March 20, 2015

Ms. Taylor Jantz-Sell
ENERGY STAR Lighting Program Manager
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Subject: ENERGY STAR Version 2 Draft 1 Lamps Specification

Dear Ms. Jantz-Sell:

This letter comprises the comments of the Pacific Gas and Electric Company (PG&E), Southern California Gas Company (SCGC), San Diego Gas and Electric (SDG&E), and Southern California Edison (SCE) in response to the Environmental Protection Agency's (EPA) release of the first draft of the ENERGY STAR Lamps specification version 2.0, intended to replace the Lamps specification Version 1.1. We support EPA's stated goal of revising this specification to keep pace with the rapidly evolving LED lamp market.

The signatories of this letter, collectively referred to herein as the California Investor Owned Utilities (CA IOUs), represent some of the largest utility companies in the Western United States, serving over 35 million customers. As energy companies, we understand the potential of appliance efficiency programs to cut costs and reduce consumption while maintaining or increasing consumer utility of the products. We have a responsibility to our customers to advocate for voluntary program requirements that accurately reflect the climate and conditions of our respective service areas, so as to maximize these positive effects.

The replacement lamp product category has been a focal point of the CA IOU's energy efficiency program strategies for over two decades, and we are currently running multiple incentive programs in support of high efficiency, high quality lamps. Since December of 2013, our residential upstream rebate program efforts have been referencing the Voluntary California Quality LED Lamp Specification (CEC Spec), published by the California Energy Commission (CEC),[1] to establish eligibility for LED rebates. The CEC Spec was designed to leverage the framework established by ENERGY STAR; it uses most of the same test procedures and metrics, and in many cases the requirements directly align with ENERGY STAR Lamps V1.1. Similar to ENERGY STAR, the CEC Spec aims to increase market acceptance of LEDs by promoting a level of user amenity that is comparable to or higher than the lamps they replace. In a number of areas the CEC Spec requirements are more stringent than those in the ENERGY STAR Lamps Version 1.1 Specification, including CRI, R9, Power Factor, Duv, dimmability, and flicker.

When first adopted, the CEC Spec was considered to be quite ambitious, as few compliant products were available, and those that were available were quite expensive. However, within one year of using the CEC Spec for our upstream rebate program eligibility, average prices of compliant products dropped by about 50%, and there was an order of magnitude increase in the availability of compliant products. In the first

[1] http://www.energy.ca.gov/2012publications/CEC-400-2012-016/CEC-400-2012-016-SF.pdf

year alone, the IOU incentive programs provided incentives for sales of over 2 million lamps that met or exceeded the minimum requirements in CEC Spec. Forecasts for 2015 are far higher.

The State of California is also now considering adoption of mandatory codes and standards requirements, effective in 2017 that would require compliance with many of the aspects of the CEC Spec both in residential new construction (Title 24) and in retail sales of lamps (Title 20). These specifications and standards are gaining momentum, and the market is responding – the performance levels in the CEC Spec are no longer as lofty and aggressive as they once seemed. Still these high quality initiatives would be further strengthened by increased utilization at the national level. National adoption of similar specifications to the CEC Spec would result in even more product availability, more competition among manufacturers, increased economies of scale and industry learning, and eventually a wider array of lower cost, higher performing products. We therefore encourage EPA to consider alignment with the CA Spec on those areas where the specifications differ.

We appreciate this opportunity to provide the following specific comments about this specification.

1. **We commend EPA for the updates to the measurement protocol in the "Frequency" section of the Lamps Version 2 Specification, and we encourage EPA to also align its flicker testing guidance and reporting requirements with the test method and reporting requirements that have been developed in Title 24's Joint Appendix 10 (JA10).**

The California utility codes and standards team and the CEC, in collaboration with other stakeholders and industry experts, have made significant progress on a test procedure to measure and report flicker in light sources, including lamps, in the proposed Joint Appendix 10 to Title 24. This test procedure started with the ENERGY STAR recommended practice for the measurement of flicker procedure but added more specificity to the equipment used and the test procedure. In addition, this test procedure adds a method of filtering the data for various low pass-cut-off frequencies so the results are aligned with the percent amplitude modulation (percent flicker) versus frequency metrics in IEEE PAR 1789. The JA10 test procedure development process received input from researchers at the Pacific Northwest National Laboratory, engineers at manufacturers of test equipment used to measure light source flicker, as well as members of the IEEE committee (PAR1789) currently working on international flicker standards for LED lighting.[2] The Title 24 rulemaking is currently underway, and adoption is expected by May 2015. The most recent draft version of the flicker test method was published by the CEC in February as part of its "45 Day Language Express Terms,"[3] and has also been included as Appendix A in this document. The California JA10 test procedure was written using ENERGY STAR's Recommended Practice for the Measurement of Light Source Flicker (August 2013) as a starting point, but a number of areas were modified to increase specificity and clarity, and to ensure repeatability. The Title 24 proposal also includes a method for processing raw flicker data in order to be able to identify and analyze levels of flicker occurring at different frequencies so as to reflect the recommended practice for flicker being developed in IEEE PAR 1789.

We support the changes being proposed in the Lamps Version 2 specification in Section 11.3 (Frequency) because they align with the testing procedures proposed in JA10. We recommend that EPA also make these changes to Section 12.4 "Flicker" of ENERGY STAR Product Specification for Lamps and in the ENERGY STAR Recommended Practice for the Measurement of Light Source Flicker. In addition, the requirements for flicker should not be limited to dimmable lamps but should apply to all lamps and

[2] P1789 *"Draft Recommended Practice for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers."* Draft 3. The Institute of Electrical and Electronics Engineers. New York. September 2014. http://grouper.ieee.org/groups/1789/
[3] http://www.energy.ca.gov/title24/2016standards/rulemaking/documents/express_terms/

luminaires; even non-dimming lamps are capable of having high levels of amplitude modulation, especially at 120 Hz (the fundamental of the rectified waveform). The IEEE PAR 1789 Standard in development recommends that percent amplitude modulation be kept below 0.08 x Frequency (Hz). At 120 Hz, the recommended maximum percent amplitude modulation (percent flicker) is 9.6%. We recommend revisions in the following areas to ENERGY STAR's Flicker Measurement Recommended Practices document, so they align with the Frequency Section of the ENERGY STAR Version 2 Draft Lamps Specification and Title 24 JA10:

- The ENERGY STAR Recommended Practice for the Measurement of Light Source Flicker (August 2013) specified a duration of only 100 milliseconds. Since the minimum frequency and the frequency increment in the Fourier transform is a function of the duration of the data analyzed, longer durations of analyzed data allows one to evaluate lower frequencies and a more granular evaluation of the data. We recommend that you increase the duration of the recorded waveform to 1 second as specified in the proposed Frequency section of the ENERGY STAR Lamps v2 draft, and similar to what is in the current draft of the JA10 (2 seconds), though we agree a measurement period of 1 second is sufficient. Equipment commonly used for recording these measurements is able to store 1 second's worth of data with relatively small file sizes that are able to be processed easily.
- The ENERGY STAR Recommended Practice for the measurement of Light Source Flicker (August 2013) does not provide specifications for linearity of response or rise time for the photosensor used in the test. JA10 provides these values: the linearity of response over the measurement range shall be less than 1%. The language EPA proposed in the Frequency Section of this Lamps v2 draft 1 should also apply to flicker: "The rise time of the sensor shall be 10 microseconds or less (where rise time is defined as the time span required for the output signal to rise from a 10% to a 90% level of the maximum value when a steady input at the maximum value is instantaneously applied)." These specifications are necessary to ensure that the sensors used to measure flicker are capable of accurately observing and recording the fluctuations in light levels of the sources being observed. If sensors with insufficient linearity of response are used, the amplitude of light source modulations will not be accurately captured. Similarly, if sensors with insufficient rise times are used, high frequency fluctuation of the light source will not be accurately captured. We recommend that the ENERGY STAR Recommended Practice align with the specifications contained in JA10 that define the measurement accuracy of the photosensor used in the test.
- The ENERGY STAR Recommended Practice requires: "*The equipment sampling rate used shall be ≥ 2 kHz.*" We recommend this be revised to align with the language used in the Frequency Section of the draft ENERGY STAR Lamps V2 specification: "*Measured data shall be recorded to a digital file with an interval between each measurement no greater than 0.00005 sec (50 microseconds) corresponding to an equipment measurement rate of no less than 20kHz, and capture at least 1 second of data.*" Ideally the test method should specify the collection of data at a frequency ten times higher than the highest flicker frequency to be analyzed in the Fourier analysis. The IEEE PAR1789 committee that is addressing flicker has developed recommendations that require an analysis of flicker up to 1,000 Hz and thus the minimum data collection frequency under consideration should be no less than 10 kHz. A data collection rate of 20 kHz allows a harmonic analysis up to 10 kHz. Thus the revised specification using an interval between measurements of no greater than 50 microseconds will provide the needed fidelity in the time domain to evaluate a light source's capability of generating perceptible and imperceptible flicker.

After the measurements are taken there are also some modifications in JA10 that impact how the data is processed, how the flicker levels are calculated, and how the data is reported. The primary changes are summarized here:

- Calculation of Flicker Index and Percent Flicker
    - The ENERGY STAR Recommended Practice does not define exactly how the calculation for flicker index or percent flicker should be conducted using the data collected. The calculations of flicker index and percent flicker require an assessment of the peak and valley of a photometric waveform– but the ENERGY STAR procedure does not clearly specify which waveform, or which peak and which valley should be used, when multiple waveforms are measured. It is not clear whether a "representative" wave form should be generated with the measured data over the test duration (for example, with a peak light output value calculated as the average of the peaks from all cycles of the waveform collected, and a minimum light output value calculated as the average of the valleys from all cycles of the waveform), or if one specific waveform is to be selected for the calculation, or if some other method is allowed. The procedure in JA10 specifies that the maximum value should be the maximum light output collected over the entire two seconds of data collection, and the minimum value should be the minimum light level collected over the entire two seconds (even if those two values don't occur in the same cycle of the wave).
- Processing Raw Flicker Data
    - In terms of processing and reporting of the flicker data the ENERGY STAR procedure says the following shall be submitted: Digitized photometric waveform data and an image of the relative photometric amplitude waveform with a period ≥ 100ms. JA10 provides specific instructions for the format of a raw flicker data .csv file that must be uploaded into a Fourier transform analysis tool.
    - It is widely known that the frequency of flicker is an important factor in determining the acceptability and health risks of flicker. Collection of the raw flicker data is essential to be able to determine the flicker performance at different cut-off frequencies. Once raw flicker data is collected it can be analyzed with Fourier transform tools to isolate flicker levels by frequency. The CEC is proposing to provide such a tool for use in the certification and compliance process that will enable users to distinguish offensive levels of flicker occurring at low frequency from undetectable levels of flicker occurring at high frequency. We have communicated with various test labs and other stakeholders conducting this testing who have confirmed that it would not add any significant burden to compile the raw data into a .csv file. A .csv (comma separated values) data file that is minimally compliant with the specification (three levels of dimming [100%, 20% and minimum], 20,000 data points corresponding to one second's worth of data recorded with 50 microsecond intervals between the data) is only 744 kBytes.
    - If the ENERGY STAR program does not want to store the raw data from the flicker tests, it would be acceptable that the test lab store this data. However, we recommend that EPA require the submittal of such a raw data file into a Fourier transform tool, similar to what is proposed for California (EPA can utilize the tool developed in CA if desired), and that the outputs of this tool (percent flicker and flicker index at various cut-off frequencies) be published in the ENERGY STAR database. This information will provide feedback to the industry on how they are comparing with their competitors in removing flicker. States and utility programs will likely also be interested in evaluating this data for setting criteria that reflects the current state of the market. The California JA10 standard intends to publish flicker data for cut-off (low pass) frequencies of 1,000 Hz, 400 Hz, 200 Hz, 90 Hz, and 40 Hz. The filtering of data is mathematical and does not require extra testing.

- If the ENERGY STAR program has the raw data files for the currently certified products we recommend that these data be processed and that percent flicker for the above frequencies be made readily available to the users of the ENERGY STAR databases.

Multiple manufacturers have submitted comments in support of CEC's flicker proposals, and members of the IEEE PAR1789 Committee that is currently developing international flicker requirements also submitted public comments to the CEC regarding the flicker proposals. Though both urged the CEC to adopt even stronger flicker requirements than proposed, both also supported the flicker test method developed in the Title 24 rulemaking. AccurIC, a manufacturer of LED drivers and a member of the IEEE PAR1789 committee, supported the CEC's efforts in a comment letter dated January 5, 2015 and agreed that the proposed JA10 test procedure would be suitable to test LED lamps for adherence to the proposed flicker standard.[4] Arnold Wilkins, a Professor at the University of Essex and member of the IEEE committee developing flicker standard PAR1789, commented to the CEC docket on February 4, 2015, stating that it was a "major innovation" to at least begin requiring the collection of raw flicker test data.[5]

To summarize, we encourage EPA to update the testing guidance used in the ENERGY STAR Lamps Specification and Recommended Practice for the Measurement of Light Source Flicker to align with JA10. We also recommend that EPA publish the reported percent flicker and flicker index values for the "raw" (unfiltered) measurement data, as well as the percent flicker and flicker index values at different cut-off frequencies, for all lamps. These data will be extremely valuable for incentive programs and market transformation efforts, if made available. These recommendations are also valid for the ENERGY STAR Luminaires Specification. We would welcome the opportunity to discuss in more detail any of the proposals contained herein regarding flicker testing and the processing and reporting of flicker data.

2. **We recommend that EPA adopt higher minimum power factor requirements.**

We recommend EPA adopt a minimum power factor requirement of 0.9. Improving power factor is cost-effective and has significant financial and greenhouse gas benefits for consumers.

Among LEDs, there are over 2,000 products in the Qualifying Product List (more than half of the LEDs) with reported power factor above 0.9. In testing of A-lamps completed by the California Lighting Technology Center for PG&E in 2012/2013, the average measured power factor was 0.9; 16 of 26 products tested achieved 0.9 or greater.[6] High power factor driver performance is being provided by a wide array of driver IC manufacturers as well; there is no shortage of competition in this market. Our research found 19 different driver IC manufacturers supplying 0.90 PF drivers, including but not limited to:

- Cirrus Logic[7]
- Fairchild Semiconductor[8]
- Infineon[9]

[4] http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-11-03_workshop/comments/AccurIC_Ltd_Comments_Regarding_the_Proposed_Voluntary_California_Quality_LED_Lamp_Specification_2015-02-06_TN-74475.pdf

[5] http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-11-03_workshop/comments/University_of_Essex_-_Arnold_Wilkins_Comment_re_2016_Building_Standards_Update_2015-02-04_TN-74467.pdf

[6] http://cltc.ucdavis.edu/sites/default/files/files/publication/140609-report-omni-directional-led-replacement-lamps_rev140807.pdf

[7] http://www.cirrus.com/en/pubs/proDatasheet/CS1610-11-12-13_F6.pdf

[8] https://www.fairchildsemi.com/datasheets/FL/FLS3217.pdf

[9] http://www.infineon.com/dgdl/Datasheet_ICL8001G+vers+1.pdf?folderId=db3a304316f66ee801178c31a9af054a&fileId=db3a3043271faefd01273dce7b0e68f6

- NXP[10]
- Power Integrations[11]
- Texas Instruments[12]
- Toshiba[13]

Based on informal conversations with driver manufacturers, incremental cost to manufacturers to improve LED lamp power factor to 0.90 power factor can be negligible. Depending on the strategy utilized, some estimates are as low as several cents or less on a per lamp basis, with the primary cost coming from a slight increase in the silicon area in the chip used for power factor correction circuitry. To investigate claims that the incremental manufacturer cost for power factor correction is negligible, the IOU team has collected power factor data from products in the ENERGY STAR product database and the Lighting Facts Database, and matched these products to over 1,000 price points collected from online retail sites. Based on analysis of these data, high power factor products do not appear to carry a significant price premium relative to lower power factor products. In fact, based on price points for over 500 replacement lamps in the 500 – 900 lumen range, average online prices for high power factor (≥0.90) LED replacement lamp products are actually slightly lower ($22.64), than the prices for lower power factor (<.90) products ($23.47). This suggests that any incremental manufacturer cost associated with 0.90 power factor is negligible. Especially when considering the economic benefits associated with improved power factor to California consumers through both a reduction in customer-side resistive losses as well as utility-side power factor correction needs, power factor improvements are cost justified.

Among CFLs, high power factor (0.85 or greater was historically considered "high power factor", often shortened as "HPF") is common in non-integrated CFL lamp and ballast systems in the United States. It is less common among integrated CFLs; most integrated CFLs have very low power factors, in the range of 0.5 to 0.6. However, in the earlier days of the American CFL market, most major manufacturers offered CFLs with power factor correction, and some still do.[14] Other countries have promoted or adopted policy initiatives to encourage or require high power factor in CFLs, and these products are therefore available from a number of major manufacturers at competitive prices in other markets. For example, in the European Union (EU), high power factor is common in higher wattage CFL products (above 25W), as explained in product literature from GE, which references EU's high power factor requirements.[15] India is another market that has a large presence of high power factor CFLs, including many residential, lower wattage product lines, for example the Philips Tornado HPF line.[16] Initial research conducted by the IOU team found that there is a wide variety of high power factor CFL products offered at popular Indian online retailers, such as flipkart.com, and that these products are offered at prices that are comparable to low power factor product prices. Appendix B includes the data collected by the IOU team from flipkart.com. When analyzing the potential impacts of strengthened power factor requirements for CFLs, we encourage EPA to draw data from these and other international markets (where products are produced in large quantities) as a reference point for product performance and costs, given that residential, integrated high power factor CFL products in the U.S. are not common.

Improving power factor yields significant societal benefits, in the form of cost savings for electric utility customers and reduced greenhouse gasses. A load with a low power factor draws more current than a load

[10] http://www.nxp.com/products/lighting_driver_and_controller_ics/ac_led_driver_ics_dimmable/SSL21082T.html
[11] http://led-driver.power.com/products/lytswitch-family/lytswitch-4/
[12] http://www.ti.com/product/tps92075
[13] http://www.toshiba.com/taec/components/Datasheet/TC62D902FG.pdf
[14] http://www.tcpi.com/business/products/lamps/cfls/tcp/springlamp-high-power-factor
[15] http://www.gelighting.com/LightingWeb/emea/images/CFL_Integrated_Spiral_T4_HPF_Lamps_Data_sheet_EN_tcm181-12649.pdf
[16] http://www.lighting.philips.com/main/prof/lamps/compact-fluorescent-integrated/energy-saver-specialties/tornado/929689431901_EU/product

with a high power factor for the same amount of useful power transferred. Higher currents mean increased resistive power losses both on the customer side of the meter, and on the utility side (grid losses). The losses from a small load (for example a CFL or LED lamp) with a poor power factor may be small, but losses increase exponentially as the total current increases (power loss is a function of the current squared times the resistance of the wiring). Three lamps with poor power factor on a circuit result in nine times the losses of one lamp.

Because residential electric customers are not generally charged for reactive energy (rkVAh), but for real energy (kWh), low power factor is sometimes mistakenly considered a problem only for utilities. However, grid efficiency (or lack thereof) is an integral part of electric rate design. In other words, if electric grids do not operate efficiently, rate payers will end up paying more for the energy they use, through higher rates; in addition to the losses on the customer side of the meter, in the long run consumers also pay for losses on the utility side of the meter. Given that CFLs now constitute roughly 30-40% of the screw-based GSL market,[17] and many project LEDs to achieve equal or greater market penetration in the next few years, power factor has huge implications for consumer energy bills, grid efficiency, and greenhouse gas emissions.

Another misconception about power factor is that a combination of leading and lagging power factors will cancel each other out. This is true to some extent when considering displacement power factor of linear loads, where sinusoidal current and voltage waveforms are out of phase with each other. Displacement power factor is generally associated with capacitive and inductive loads; inductive loads, like motors, have "lagging" power factor, where current lags behind voltage, while typical capacitive loads (capacitors, electronics) have "leading" power factor (where the current leads voltage). However, non-linear loads with poor power factor due to high levels to total harmonic distortion (generating distortion power factor) cannot be cancelled out by loads with lagging power factor. CFL ballasts and LED drivers are examples of such non-linear loads (i.e. they draw current in short spikes which generally do not relate to the voltage waveform). For these types of non-linear loads, the combination of leading and lagging power factors will not cancel each other out predictably, consistently or effectively. Additionally, there is no displacement effect unless the two types of linear-load equipment within a given metered circuit operate at exactly the same time. The low incidence of concurrent operation is rarely considered when the displacement argument is made.

Given the low cost of power factor correction at the end use as compared to correcting for poor power factor on the utility grid, we recommend that the ENERGY STAR Lamps Specification increase the power factor criteria to 0.9. This assures that both power factor is high and that total harmonic distortion is low. A high power factor specification in ENERGY STAR harmonizes well with utility objectives in specifying ENERGY STAR for both consumer amenity and utility grid efficiency.

3. Other Recommendations

The ENERGY STAR Product Specification for Lamps Version 2.0 has made a number of improvements that we support, including:

- We support the broadening the scope to include color tunable and communicating lamps
- We support the move to requiring an R9 value of 0 or higher and would recommend that EPA evaluate the impacts of setting a higher minimum R9 value of 50 (at least for LEDs) to align with the CEC Spec.
- We recommend that EPA consider adoption of 90CRI (at least for LEDs) to align with the CEC Spec.

[17] http://www.nema.org/news/Pages/Compact-Fluorescent-Lamp-Shipments-Continue-to-Lag.aspx

- We support dropping the start time to 0.5 seconds; this improves the user experience of lamps and is achievable for most products on the market.
- The proposed efficacy level would be difficult for many current CFLs (particularly those below 900 lumens and specialty CFLs) to meet, and there is little room for improvement beyond current CFL efficacy levels. EPA should consider setting different efficacy levels by lumen bin or set different efficacy levels for LEDs and CFLs. EPA should not set efficacy levels so high that CFLs could not meet them.
- We would also like to highlight and commend EPA for removing the exception for omni-directional lamps less than 10 Watts to be rated using the ambient temperature test without being labeled “not for use in totally enclosed or recessed fixtures.” The new specification would require all lamps that would not have this disclaimer to be tested using the elevated temperature test. This is important so that we can, in good faith, indicate to our customers that ENERGY STAR lamps will last their rated lifetime in recessed cans and in enclosed luminaires as long as they are not labeled “not for use in totally enclosed or recessed fixtures.” A common complaint of CFL’s has been that they have not had their rated life as claimed when used in enclosed or recessed fixtures.
- In addition to the current requirements being developed, we recommend that EPA adopt a series of forward-looking specifications (higher tiers) that would become effective in future ENERGY STAR revisions. This would be valuable for manufacturers for their roadmap development.

In conclusion, we would like to reiterate our support to EPA for updating its Lamps Specification. We thank EPA for the opportunity to be involved in this process and encourage EPA to carefully consider the recommendations outlined in this letter.

Sincerely,

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Appendix A. Draft version of Title 24 Joint Appendix JA10 Flicker Test Procedure (current as of February 2015)

Joint Appendix JA10

– Test Method for Measuring Flicker of Lighting Systems and Reporting Requirements

JA10.1 Introduction

This test method quantifies flicker from lighting systems which may include all of the following components: lamps, ballasts or drivers and dimming controls. This test method measures the fluctuation of light from lighting systems and processes this signal to quantify flicker as a percent amplitude modulation (percent flicker) below a given cut-off frequency (frequency above which the signal is filtered to remove high frequency components).

JA10.2 Equipment Combinations

The test results measured using this method are specific to each combination of:

- Light source and a representative dimmer; or
- Low voltage lamp together with a representative transformer and a representative dimmer (if applicable); or
- Light source and a representative dimming control (if applicable); or
- Light source together with a representative driver, and a representative dimming control (if applicable); or
- Light source together with a representative ballast, and a representative dimming control (if applicable).

The test results measured using this method are specific to each combination of:

- Light source or lamp; and
- Dimmer or dimming control; and
- Driver or ballast (if applicable); and
- Transformer (if applicable).

If the control or transformer requires a greater load than what is provided by a single sample of the unit under test, additional load will be created by adding quantities of the identical light source, and ballast or driver if applicable on the same circuit receiving the control signal.

Flicker measurements of a phase cut dimmer controlling an incandescent line voltage lamp shall be considered representative for that dimmer with any line voltage incandescent lamp.

Flicker measurements of a phase cut dimmer controlling a transformer for low voltage incandescent lamps shall be representative only for that combination of dimmer and transformer with any incandescent lamp.

Flicker measurements of all non-incandescent lamp sources controlled by a phase cut dimmer represents only the specific combination of phase cut dimmer, ballast or driver, and lamp. These results cannot be applied to other combinations of dimmer, ballast, driver or lamp.

Flicker measurements of light sources controlled by 0-10 volt control, digital control, wireless control or powerline carrier control, the flicker measurement is specific to that combination of control type and ballast or driver and lamp. Test results of the lamp and ballast or driver combination can be applied to other systems that have another control of the same type (0-10 volt, digital etc.) providing the control signal.

JA10.3 Test Equipment Requirements

Test Enclosure: The test enclosure does not admit stray light to ensure the light measured comes only from the UUT (unit under test). Provision shall be made so the test enclosure is able to maintain a constant temperature of 25°C ±5°C.

Photodetector: The photodetector fits the International Commission on Illumination (CIE) spectral luminous efficiency curve, V(λ)within 5% (f1'<5%). The linearity of response over the measurement range shall be less than 1%. The response time of the sensor shall be 10 microseconds or less.

Signal amplifier: If a signal amplifier is needed to increase the voltage to a range appropriate for the signal recording device, the bandwidth of the signal amplifier shall be at least 20 kHz for the amplification gain required to conduct the test.

Device for data collection: Digital oscilloscope with data storage capability or similar equipment able to store high frequency data from the photodetector, at a sample rate greater than or equal to 100 kHz for a minimum record rate of greater than or equal to 2 seconds (e.g. at least 200,000 samples at 100 kHz).

JA 10.4 Flicker Test Conditions

Product wiring setup: Fluorescent ballasts shall be wired in accordance to the guidelines provided in the DOE ballast luminous efficiency test procedure in 10 CFR 430.23(q).

Product pre-conditioning: All fluorescent lamps shall be seasoned (operated at full light output) at least 100 hours before initiation of the test. Seasoning of other lamps types is not required.

Input power: Input power to UUT (unit under test), shall be provided at the rated primary voltage and frequency within 0.5% for both voltage and frequency. When ballasts are labeled for a range of primary voltages, the ballasts should be operated at the primary application voltage. The voltage shall have a sinusoidal wave shape and have a voltage total harmonic distortion (THD) of no greater than 3%.

Temperature: Temperature shall be maintained at a constant temperature of 25°C ±5°C.

Dimming levels: Measurements shall be taken within 2% of the following increments of full light output: 100%, 20%, and minimum dimming level where 100% full light output is defined as operating the light source at the maximum setting provided by the control. When the minimum light output of the systems is greater than 20% of full light output, then the flicker measurements are taken at the minimum light output. For dimming fluorescent ballasts, lamp arc power may be used as a proxy for light output for the purpose of setting dimming levels for collecting test measurements.

JA10.5 Test Procedure

Lamp stabilization: Lamp stabilization shall be determined in accordance with:

IES-LM9 for circleline, and U-tube fluorescent systems;

Code of Federal Regulations - 10 CFR 430.23(q) for linear fluorescent systems;

IES-LM66 for compact fluorescent systems and induction lighting systems;

IES_LM-79 for light emitting diode systems and

IES-LM-46 for high intensity discharge systems.

Lamp light output shall be stabilized in advance of taking measurements at each dimming level.

Recording interval: Measured data shall be recorded to a digital file with an interval between each measurement no greater than 0.00005 sec (50 microseconds) corresponding to an equipment measurement rate of no less than 20kHz.

Equipment measurement period: shall be greater than or equal to 2 seconds.

For each dimming level after the lamps have stabilized, record lighting measurements (in footcandles or volts) from test equipment with readings taken at intervals of no greater than 50 microseconds. These readings are compiled for an equipment period of no less than two seconds into a comma separated data file (*.csv).

JA 10.6 Calculations

Use CEC Flicker Data Analysis Tool to perform the following data manipulation and calculation tasks for each dimming level (100%, 20% or minimum dimming level claimed by the manufacturer):

Calculate percent amplitude modulation (percent flicker) of unfiltered data over the duration of the test for a given dimming level using the following equation:

$$\text{Percent Amplitude Modulation} = \frac{(\text{Max} - \text{Min})}{(\text{Max} + \text{Min})} \times 100$$

Where,

Max is the maximum recorded light level or voltage from the test apparatus during the duration of the test for a given dimming level.

Min is the minimum recorded light level or voltage from the test apparatus during the duration of the test for a given dimming level.

Conduct a Fourier analysis to transform data for each dimming level into the frequency domain with no gaps or manipulation of the data within the window of data selected.

Filter frequency data to evaluate the data under four additional different conditions: frequencies under 40 Hz (data above 40 Hz is set to 0), and frequencies under 90 Hz, 200 Hz, 400 Hz and 1,000 Hz.

Perform inverse Fourier transform to place data back in time domain.

Calculate percent amplitude modulation on resulting time domain data for each filtered dataset over at least half of the full sampling duration (at least one second of filtered data in the time domain).

JA 10.7 Test Report and Data Format

For all systems where reporting of flicker is required, the test data shall be submitted to the California Energy Commission in the format specified in Table JA-10.

TABLE JA-10. FLICKER DATA TO BE RECORDED AND SUBMITTED TO THE CALIFORNIA ENERGY COMMISSION	
Data	Units/Format

TABLE JA-10. FLICKER DATA TO BE RECORDED AND SUBMITTED TO THE CALIFORNIA ENERGY COMMISSION	
Data	Units/Format
Test Date	2 comma separated data values: Date, and: mm/dd/yyyy
Test Operator	5 comma separated data values: Test Operator, and: Company, Contact Name, Phone Number, e-mail address
Entity submitting results	5 comma separated data values: Entity submitting results, and: Company, Contact Name, Phone Number, e-mail address
Product submitted for certification	5 comma separated data values: Product for certification, and: Product type (dimmer, ballast or driver, lamp etc.) manufacturer, model number, other description
Tested lighting system component: Dimmer	5 comma separated data values: Dimmer, and: Manufacturer, model number, other description (enter NA if not applicable)
Tested lighting system component: light source (lamp or light engine)	4 comma separated data values: Light source, and: Manufacturer, model number, other description
Tested lighting system component: Ballast or Driver	5 comma separated data values: Ballast or Driver, and: Manufacturer, model number, other description (enter NA if not applicable also applies to integral lamps)
Recording interval	sec (no greater than 0.00005 sec)
Count of data points	2 comma separated data values: Count of data points: number of measurements, no less than 40,000.
Equipment Measurement Period	sec (no less than 2 seconds)
Nominal Percent of Light Output Header	4 comma separated text values: Nominal percent of maximum output, 100%, 20% and minimum rated light output.
Fraction of rated light output integrated over measurement period at 100%, 20% and minimum fraction of light output.	4 comma separated data values: Fraction of rated light output integrated over measurement period at 100%, 20% and minimum fraction of light output.
Amplitude modulation separator	Text string: “Amplitude modulation: unfiltered, 1,000 Hz, 400 Hz, 200 Hz, 90 Hz, 40 Hz for the following fractions of full light output: 100%, 20% and minimum fraction of light output”
Amplitude modulation unfiltered	4 comma separated data values: calculated percent amplitude modulation unfiltered for each dimming level (100%, 20% and minimum fraction of light output)
Amplitude modulation with 1,000 Hz cut-off	4 comma separated data values: calculated percent amplitude modulation, data filtered with a 1,000 Hz cut-off frequency for each dimming level: (100%, 20% and minimum fraction of light output)

TABLE JA-10. FLICKER DATA TO BE RECORDED AND SUBMITTED TO THE CALIFORNIA ENERGY COMMISSION	
Data	Units/Format
Amplitude modulation with 400 Hz cut-off	4 comma separated data values: calculated percent amplitude modulation, data filtered with a 400 Hz cut-off frequency for each dimming level: (100%, 20% and minimum fraction of light output)
Amplitude modulation with 200 Hz cut-off	4 comma separated data values: calculated percent amplitude modulation, data filtered with a 200 Hz cut-off frequency for each dimming level: (100%, 20% and minimum fraction of light output)
Amplitude modulation with 90 Hz cut-off	4 comma separated data values: calculated percent amplitude modulation, data filtered with a 90 Hz cut-off frequency for each dimming level: (100%, 20% and minimum fraction of light output)
Amplitude modulation with 40 Hz cut-off	4 comma separated data values: calculated percent amplitude modulation, data filtered with a 40 Hz cut-off frequency for each dimming level: (100%, 20% and minimum fraction of light output)
Raw data separator	Text string: “Unfiltered raw photometric data for the following fractions of full light output: 100%, 20% and minimum fraction of light output”
Raw Photometric Flicker Waveform (unfiltered) at 100%, 20% and minimum fraction of light output.	4 comma separated data values per row, with the number of rows being the number of data points taken during the test duration. Each row contains the measurement for the unit under test at the following dimmed conditions: 100%, 20% and minimum fraction of light output

Appendix B. Price data collected from Indian retailer flipkart.com for high power factor and low power factor CFLs. Conversion rate utilized was 62.12 Rupees to the Dollar (current as of 2/17/2015)

Date Price Collected	Manu-facturer	Product Name	Power Factor	Watt-age	Base Type	Sku Price (Rupees)	Units per Sku	Price per Unit (Rupees)	Price Per Unit (U.S. $)
2/17/2015	Eveready	Eveready 5 Watt Mini Combo Pack CFL Bulb	HPF	5	b22	222	2	111	$1.78
2/17/2015	Eveready	Eveready 8 Watt Mini Combo Pack CFL Bulb	HPF	8	b22	234	2	117	$1.87
2/17/2015	Eveready	Eveready 15 Watt CFL Bulb	HPF	15	b22	225	2	112.5	$1.80
2/17/2015	Havells	Havells DU 5 Watt B-22 Cool Day Light HPF CFL Bulb	HPF	5	B22	420	3	140	$2.24
2/17/2015	Havells	Havells DU 5 Watt B-22 Warm HPF CFL Bulb	HPF	5	b22	427	3	142.3	$2.28
2/17/2015	Havells	Havells TU 8 Watt B-22 Cool Day Light HPF CFL Bulb	HPF	8	b22	328	2	164.0	$2.62
2/17/2015	Havells	Havells T3 Spiral 15 Watt B-22 CDL HPF CFL Bulb	HPF	15	b22	469	2	234.5	$3.75
2/17/2015	Havells	Havells T3 Spiral 20 Watt B-22 WW HPF CFL Bulb	HPF	20	b22	523	2	261.5	$4.18
2/17/2015	Havells	Havells TU 20 Watt B-22 Cool Day Light HPF CFL Bulb	HPF	20	B22	375	2	187.5	$3.00
2/17/2015	Havells	Havells T3 Spiral 23 Watt B-22 CDL HPF CFL Bulb	HPF	23	b22	545	2	272.5	$4.36
2/17/2015	Philips	Philips ESSENTIAL HPF B22 8W CFL Bulb	HPF	8	b22	140	1	140.0	$2.24
2/17/2015	Philips	Philips TORNADO HPF E14 8W CFL Bulb	HPF	8	E14	255	1	255.0	$4.08
2/17/2015	Philips	Philips GENIE HPF B22 11W CFL Bulb	HPF	11	B22	150	1	150.0	$2.40
2/17/2015	Philips	Philips GENIE HPF E27 11W CFL Bulb	HPF	11	e27	190	1	190.0	$3.04
2/17/2015	Philips	Philips TORNADO HPF E27 11W CFL Bulb	HPF	11	E27	265	1	265.0	$4.24
2/17/2015	Philips	Philips TORNADO HPF B22 15W CFL Bulb	HPF	15	B22	220	1	220.0	$3.52
2/17/2015	Philips	Philips TORNADO HPF B22 15W E27 CFL Bulb	HPF	15	B22	204	1	204.0	$3.26
2/17/2015	Philips	Philips TORNADO HPF B22 20W CFL Bulb	HPF	20	B22	209	1	209.0	$3.34
2/17/2015	Philips	Philips ESSENTIAL HPF B22 23W CFL Bulb	HPF	23	b22	250	1	250.0	$4.00
2/17/2015	Philips	Philips ESSENTIAL HPF E27 23W CFL Bulb	HPF	23	e27	250	1	250.0	$4.00
2/17/2015	Philips	Philips TORNADO HPF B22 23 W CFL Bulb	HPF	23	B22	248	1	248.0	$3.97
2/17/2015	Philips	Philips TORNADO HPF E27 23W CFL Bulb (White)	HPF	23	E27	290	1	290.0	$4.64
2/17/2015	Eveready	Eveready 27 Watts Spiral Combo Pack CFL Bulb	LPF	27	b22	439	2	219.5	$3.51
2/17/2015	Philips	Philips GENIE B22 11W CFL Bulb	LPF	11	b22	158	1	158.0	$2.53
2/17/2015	Philips	Philips TORNADO E14 11w CFL Bulb	LPF	11	e14	275	1	275.0	$4.40
2/17/2015	Philips	Philips Tornado 15 Watts CFL Bulb	LPF	15	b22	261	1	261.0	$4.18
2/17/2015	Philips	Philips ESSENTIAL B22 23W CFL Bulb	LPF	23	b22	180	1	180.0	$2.88
2/17/2015	Philips	Philips Tornado B22 23 W CFL Bulb	LPF	23	B22	240	1	240.0	$3.84
2/17/2015	Philips	Philips TORNADO E27 23W CFL Bulb	LPF	23	e27	290	1	290.0	$4.64
2/17/2015	Philips	Philips Tornado 27 Watts CFL Bulb	LPF	27	b22	310	1	310.0	$4.96
2/18/2015	Wipro	Wipro 15 Watt Combo Pack CFL Bul	LPF	15	b22	433	3	144.3	$2.31