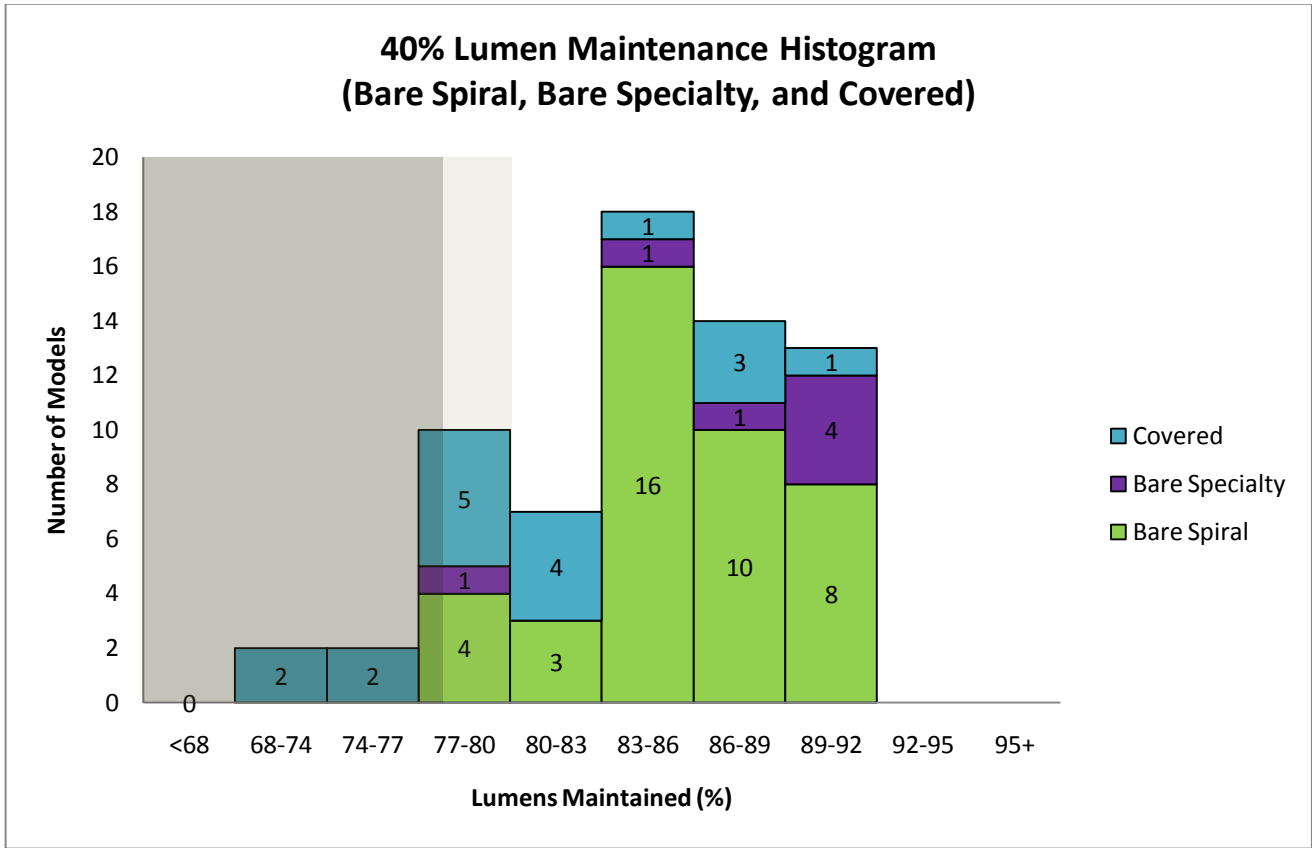
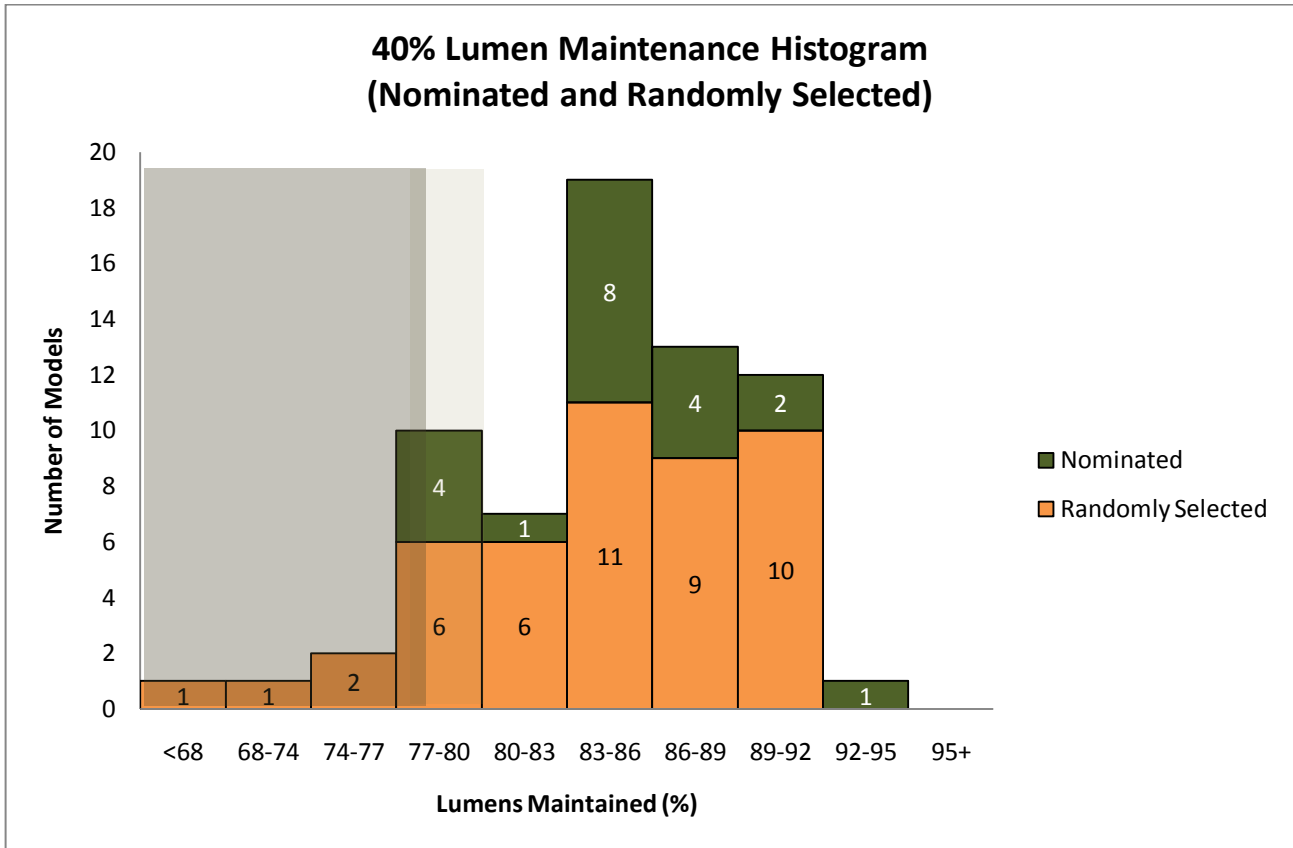


Figure 21



INTERIM LIFE TEST

The Interim Life Test measures how many of the 10 samples are still lit at 40 percent of the CFL’s rated life. Models with nine or ten samples still lit at 40 percent of rated life pass the test. If exactly eight samples stay lit, then the model scores as a marginal failure. The dark gray shaded regions of Figures 22 and 23 indicate a full test failure, and the light gray shaded regions indicate a marginal failure.

Of the ten tests, the Interim Life Test had the second lowest passing rate with only 87 percent of models passing. Bare specialty models were the worst performers with only 71 percent of models passing (five of seven passed; the other two were full failures). Bare spiral and covered models had passing rates of 86 percent and 95 percent, respectively.

Figure 22

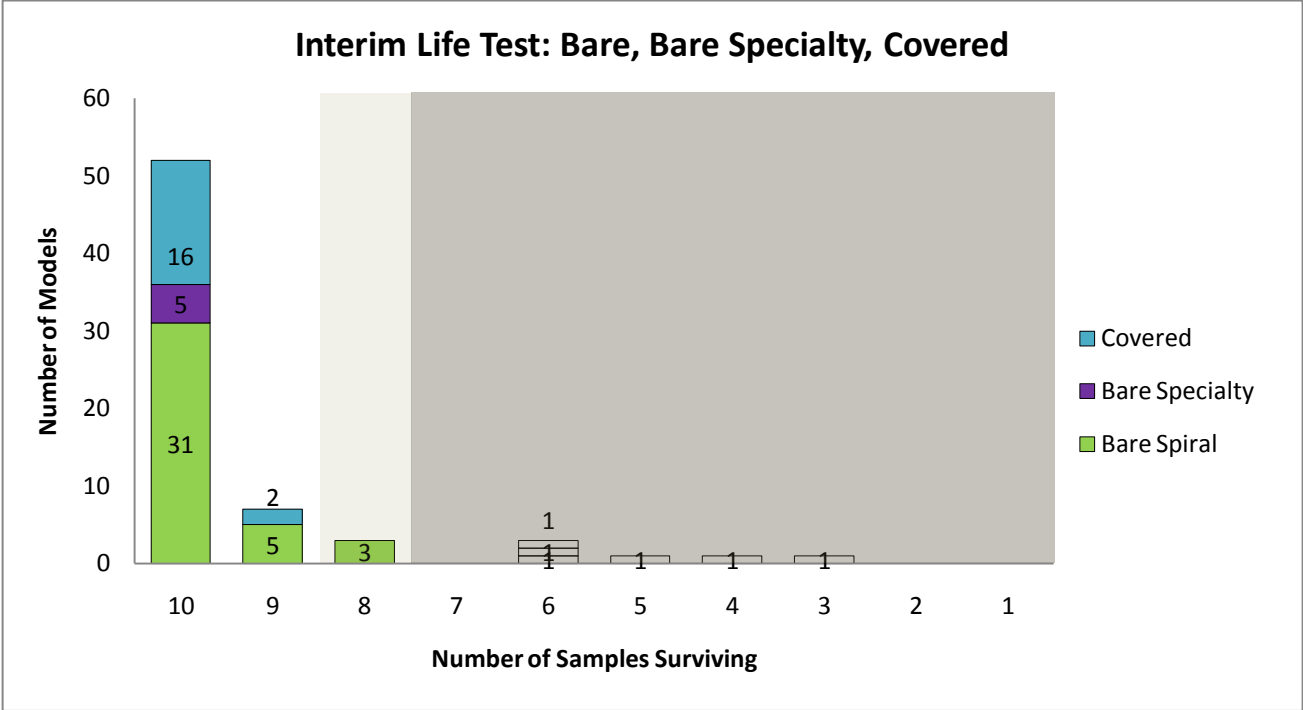


Figure 23

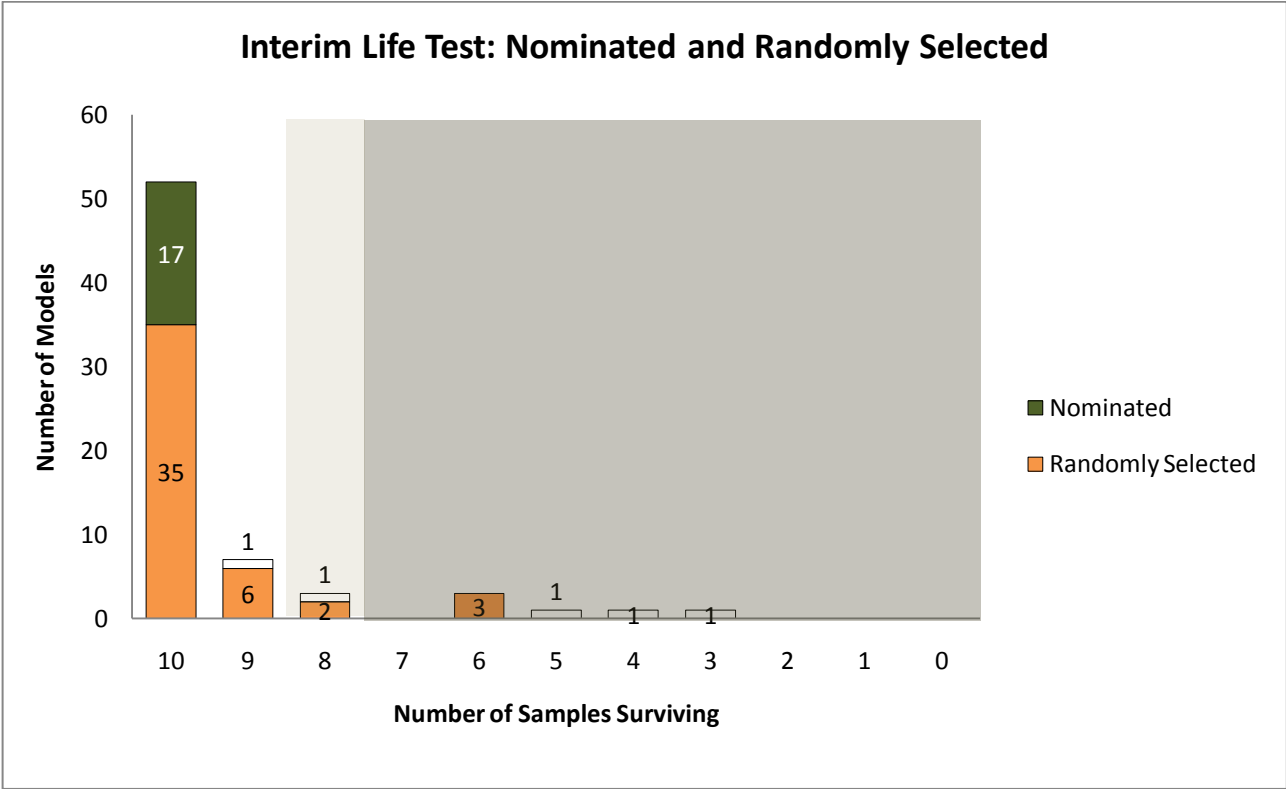


Table 9. Interim Life Test Results

	Number of Models Tested	Percent of Models			Number of Samples Passed Initial Test	
		Passed Initial Test	Marginal Failure (Retest)	Full Failure	Mean	Median
All Models	68	87%	4%	9%	9.3	10
Bare Spiral	42	86%	7%	7%	9.3	10
Bare Specialty	7	71%	0%	29%	8.6	10
Covered	19	95%	0%	5%	9.7	10
Nominated	20	90%	5%	5%	9.6	10
Randomly Selected	48	86%	4%	10%	9.3	10

ALL TESTS

Of the 68 models in Batch 2, 32 passed all tests performed (47%), 29 fully failed at least one test (43%), and the remaining 7 had at least one marginal failure but no full failures (10%). All tested models passed three tests: the Efficacy, Starting Time, and Color Rendering Index Tests. When marginal failures are included, the Run-Up Time, Chromaticity, Interim Life, and Rapid Cycle Stress Tests had the highest failure rates, with 13%, 13%, 13%, and 21% of models failing, respectively. While the Rapid Cycle Stress Test had the highest failure rate, 40% of those failures were marginal. In contrast, 100% of chromaticity failures were full failures. Overall, 80% of all failures were full failures and 20% were marginal. See Table 10.

Table 10. Detailed Results for All Tests

Summary	Efficacy	Starting Time	Run Up Time	Power Factor	1,000 Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test	Total Tests	Total Models
Passing Criteria	Minimum 33 60, depending on W and Model Type	<1,000 ms	<60 sec (non amalgam), <180 sec (amalgam)	>0.5	Must be >90%	>80% of 100 hour lumen average	>80	9/10 coordinates must fall inside ellipse	5/6 samples must meet rated lifetime	9/10 samples must last 40% of rated life		
All											680	68
Mean	64.7	251	68	0.553	93%	85%	82.8	9.3	5.3	9.3		
Median	67.2	170	45	0.547	94%	85%	82.9	10	6	10		
Full Failures	0	0	8	2	6	5	0	9	8	6	44	29
Bare Spiral Models	0	0	2	1	0	1	0	0	6	3	13	9
Bare Specialty Models	0	0	1	1	0	0	0	3	0	2	7	5
Covered Models	0	0	5	0	6	4	0	6	2	1	24	15
Marginal Failures								0	6	3	9	7
Bare Spiral Models								0	5	3	8	6
Bare Specialty Models								0	0	0	0	0
Covered Models								0	1	0	1	0
% Failing Test	0%	0%	15%	3%	9%	7%	0%	15%	21%	13%		44%
% Full Failure	0%	0%	100%	100%	100%	100%	0%	100%	57%	67%		80%

Summary	Efficacy	Starting Time	Run Up Time	Power Factor	1,000 Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test	Total Tests	Total Models
Passing Test	68	68	60	66	62	63	68	58	54	59	626	38
Bare Spiral Models	42	42	40	41	42	41	42	42	36	39	480	26
Bare Specialty Models	7	7	6	6	7	7	7	4	7	5	63	2
Covered Models	19	19	14	19	13	15	19	13	16	18	214	4
% Passing Test	100%	100%	85%	97%	91%	93%	100%	85%	79%	87%		47%
Nominated											200	20
Mean	67.2	343	74	0.576	93%	85%	82.4	8.9	5.6	9.6		
Median	66.4	200	57	0.553	94%	84%	82.5	10	6	10		
Full Failures	0	0	2	1	2	0	0	4	1	1	11	9
Bare Spiral Models	0	0	1	0	0	0	0	0	1	1	2	1
Bare Specialty Models	0	0	1	1	0	0	0	2	0	0	4	3
Covered Models	0	0	0	0	2	0	0	2	0	0	4	4
Marginal Failures								0	1	1	2	2
Bare Spiral Models								0	1	1	2	2
Bare Specialty Models								0	0	0	0	0
Covered Models								0	0	0	0	0
% Failing Test	0%	0%	15%	5%	10%	0%	0%	20%	10%	10%		
% Full Failure	0%	0%	100%	100%	100%	0%	0%	100%	50%	50%		30%
Passing Test	20	20	18	19	18	20	20	16	18	18		10
Bare Spiral Models	11	11	10	11	11	11	11	11	9	9	187	8
Bare Specialty Models	4	4	3	3	4	4	4	2	4	4	36	1
Covered Models	5	5	5	5	3	5	5	3	5	5	46	1
% Passing Test	100%	100%	85%	95%	90%	100%	100%	80%	90%	90%		50%

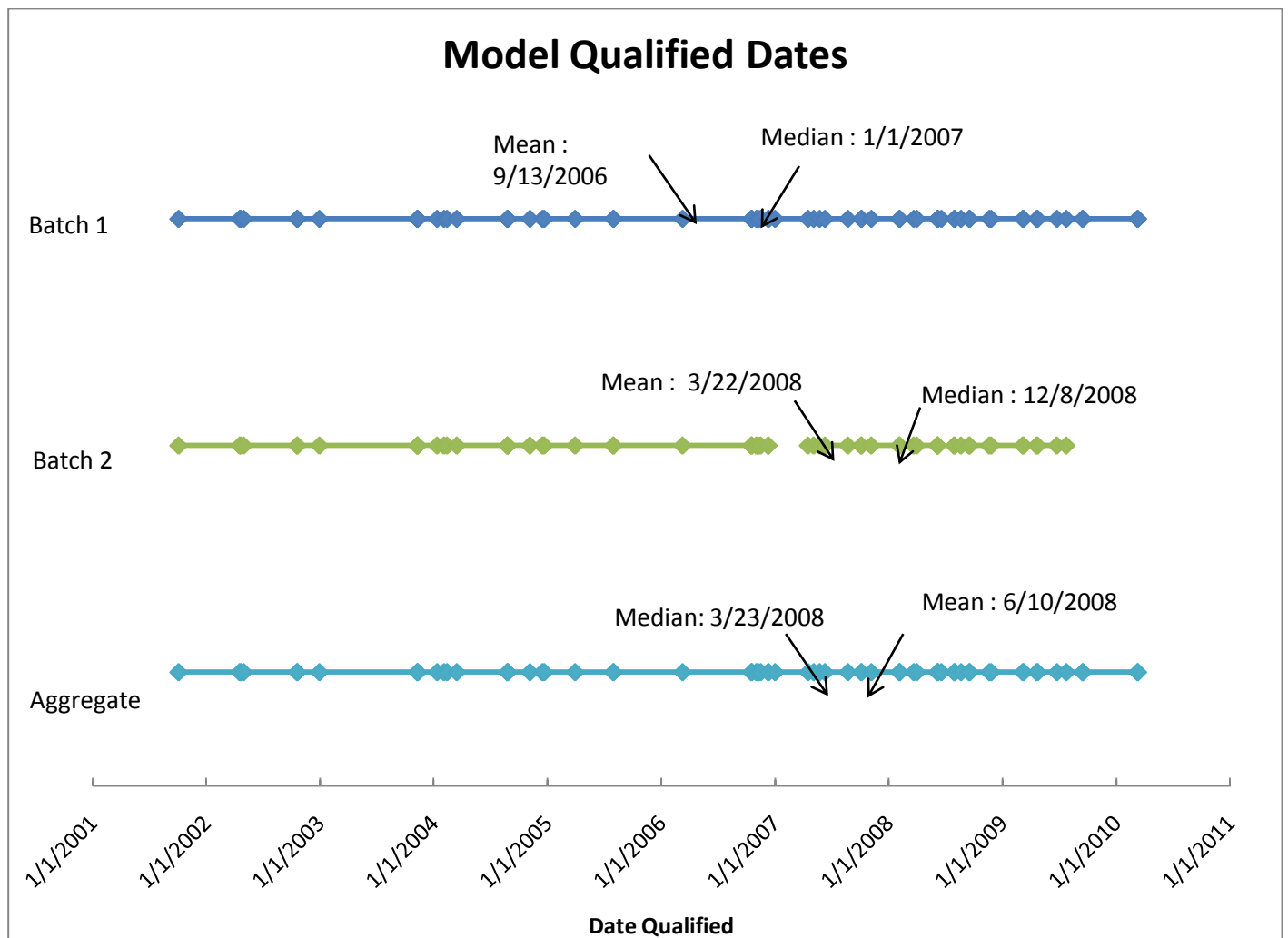
Summary	Efficacy	Starting Time	Run Up Time	Power Factor	1,000 Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test	Total Tests	Total Models
Randomly Selected											480	48
Mean	64.65	251	65	0.544	92%	85%	83	9.2	5.2	9.3		
Median	68.2	150	44	0.546	93%	86%	83	10	6	10		
Full Failures	0	0	7	1	4	5	0	5	6	5	32	18
Bare Spiral Models	0	0	3	1	0	1	0	0	5	2	12	6
Bare Specialty Models	0	0	0	0	0	0	0	1	0	2	3	2
Covered Models	0	0	4	0	4	4	0	4	1	1	18	10
Marginal Failures								0	5	2	7	5
Bare Spiral Models								0	4	2	6	4
Bare Specialty Models								0	0	0	0	0
Covered Models								0	1	0	1	0
% Failing Test	0%	0%	15%	3%	8%	10%	0%	12%	23%	14%		
% Full Failure	0%	0%	100%	100%	100%	100%	0%	100%	64%	71%		38%
Passing Test	48	48	41	47	44	43	48	43	37	41	638	22
Bare Spiral Models	31	31	28	30	31	30	31	31	22	27	292	18
Bare Specialty Models	3	3	3	3	3	3	3	2	3	1	27	1
Covered Models	14	14	10	14	10	10	14	10	12	13	319	3
% Passing Test	100%	100%	85%	97%	92%	90%	100%	88%	77%	86%		46%

COMPARISON OF BATCHES 1 AND 2

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

The models tested in Batch 1 were procured beginning in April 2009 and the models tested in Batch 2 were procured beginning almost a year later in February 2010. The median date of first qualification for Batch 1 models is January 1, 2007, while the median date for Batch 2 models is December 8, 2008, suggesting that the models included in Batch 2 were significantly newer to the market than the models included in Batch 1. See Figure 24.

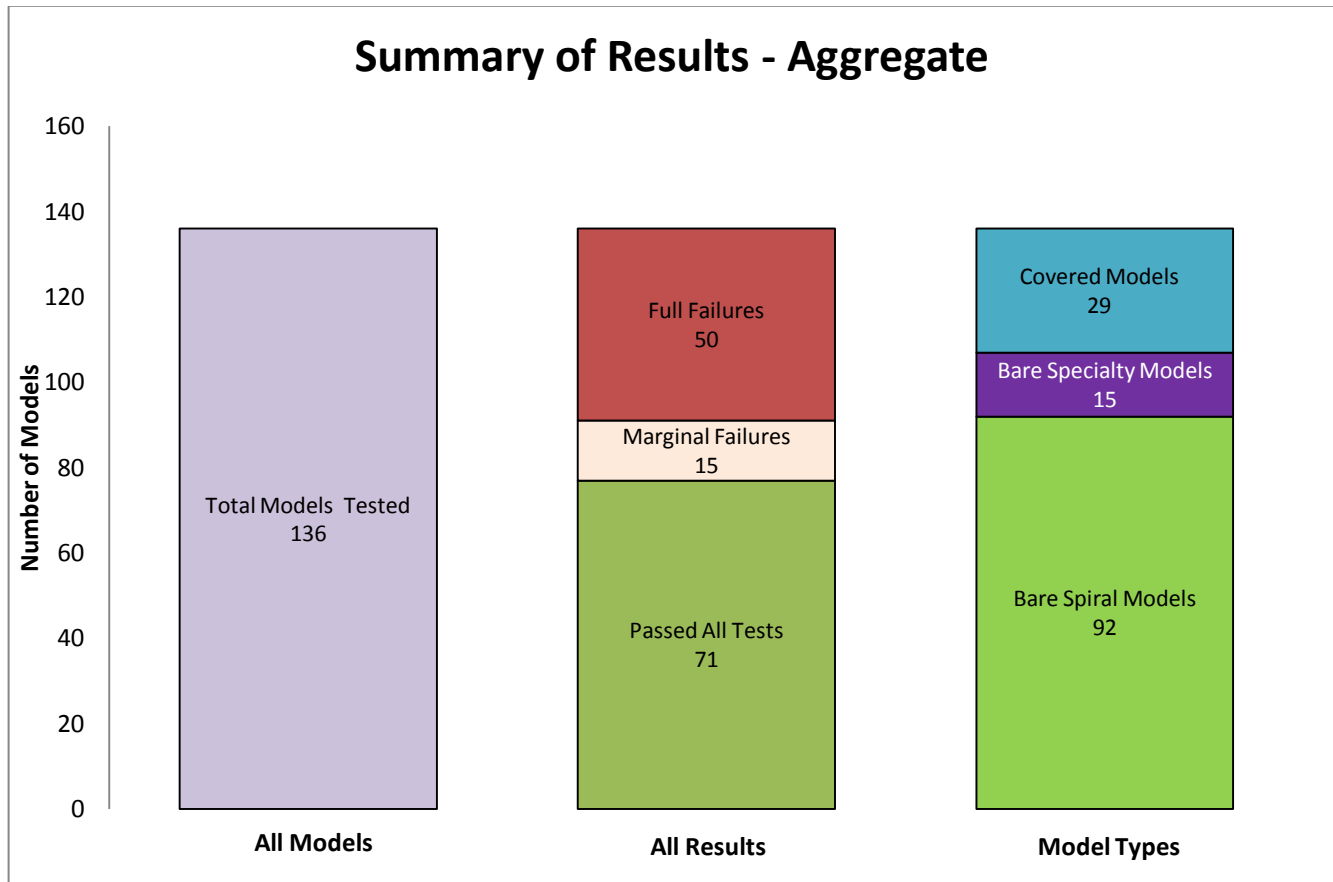
Figure 24



SUMMARY OF RESULTS BY MODEL TYPE

A total of 136 models had been tested as of August 1, 2011, with Batch 1 and Batch 2 containing an equal number of models (68). A majority of the models tested (68%) were bare spiral lamps, 11% were bare specialty lamps, and 21% were covered models. See Figure 25.

Figure 25



Batch 1 is composed of 68 models, with bare spiral, bare specialty, and covered models representing 74%, 12%, and 14% of the total, respectively. In Batch 1, 57% of models passed all tests, 12% marginally failed, and 31% fully failed one or more tests. See Figure 26.

Batch 2 also is composed of 68 models, with bare spiral, bare specialty, and covered models representing 62%, 12%, and 28% of the total, respectively. In Batch 2, 47% of models passed all tests, 10% marginally failed, and 43% fully failed one or more tests. See Figure 27.

There is a nearly two-fold difference in the number of covered models tested between Batch 1 and Batch 2. The full failure rate in Batch 2 is 12 percentage points higher than in Batch 1, and there is a corresponding difference in passing rates. The greater proportion of covered models in Batch 2 relative to Batch 1 is largely responsible for the difference in overall failure rates between the two batches, as can be seen in Figure 29 and Figure 30.

Figure 26

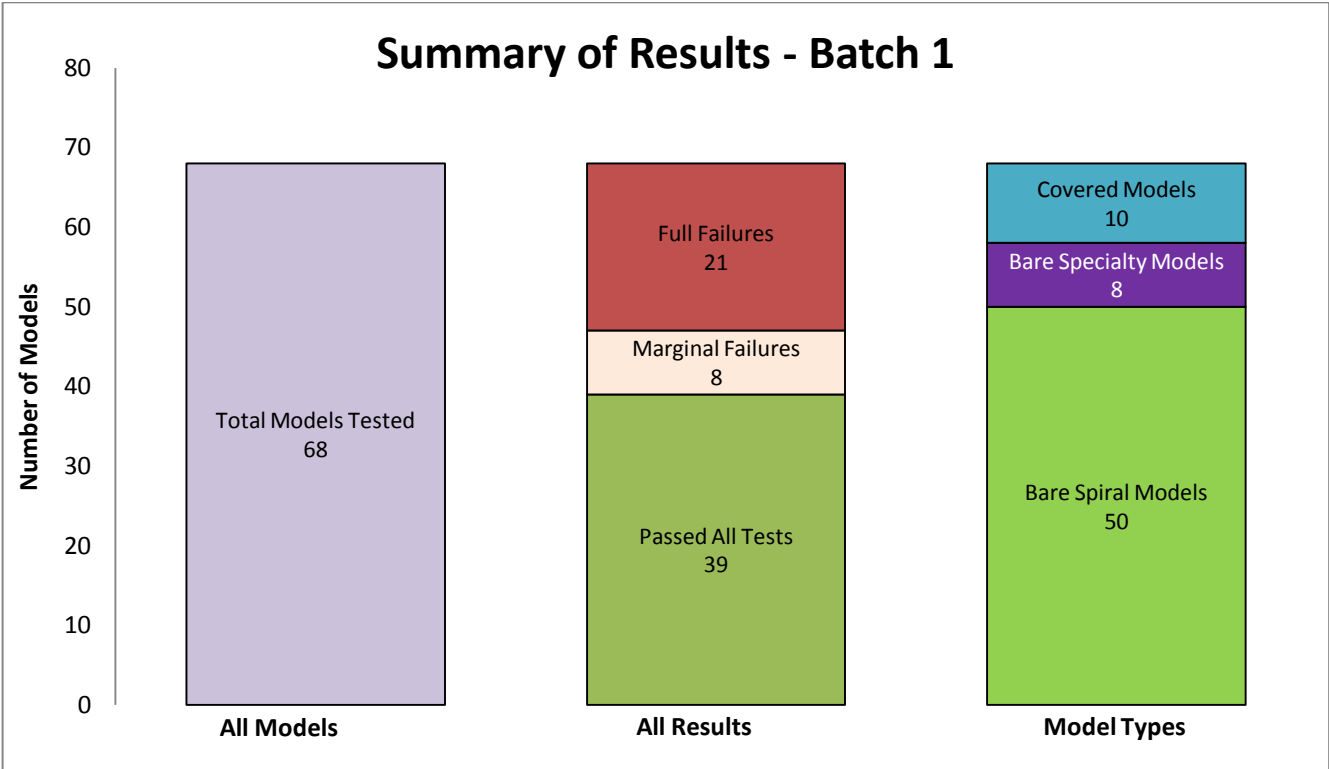
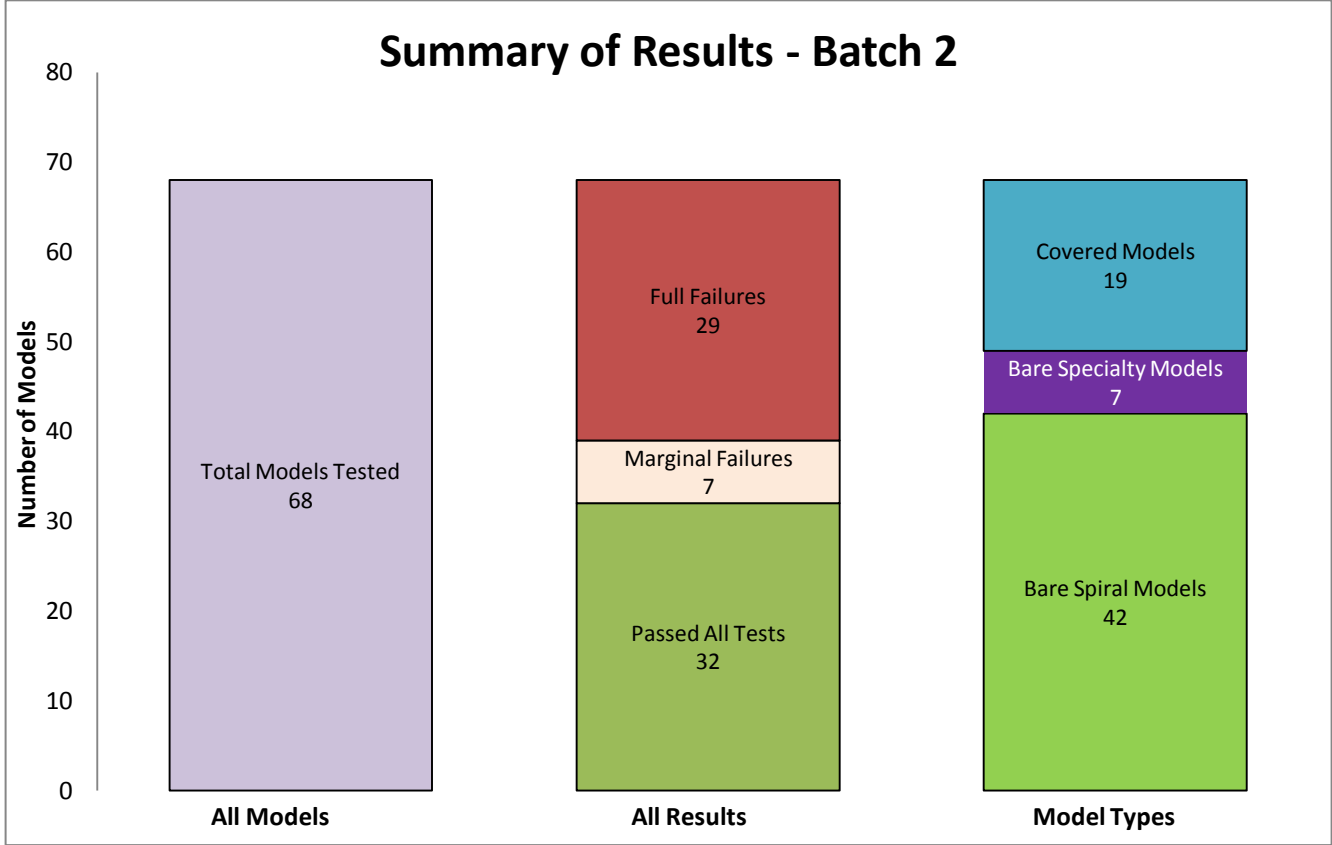
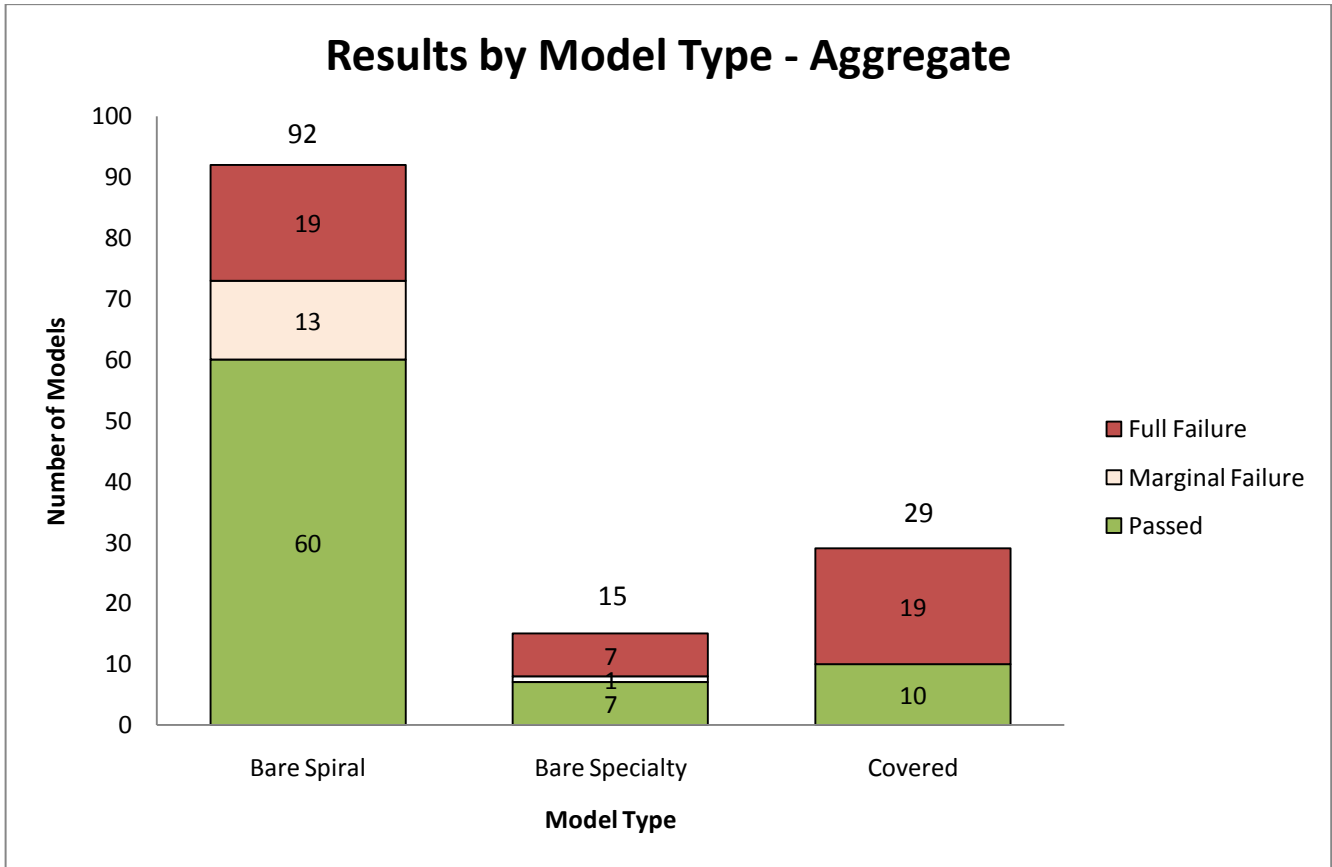


Figure 27



If Batch 1 and Batch 2 are taken together, bare spiral models had a 21 percent failure rate, bare specialty models had a 47 percent failure rate, and covered models performed worst with 66 percent of models failing. See Figure 28.

Figure 28



In Batch 1, bare spiral models performed best, with 63% of models passing all tests; 50% of bare specialty models passed all tests; and covered models performed worst, with only 30% of models passing all tests. See Figure 29.

Bare spiral models were also the best-performing model type in Batch 2, with 62% of models passing all tests, in contrast to bare specialty and covered models, which had passing rates of 29% and 21%, respectively. See Figure 30.

The failure rates of bare spiral and covered models varied little between the two batches. However, the failure rate for bare specialty models increased from 38% in Batch 1 to 71% in Batch 2.

Figure 29

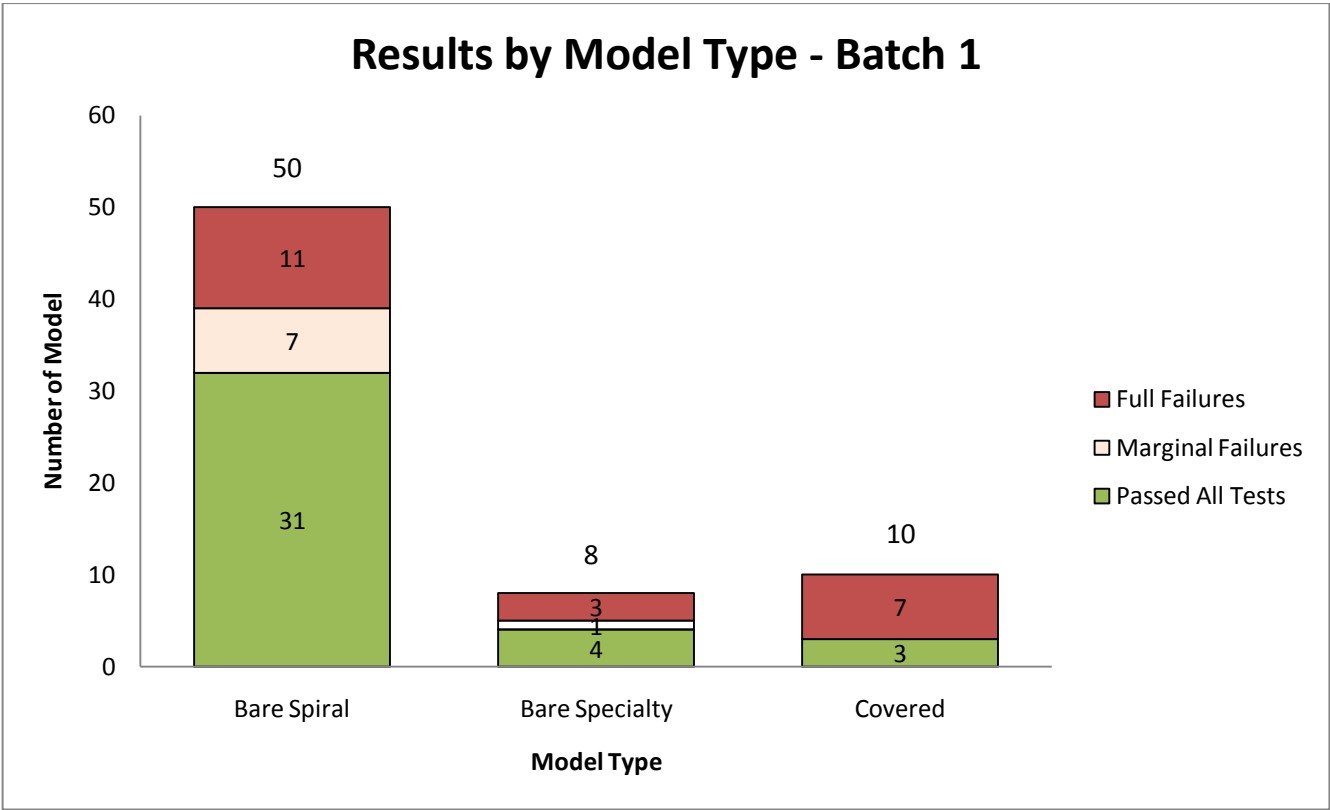
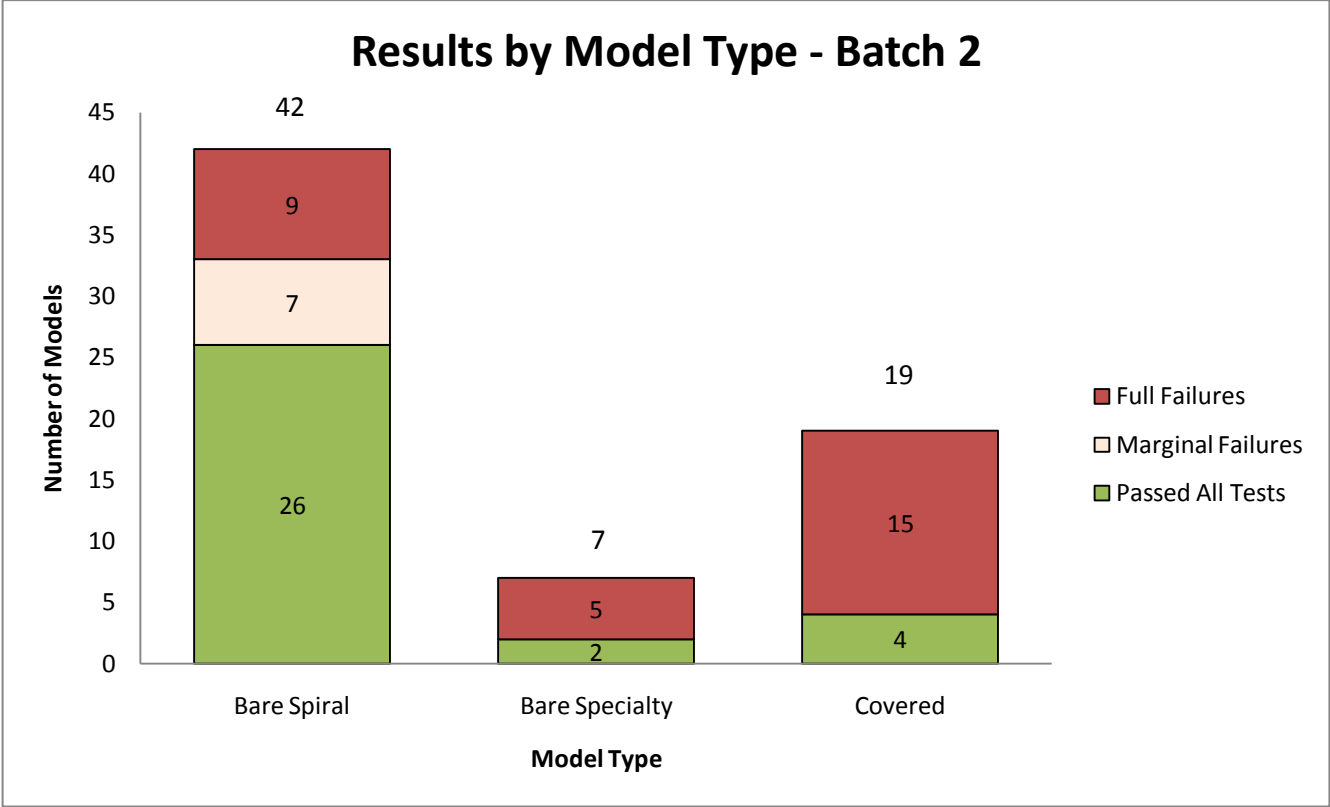


Figure 30

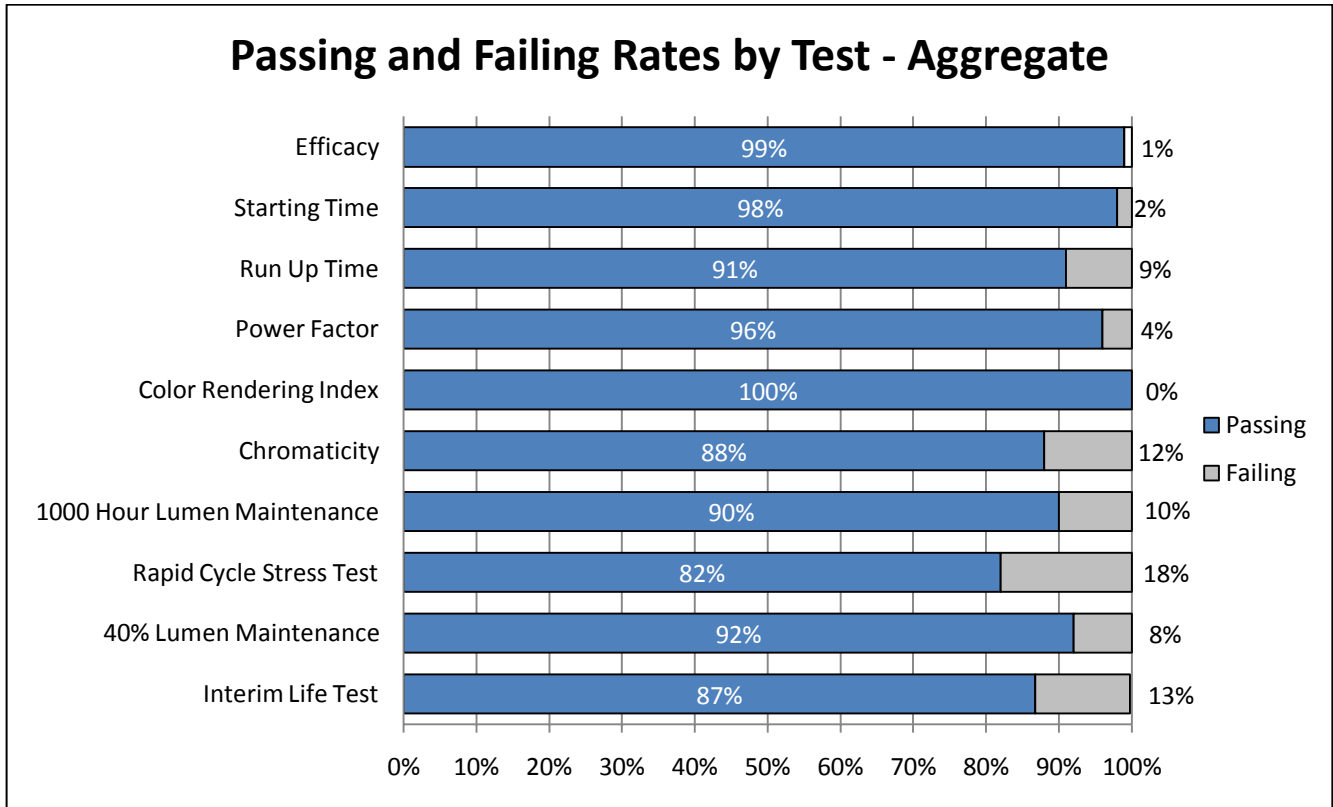


SUMMARY OF RESULTS BY TEST

This section compares model performance on each of the ten tests for the two batches and the three model types.

In Batch 1 and Batch 2 combined, the only test with a 100% passing rate was Color Rendering Index. The tests with the lowest passing rates overall were the Chromaticity Test, Rapid Cycle Stress Test, and Interim Life Test, which had passing rates of 88%, 82%, and 87%, respectively. The remaining six tests had passing rates between 90% and 99%. See [Figure 31](#).

Figure 31



On the whole, passing rates varied little between Batch 1 and Batch 2. Notable exceptions are Run-Up Time and Rapid Cycle Stress Test, with passing rates declining by 13 percentage points and 8 percentage points, respectively. See [Figure 32](#).

Figure 32

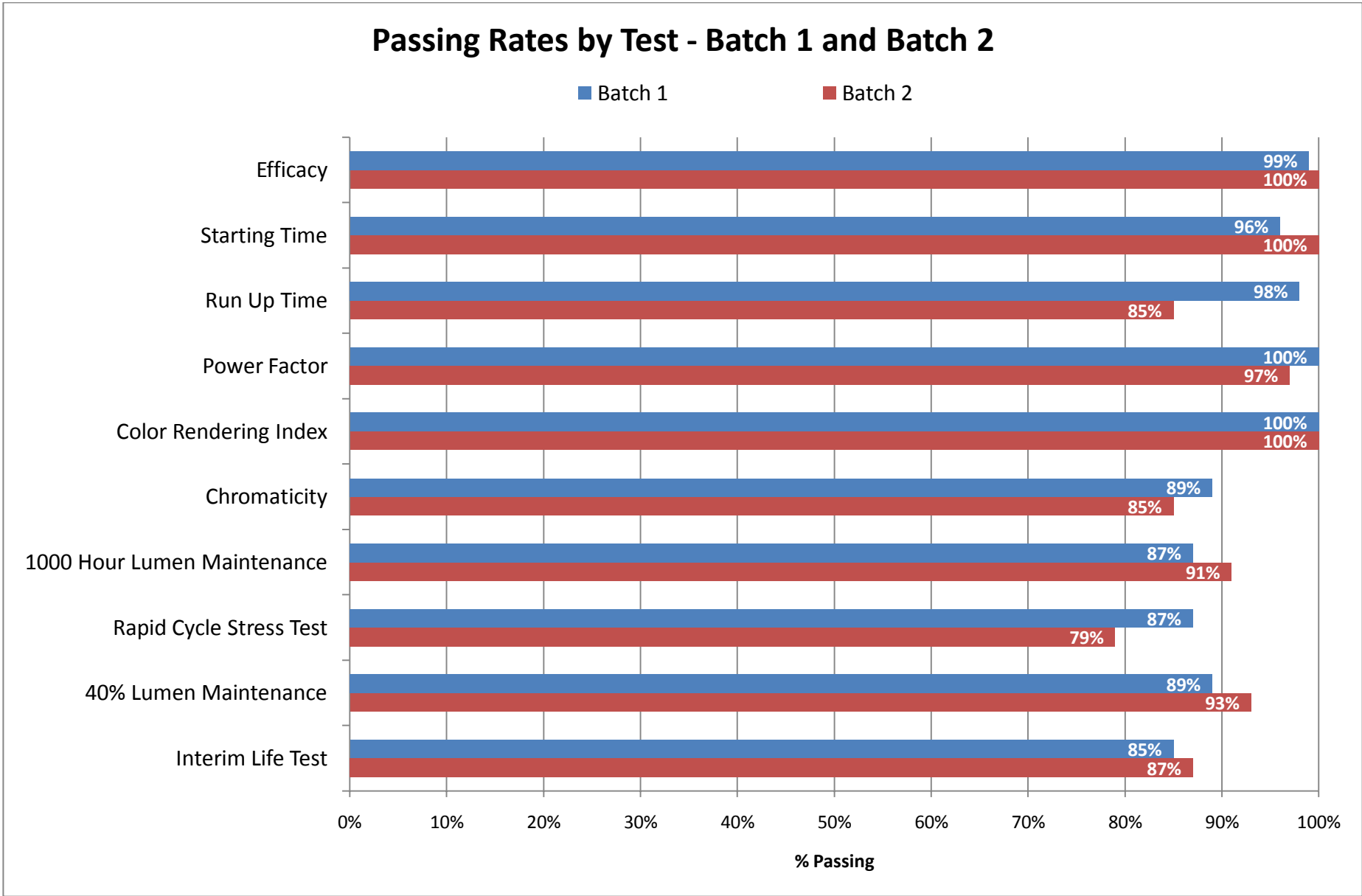
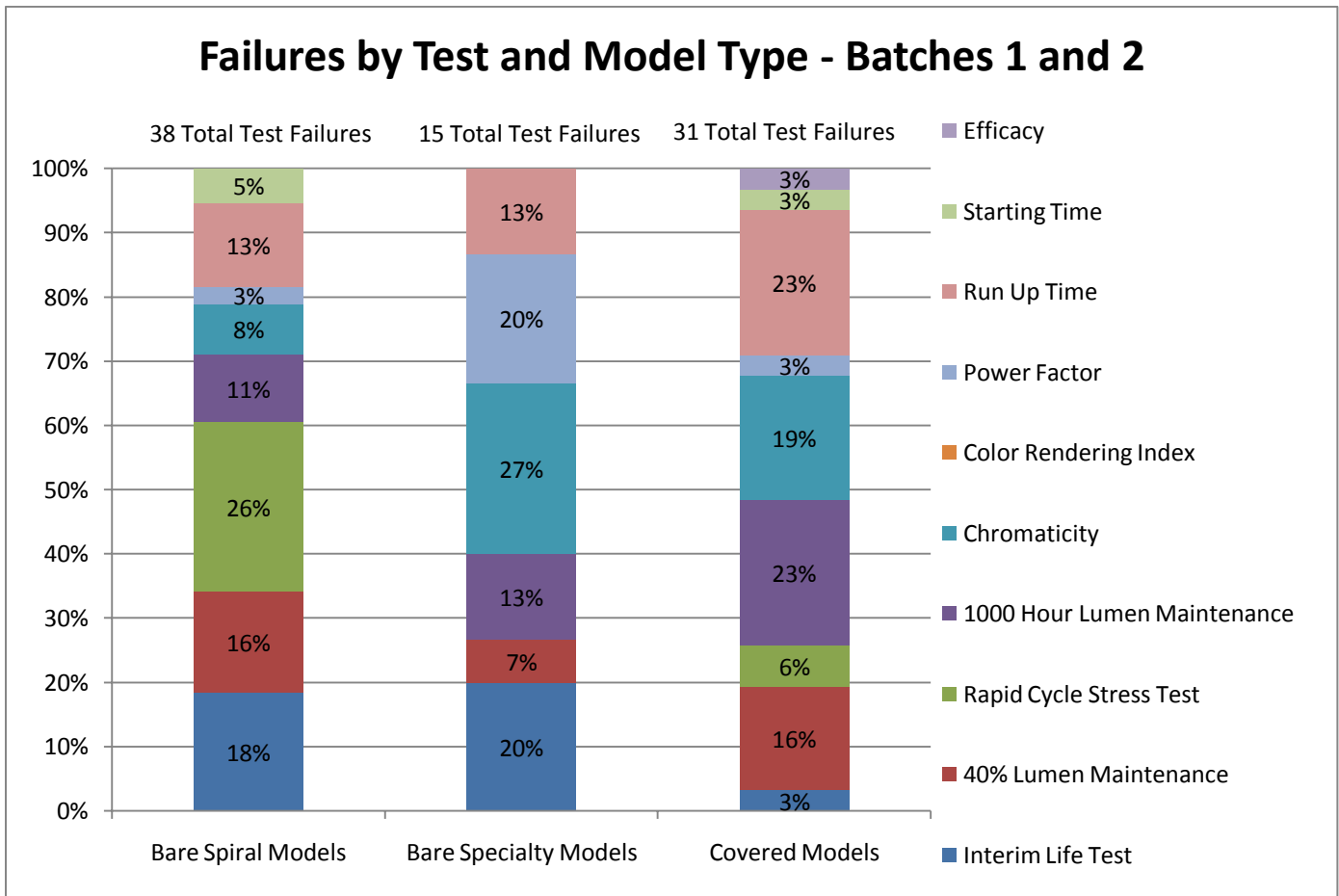


Figure 33 shows how the test failures to date are distributed across the ten tests for each of the three lamp types. For example, the Rapid Cycle Stress Test accounted for 26% of the test failures experienced by bare spiral models; more bare spiral models failed that test than any other test. The Chromaticity Test accounted for 27% of bare specialty failures, making that test the most difficult for bare specialty models. The Run-Up Time and 1,000-Hour Lumen Maintenance Tests had the highest failure rates for covered models; each test represented 23% of covered model failures. The failure distribution across the ten tests is similar for bare specialty and covered models, but is very different for bare spiral models.

Figure 33



The next two figures show how the test failures to date are distributed across the ten tests for each of the three lamp types, first for Batch 1 ([Figure 34](#)) and then for Batch 2 ([Figure 35](#)). Again, each of the three lamp types had high failure rates in different tests.

For bare spiral models, only two tests accounted for significant numbers of failures in both Batch 1 and Batch 2: Rapid Cycle Stress Test and Interim Life Test. The 40 Percent Lumen Maintenance Test accounted for 23% of failures in Batch 1, whereas the Run-Up Time Test accounted for 25% of failures in Batch 2.

For bare specialty models, the Run-Up Time, Power Factor, Chromaticity, and Interim Life Tests produced failures in both batches. The 1,000-Hour Lumen Maintenance Test, which accounted for 25% of the failures in Batch 1, had no failures in Batch 2, while the Chromaticity Test, which was responsible for just 13% of failures in Batch 1, was responsible for 43% of failures in Batch 2.

For covered models, the Run-Up Time Test and the two lumen maintenance tests produced failures in both batches. No covered models in Batch 1 failed the Chromaticity Test, though this test accounted for 25% of the failures in Batch 2.

Figure 34

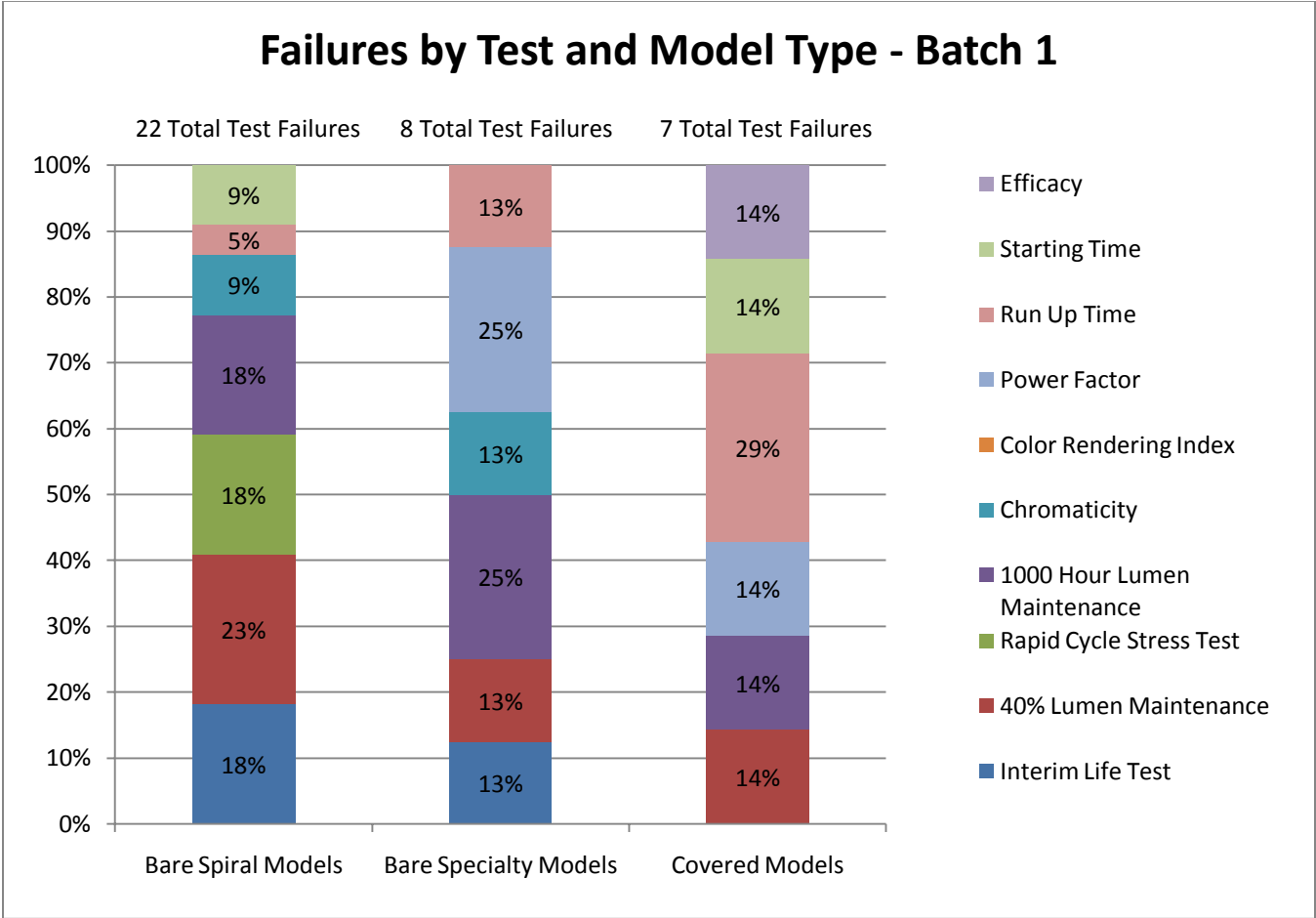
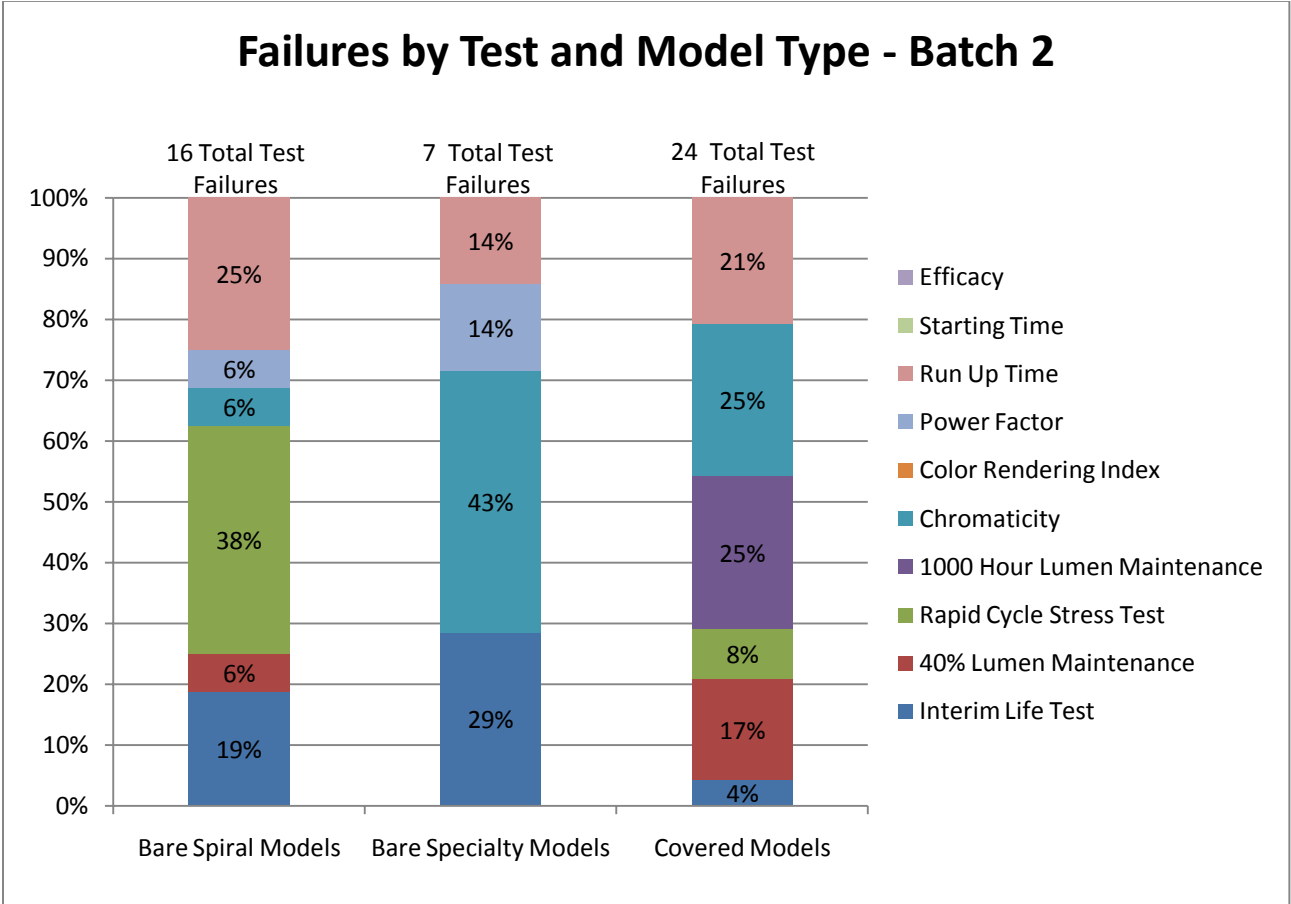


Figure 35



The mean and median values for all tests in Batches 1 and 2 are presented in Table 11. Only results for the Starting Time and Run-Up Time Tests differed significantly between the batches:

- The mean and median for starting time decreased by 100 ms or more from Batch 1 to Batch 2.
- For run-up time, the opposite occurred: the mean and median run-up time for all models tested increased by 12 seconds or more from Batch 1 to Batch 2.

Table 11. Comparison of Batch 1 and Batch 2 Mean and Median of Measured Values

Test	Passing Criteria	Mean		Median	
		Batch 1	Batch 2	Batch 1	Batch 2
Efficacy	Varies by type	65.3	64.7	67.8	67.2
Starting Time	< 1000 milliseconds	360	251	270	170
Run-Up Time	< 60 or < 180 seconds	48	68	33	45
Power Factor	> 0.5	0.59	0.55	0.56	0.55
Color Rendering Index	> 80	82.7	82.8	82.4	82.9
Chromaticity	9/10 coordinates inside ellipse	9.5	9.3	10	10
1,000-Hour Lumen Maintenance	> 90%	93%	93%	94%	94%
Rapid Cycle Stress Test	5/6 survive to half of rated life	5.4	5.3	6	6
40% Lumen Maintenance	> 80%	85%	85%	86%	85%
Interim Life Test	9/10 survive to 40% of rated life	9.2	9.3	10	10

CONCLUSION

The results of this round of testing indicate that the testing system that is in place is effective at finding non conforming models through “off the shelf” testing. The discrepancy found between initially qualified and listed models and the models tested here is a reflection of the dynamic nature of lighting manufacturing. As this testing program continues, and model failures are discovered, it is anticipated that failure rates will decrease as manufacturers develop more robust and continuous model performance monitoring.

The performance of the 68 models in Batch 2 was mixed. Four tests had passing rates under 90%: the Run-Up Time, Chromaticity, Rapid Cycle Stress, and Interim Life Tests. On each of these tests, a sizeable proportion of the failures were significant underperformers (more than two standard deviations from the mean).

When we shift our perspective to look at each model's ability to pass all the tests, we see that fewer than half of the tested models passed all of the tests. Each of these models was required to pass all of the tests to become ENERGY STAR qualified.

Specialty lamps, on the whole, performed worse than bare spirals. Of the three lamp types, bare specialty lamps turned in the worst performance.

On the whole, there is little difference in performance between Batch 1 and Batch 2 models, as evidenced by the similarity between the two batches in the mean and median values for each of the ten tests. The proportion of specialty models that passed all ten tests dropped from Batch 1 to Batch 2, but it is not clear that this drop is meaningful given the relatively small number of specialty models tested to date.

The verification testing program provides EPA with a mechanism for ensuring that ENERGY STAR qualified models available in the marketplace perform as promised. In addition, the test results likely reflect consumers' experiences with ENERGY STAR qualified 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 qualified CFLs, as the sample of models tested is not representative of ENERGY STAR shipments. There are three key reasons why this is so.

First, the CFL Qualified Products List is highly dynamic. The tested models were purchased in 2009 and 2010. Many of the models that were available then are no longer available, and many new models have been introduced since.

Second, certain subsamples of tested models are quite small. For example, only 15 covered CFL models have been tested to date. Of course, the total number of models tested and the quantity of data on those models will grow as additional cycles of verification testing are completed.

Third, the tested models are not representative of actual shipments of ENERGY STAR models. Some of the models that have been tested are sold in large volumes while others have much smaller sales volumes. The test results are not weighted to reflect these differences.

D&R conducted two analyses to assess the amount of sample bias introduced by two factors and found no evidence that either factor was an important source of bias.

One potential source of bias arises because a large portion of the tested models are nominated rather than randomly selected. To quantify the bias introduced by nominations, D&R compared results for the 69 randomly selected models with those for the 67 nominated models. For each of the 10 tests, D&R calculated the difference in means between the two groups of models and evaluated the statistical significance of that difference. It found that for 8 of the 10 tests, the two means were not meaningfully different. For the Color Rendering Index and Rapid Cycle Stress Tests, however, there were small, though meaningful differences between the means of the two groups. (For CRI: 82.83 (random) vs. 82.41 (nominated); for RCST: 5.20 (random) vs. 5.58 (nominated)).

If models were selected at random, then over time each OEM's share of base models tested should approach its share of qualified base models. At present, some OEMs are overrepresented in the sample, while others are underrepresented, another potential source of bias. If, for example, those that are overrepresented had better-performing models on the whole, then the observed number of failures would be lower than the expected or "true" number of failures. D&R's analysis has shown that this is not in fact an important source of bias in the test results to date.

APPENDIX

The ENERGY STAR CFL Third Party Testing and Verification Program exists to support the U.S. Environmental Protection Agency in ensuring that compact fluorescent lamps (CFLs) qualified and labeled as ENERGY STAR continue to meet all ENERGY STAR CFL qualification criteria. The table below presents results for the 68 models selected in Cycle 2 that completed testing by August 1, 2011 (Batch 2).

KEY	
Failed	The model fully failed the test in question.
Significantly Underperforming	The model failed the test in question and its measured performance was more than two standard deviations away from the mean.
Marginal Failure	The model was a marginal failure, meaning that one less sample than required passed (e.g., if 9 out of 10 are required, only 8 out of 10 passed).
3% Applied	The model passed the Efficacy and/or Lumen Maintenance Test with performance between 97% and 99.9% of the minimum requirement.
p	The model passed.

Table 12. Detailed Results for Each of the 68 Models Included in Batch 2

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Color Temp (Kelvin)	Efficacy	Starting Time	Run Up Time	Power Factor	Maintenance 1,000 Hour Lumen	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test
Bare-spiral (dimnable)	15	900	10000	2700	p	p	p	p	p	p	p	p	p	p
Bare-spiral (dimnable)	15	900	10000	2700	p	p	p	p	89.76%	p	p	p	3	p
Bare-spiral (dimnable)	24	1500	8000	2700	p	p	131	p	p	p	p	p	p	p
Bare-spiral (3-way)	28	1750	6000	3500	p	p	p	0.498	p	p	p	4	p	p
Bare-spiral (3-way)	29	2150	8000	2700	p	p	p	p	p	p	p	7	p	p
Bare-spiral (3-way)	28	1800	8000	2700	p	p	p	p	88.92%	77.68%	p	4	p	4
Bare-spiral (3-way)	28	1800	6000	3000	p	p	p	p	p	p	p	p	p	6
Covered-Candle	7	300	10000	2700	p	p	p	p	82.60%	70.51%	p	p	4	p
Covered A-line	15	800	8000	2700	p	p	p	p	p	p	p	p	p	p
Covered A-line	14	800	8000	2700	p	p	p	p	p	p	p	6	p	p
Covered reflector	23	1350	8000	2700	p	p	236	p	89.73%	p	p	p	p	p

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Color Temp (Kelvin)	Efficacy	Starting Time	Run Up Time	Power Factor	Maintenance 1,000 Hour Lumen	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test
Covered reflector	23	1300	10000	2700	p	p	p	p	p	p	p	p	p	p
Covered reflector	15	700	10000	2700	p	p	p	p	82.22%	72.82%	p	3	p	6
Covered reflector	16	750	8000	2700	p	p	p	p	86.98%	79.92%	p	7	p	p
Covered reflector	26	1300	8000	2700	p	p	p	p	82.71%	76.41%	p	6	p	p
Covered reflector	11	430	8000	2826	p	p	p	p	86.39%	79.76%	p	p	p	p
Covered reflector	20	900	8000	2700	p	p	p	p	87.45%	78.66%	p	p	p	p
Covered reflector	14	495	8000	3000	p	p	p	p	p	p	p	p	p	p
Covered reflector	16	750	8000	3000	p	p	p	p	86.57%	78.54%	p	7	p	p
Covered reflector	23	1200	8000	3000	p	p	197	p	p	p	p	p	p	p
Covered reflector	23	1200	8000	3500	p	p	213	p	88.38%	79.56%	p	p	p	p
Covered reflector	20	930	8000	2700	p	p	p	p	p	p	p	p	2	p
Covered reflector	23	1300	8000	2700	p	p	p	p	p	74.46%	p	p	p	p

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Color Temp (Kelvin)	Efficacy	Starting Time	Run Up Time	Power Factor	Maintenance	1,000 Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test
Covered reflector	16	750	8000	3000	p	p	105	p	p	p	p	p	p	p	p
Covered reflector	14	650	8000	2700	p	p	p	p	p	p	p	p	p	p	p
Covered A-line	14	800	12000	2700	p	p	74	p	p	p	p	p	7	p	p
Bare-spiral	9	600	10000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	23	1690	10000	2700	p	p	p	p	p	p	p	p	3	p	p
Bare-spiral	24	1600	10000	2700	p	p	p	0.49	p	p	p	p	p	p	p
Bare-spiral	11	700	10000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	20	1200	10000	4100	p	p	p	p	p	p	p	p	1	p	p
Bare-spiral	13	900	10000	4100	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	20	1200	10000	4100	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	9	500	12000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	23	1600	12000	2700	p	p	p	p	p	p	78.75%	p	0	4	p
Bare-spiral	23	1600	12000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	23	1600	10000	2700	p	p	p	p	p	p	p	p	p	4	p
Bare-spiral	23	1600	10000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	20	1400	15000	2700	p	p	p	p	p	p	p	p	p	4	p

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Color Temp (Kelvin)	Efficacy	Starting Time	Run Up Time	Power Factor	Maintenance	1,000 Hour Lumen Maintenance	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test
Bare-spiral	18	1200	10000	4100	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	23	1600	10000	4100	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	13	800	10000	4100	p	p	p	p	p	p	p	p	p	4	p
Bare-spiral	20	1200	10000	2700	p	p	p	p	p	p	p	p	p	p	6
Bare-spiral	26	1750	10000	2700	p	p	p	p	p	p	p	p	p	p	8
Bare-spiral	20	1200	10000	5000	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	19	1200	12000	2700	p	p	p	p	p	p	p	p	p	3	p
Bare-spiral	23	1600	10000	5000	p	p	p	p	88.99%	77.53%	p	p	p	p	8
Bare-spiral	14	810	10000	2700	p	p	105	p	p	79.84%	p	p	p	p	p
Bare-spiral	25	1700	12000	2800	p	p	p	p	p	p	p	p	p	p	8
Bare-spiral	25	1800	10000	2700	p	p	p	p	p	p	p	p	p	p	5
Bare-spiral	13	900	8000	2700	p	p	p	p	p	p	p	p	p	p	p

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Color Temp (Kelvin)	Efficacy	Starting Time	Run Up Time	Power Factor	Maintenance	1,000 Hour Lumen	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test
Bare-spiral	18	1250	10000	2700	p	p	p	p	p		79.43%	p	p	p	p
Bare-spiral	13	900	12000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	13	825	8000	2700	p	p	p	p	p	p	p	p	p	3	p
Bare-spiral	20	1200	10000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	23	1625	10000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	13	782	10000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	20	1200	10000	2700	p	p	p	p		89.22%	p	p	p	3	p
Bare-spiral	23	1600	10000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	18	1300	10000	2700	p	p	p	p	p	p	p	p	p	p	p
Bare-spiral	19	1100	10000	5000	p	p	p	p	p	p	p	p	p	4	p
Bare-spiral	9	540	10000	2700	p	p	p	p		89.96%	p	p	p	p	p
Bare-spiral	27	1750	10000	5000	p	p	p	p	p	p	p	p	p	p	p

Model Type	Energy Used (Watts)	Light Output (Lumens)	Life (hours)	Color Temp (Kelvin)	Efficacy	Starting Time	Run Up Time	Power Factor	Maintenance 1,000 Hour Lumen	40 Percent Lumen Maintenance	Color Rendering Index	Chromaticity Coordinates	Rapid Cycle Stress Test	Interim Life Test
Bare-spiral	20	1200	10000	2700	p	p	p	p	p	p	p	p	p	p
Bare-spiral	26	1750	10000	2700	p	p	81	p	p	p	p	p	3	3
Bare-spiral	18	1200	10000	4100	p	p	p	p	p	p	p	p	p	p
Bare-spiral	11	660	10000	2700	p	p	p	p	p	p	p	p	p	p
Bare-spiral	25	1600	8000	2700	p	p	p	p	p	p	p	p	p	p