The Narragansett Electric Company
d/b/a National Grid

Street Light Metering Pilot
Final Report

November 21, 2017

RIPUC Docket No. 4513

Submitted to:
Rhode Island Public Utilities Commission

Submitted by:
nationalgrid

Filing Letter

nationalgrid

Robert J. Humm
Senior Counsel

November 21, 2017

VIA HAND DELIVERY & ELECTRONIC MAIL

Luly E. Massaro, Commission Clerk
Rhode Island Public Utilities Commission
89 Jefferson Boulevard
Warwick, RI 02888

RE: Docket 4513 – In Re: Proceeding to Establish a Pilot Metering Proposal for Municipal-Owned Streetlights
National Grid's Final Report

Dear Ms. Massaro:

Enclosed please find National Grid's[1] Street Light Metering Pilot Final Report in the above-referenced docket. At the direction of the Public Utilities Commission (PUC), National Grid conducted a pilot metering program for municipal-owned street lights (the Pilot) to address (1) meter accuracy, (2) integration of meters with National Grid's billing system, (3) a comparison of metered rates to unmetered rates, and (4) cost allocation. The Pilot included a two-stage process, with each stage comprised of two phases. Stage 1-Phase 1 called for laboratory testing of networked lighting control integrated circuit metering devices, or "nodes." Stage 1-Phase 2 provided for field testing of networked meter nodes in collaboration with the Rhode Island Department of Transportation. Stage 2-Phase 1 involved the determination of how information collected from the meter nodes could be accurately and securely integrated into National Grid's Information Systems (i.e., its meter data management and billing systems). Stage 2-Phase 2 focused on a comparative analysis of the metering data compared to National Grid's unmetered consumption calculations and the preparation of a final report on the results of the Pilot.

The Final Report summarizes the results for Stage 1-Phases 1 and 2, as well as Stage 2-Phase 2.[2] The general conclusion reached through the accuracy testing phases of the Pilot is that the network lighting controls did not meet the accuracy measurement tolerance criteria established by the American National Standards Institute (ANSI) C12.20 for revenue grade meters. Prior to the adoption of nodes and supporting network infrastructure use for street lighting metering, appropriate ANSI industry accepted testing protocols must be available to qualify the specified revenue grade accuracy

[1] The Narragansett Electric Company d/b/a National Grid (National Grid).

[2] Although National Grid initially worked to understand and recognize the Information System impacts associated with the application of the new metering technology, the assessment proved much more complicated and time-consuming than originally estimated, resulting higher costs and a more expanded schedule than originally proposed. As a result, on March 10, 2017, the PUC suspended Stage 2-Phase 1 through the completion of the Stage 1 testing.

280 Melrose Street, Providence, RI 02907
T: 401-784-7415 ■ robert.humm@nationalgrid.com ■ www.nationalgrid.com

of the integrated circuit meters. Thus, after completing the laboratory and field testing, National Grid has a number of concerns with using metered devices for street light billing at this point. Based on the observation that unmetered calculations performed comparably to the control device measurements, it appears that using the unmetered calculation method for billing remains a less expensive way to achieve similar results.

Thank you for your attention to this matter. If you have any questions, please contact me at 401-784-7415.

Very truly yours,

Robert J. Humm

Enclosure

cc: Docket 4513 Service List
Leo Wold, Esq.
Steve Scialabba, Division

Certificate of Service

I hereby certify that a copy of the cover letter and any materials accompanying this certificate was electronically transmitted to the individuals listed below.

The paper copies of this filing are being hand delivered to the Rhode Island Public Utilities Commission and to the Rhode Island Division of Public Utilities and Carriers.

____
Joanne M. Scanlon

November 21, 2017
Date

Docket No. 4513 - National Grid – Streetlight Metering Pilot Proposal
Service List updated 1/20/17

Name/Address	**E-mail Distribution**	**Phone**
Raquel Webster, Esq. National Grid 280 Melrose Street Providence, RI 02907	Raquel.Webster@nationalgrid.com; celia.obrien@nationalgrid.com; Robert.Humm@nationalgrid.com; Joanne.scanlon@nationalgrid.com; Jeanne.lloyd@nationalgrid.com; John.walter@nationalgrid.com;	781-907-2121 401-784-7288
Leo Wold, Esq Dept. of Attorney General 150 South Main St. Providence, RI 02903	Lwold@riag.ri.gov; Jmunoz@riag.ri.gov; dmacrae@riag.ri.gov; joseph.shilling@dpuc.ri.gov; Al.contente@dpuc.ri.gov; Steve.scialabba@dpuc.ri.gov;	401-274-4400 Ext. 2218
Richard Hahn Daymark Energy Advisors One Washington Mall, 9th floor Boston, MA 02108	rhahn@daymarkea.com;	
Seth H. Handy, Esq. (for RILCT / WCRPC) HANDY LAW, LLC 42 Weybosset Street Providence, RI 02903	seth@handylawllc.com; lightsmart@tds.net;	401-626-4839
Brian Daniels, Executive Director RI League of Cities and Towns (RILCT) One State St., Suite 502 Providence, RI 02908	bdaniels@rileague.org; peder@rileague.org;	401-272-3434
Jeff Broadhead, Executive Director Washington County Regional Planning Council (WCRPC) 344 Main St., Suite 202 Wakefield, RI 02879	jb@wcrpc.org;	401-792-9900
Chris Kearns, Chief Program Development	Christopher.Kearns@energy.ri.gov;	401-574-9113

FINAL REPORT

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I. Abstract

The Narragansett Electric Company d/b/a National Grid (National Grid) conducted a multi-faceted study to investigate networked lighting control (node or NLC) solid state integrated circuit meter accuracy and the operational performance of the integral wireless communication networks and data management systems pursuant to Rhode Island Public Utilities Commission (PUC) Report and Order No. 22413 issued on May 20, 2016 in Docket No. 4513.

The metering pilot project included the following objectives: gauge meter accuracy; integrate meter technology with National Grid's billing system; compare the investment and implementation of NLC meter technology to unmetered rates; and the allocation of associated costs.

The project scope included two unique testing stages, each subdivided into two phases to isolate and assess independent device meter accuracy, network communication operational performance, data transmission accuracy, comparative in-service metering field application performance, and an assessment of programming costs and scheduling required for Information System interfaces to integrate NLC street light metering into existing billing services.

Stage 1 involved meter accuracy testing, which occurred in the following two phases: (1) a controlled laboratory environment, and (2) in the field. Stage 1-Phase 1 meter accuracy testing in a controlled laboratory environment maintained compliance with the American National Standards Institute (ANSI) C12.20 meter testing industry standards to the greatest extent possible utilizing National Institute of Standards and Technology certified testing equipment. The testing included laboratory "Meter Farm" configuration to observe the operational performance of a simulated complete network application, which included the use of various light emitting diode (LED) luminaires to promote actual operating electrical load conditions. Stage 1-Phase 2 meter testing occurred within designated locations provided by the Rhode Island Department of Transportation (RIDOT) to further qualify and assess the operational performance and meter viability in real-world conditions. The testing within RIDOT's network is also referred to as field testing. This in-service network application provided National Grid with the ability to perform a comparison of the integrated circuit metering from the nodes with existing automated meter reading from the encoder receiver transmitter "standard" meter technology. Stage 2 of the pilot project, to assess the estimation of costs and schedule to integrate the proposed street light metering data into National Grid's various Information Systems to achieve metered street light billing, has been suspended by the PUC until the completion of the laboratory and field testing as a result of an increase in time, costs, and complexity than originally anticipated.

The conclusions represent a commentary on the present state of the various technologies associated with the networked integrated circuit metering application, the business transitions

occurring within the outdoor lighting market segment, and the various external forces conflicting with the utility-oriented outdoor lighting business paradigm.

To effectively implement the networked meter technology contemplated in the pilot program, industry standards are needed to establish accepted testing protocols to support the utility industry's required definition of revenue grade metering for street lighting and associated attachment applications. Utilities, in collaboration with their regulators and other stakeholders, should work to establish approved performance thresholds and standardized qualification requirements. The baseline metric requirements established by the industry would then govern the entities providing and utilizing the associated technologies.

Under National Grid's pilot program, the integrated circuit meter technology received and tested from the various manufacturers generally performed adequately enough to provide reasonable energy consumption measurement values. However, the testing results indicated that the current marketing of integrated circuit meter technology as "revenue grade" compliant is not completely accurate. The laboratory testing results demonstrated significant accuracy performance variability between manufacturers in addition to notable variance between individual devices from the same manufacturer. These levels of inconsistency may be addressed by the manufacturers as industry standards are adopted and compliance requirements are established by the end-user community.

National Grid's study found that both the communication network operations and the proprietary head-end software present a diverse array of challenges to overcome before the data management hosting or data transmissibility, as it will be associated with an end-user interface process, can be described as user-friendly. Many concerns became apparent when meter data information received from the variable operating schedule testing in the laboratory Meter Farm application presented meter read data inconsistencies, timing anomalies, and inexplicable and random data gaps.

The comparative findings associated with the node's integrated circuit and standard automated meter reading meter technologies assessment from the in-service field application identified that the current utility unmetered consumption model provides a reasonable determination of energy consumption as compared to the consumption measurements provided through the use of existing standard metering of the entire street lighting circuit or the aggregation of the individual node meters. In consideration of the complexities associated with required Information System interface programming and the total costs of procurement, deployment, and operating a networked meter system, at this time the more economic approach would be to employ additional unmetered billing metrics to the existing billing system and utilize individual static dimming or part-night photoelectric controls to achieve the desired luminaire operations.

II. Acknowledgements

National Grid completed the street light metering pilot project under the direction of John Walter, Principal Engineer – Outdoor Lighting for National Grid and managed by Edward Bonetti, Project Manager (Retired) for National Grid. Principal investigator for the project was John Williams, Senior Engineer for The Eastern Specialty Company (TESCO), a subsidiary of Advent Design Corporation. Lead analyst for billing and Information Systems on the project was Eric Russell, Senior Analyst – Bill Project Management and Services for National Grid.

The following individuals and companies also contributed their expertise, collaboration, and timely support to achieve the objectives of this project: Larry Durante and Susan Rodriguez of National Grid; Michael Poplawski of Pacific Northwest National Laboratory; TESCO; Rhode Island Department of Transportation; Cimcon Lighting Inc.; Sunrise Technologies; SELC Ireland Limited; Silver Spring Networks; Florida Power & Light; Georgia Power; San Diego Gas & Electric; and Light Smart Energy Consulting, LLC.

III. List of Abbreviations

A	Amperes
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
ANSI	American National Standards Institute
CSS	National Grid Customer Service System
DALI	Digital Addressable Lighting Interface
DCU	Data Concentration Unit (a.k.a. "Gateway" or "Access Point")
ERT	Encoder Receiver Transmitter
FPL	Florida Power & Light
FSU	Field Service Unit
HID	High Intensity Discharge
Hz	Hertz, (a unit measure of frequency)
IC	Integrated Circuit
IR	Infrared
IS	Information Systems
MOU	Memorandum of Understanding
MTB	Meter Test Board
LED	Light Emitting Diode
NIST	National Institute of Standards and Technology
NLC	Network Lighting Control (a.k.a. "node" or "device")
OER	Rhode Island Office of Energy Resources
PC	Personal Computer
Pf	Power factor
PNNL	Pacific Northwest National Laboratory (US Department of Energy affiliate)
PUC	Rhode Island Public Utilities Commission
RFI	Request for Information
RIDOT	Rhode Island Department of Transportation
SDG&E	San Diego Gas & Electric
SOW	Statement of Work
SSN	Silver Spring Networks
TESCO	The Eastern Specialty Company
THD	Total Harmonic Distortion
V	Volts
VA	Volt-Amperes
W	Watts

Wh	Watt-hour
XML	Extensible Markup Language

IV. List of Attachments

1. RI Street Light Metering Pilot Project - IC Meter Testing (TESCO RFI Response)
2. Photocell Node Bench Testing - Project 8594
3. MTB Calibration Report - 4/21/2015
4. MTB Calibration Report - 4/20/2016
5. Radian Research Inc. Certificate of Calibration
6. Photocell Node Meter Farm Testing - Project 8594
7. Photo Cell Meter Test Equipment
8. National Grid Panel
9. Wire Trough Assembly – Bottom Row
10. Meter Farm Testing Data Final Report
11. Meter Farm Schedule Graphs
12. RI-DOT Selected Sites
13. RIDOT- Frenchtown Road Park & Ride - PROPOSED TEST OPERATING SCHEDULE
14. Frenchtown Road Park & Ride - Working Schedule
15. Street Light Metering Pilot – IS Effort
16. RI-DOT Sites (Burn Hour Calcs)
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1. Pilot Project Overview

On July 15, 2013, Rhode Island enacted the Municipal Streetlight Investment Act, R.I. Gen. Laws § 39-30-1, *et seq.* (the Act), to allow Rhode Island cities and towns to purchase the public street lights owned by National Grid within their municipal boundaries. On October 31, 2014, the PUC approved National Grid's filing to implement its Street and Area Lighting – Customer Owned Equipment S-05 tariff, currently RIPUC No. 2179 (the S-05 Tariff), in Docket No. 4442. *See* PUC Report and Order No. 21704. The PUC initially addressed the issue of metering technology as part of Docket No. 4442. To achieve greater energy cost savings, municipalities want to implement advanced network control technology to remotely program the variable operating schedule of new solid state LED luminaires. Such lighting control technology could help the functionality, compliancy, and simplicity of wireless networked lighting control systems to provide an accurate energy consumption measure through the use of the on-board revenue-grade integrated circuit meter technology. Additionally, the availability of funding resources through various energy efficiency-related programs, such as those provided by National Grid and the Rhode Island Office of Energy Resources (OER), supported the early adoption of the control technology. Early in the process of municipalities being able to purchase their street lights from National Grid, municipalities expressed an interest in using aggregated street light node meter readings for the purpose of utility billing for the electric energy consumed, which was not an option at the time. In Docket No. 4442, "the PUC found that the evidence in the record did not support a finding of significant savings from metering," but "recognized that the cities and towns believe they will be able to achieve sufficient additional savings through investment in metering technology at the same time as a change-out of the lighting controls." PUC Report and Order No. 21704 at 44. Accordingly, on July 25, 2014, the PUC opened Docket No. 4513 to establish a pilot metering program for the municipal-owned street lights (the Pilot). The PUC indicated that the goals of the Pilot should, at a minimum, address meter accuracy, integration with the billing system, a comparison of metered to unmetered rates, and cost allocation.

On October 23, 2014, National Grid proposed the initial Pilot scope and schedule in this docket. National Grid's proposal created a plan to (i) evaluate the meter manufacturer's laboratory test results; (ii) confirm the claims of the meter manufacturers through testing by National Grid in a controlled environment using sample sizes of each meter to provide a statistically significant result; (iii) evaluate the technical and communication capabilities of each meter; and (iv) select successful meter candidates for field testing with communications in a sample selected to provide statistically significant results.

On March 23, 2015, following an extensive exchange of commentary and recommended modifications, including the completion of a municipal customer survey to assess the level of potential municipality participation meeting specific infrastructure and scheduling requirements and a technical session with all parties, National Grid filed a revised Pilot scope and schedule. The PUC initiated further data requests from all parties to qualify the Pilot's testing structure, processes, schedule, and cost estimate to achieve the intended objectives. On July 1, 2015, the PUC approved National Grid's Pilot, with certain modifications, after nearly a year of negotiation and discussion with Rhode Island municipalities and OER regarding the scope and costs of the Pilot. On July 27, 2015, National Grid filed a second revision to the Pilot in compliance with the PUC's July 1, 2015 Open Meeting decision.

The final approved Pilot established a two-stage process, with each stage comprised of two phases. Stage 1-Phase 1 called for laboratory testing of integrated circuit metering devices. Stage 1-Phase 2 provided for field testing of networked meter nodes to be installed as part of a separate pilot project by RIDOT. Stage 2-Phase 1 involved the determination of how information collected from the meter nodes could be accurately and securely integrated into National Grid's Information Systems (i.e., its meter data management and billing systems). Stage 2-Phase 2 would be a comparative analysis of the metering data compared to National Grid's unmetered consumption calculations and the preparation of a final report on the results of the Pilot. Beginning August 19, 2015, National Grid assigned a project manager to the Pilot to oversee and manage the various aspects of the Pilot. National Grid also began drafting memorandum of understanding agreements and confidentiality and nondisclosure agreements for all participating parties.

Throughout Stage 1 of the Pilot, a number of aspects of the Pilot took far longer than planned and cost more than expected for reasons outside of National Grid's control. First, initial program administrative requirements to establish memorandum of understanding agreements and execute procurement transactions for the products and services necessary to achieve the established objectives took longer than the planned schedule. Further delays occurred regarding issues related to the specification of node performance criteria and vendor production, re-calibration, and delivery. The Pilot experienced secondary technical problems associated with node network interfacing and meter data retrieval from the network service provider's head-end software. Additional significant delays occurred due to the length of time it took RIDOT to provide an executed memorandum of understanding for RIDOT's participation in the Pilot and the definitive lighting location and operating schedule applications to be tested.

Before testing occurred, National Grid conducted a rigorous investigation of testing firms having the capability and qualifications to perform the anticipated industry standard testing of the node's integrated circuit meters. National Grid's extensive investigation identified The Eastern Specialty Company (TESCO) as the most qualified independent meter testing firm to perform the various platforms of tests. In conjunction with the search for the independent testing vendor, National Grid attempted to acquire the integrated meter manufacturer's performance test results typically produced by an independent testing laboratory to qualify the meters. The initial investigative search proved unsuccessful, so National Grid requested similar independent testing documentation from the vendors from which National Grid planned to acquire the nodes for future testing. However, National Grid's second request also proved unsuccessful, except for one vendor's internal quality assurance and quality control testing program results.

The valuable collaboration between TESCO, Pacific Northwest National Laboratory, and National Grid led to the development and execution of the testing plan associated with each phase of the Pilot. National Grid performed additional research and made inquiries to other utilities across the country that currently engaged in the application and utilization of networked street lighting control systems. National Grid interviewed personnel from Florida Power & Light, Georgia Power, and San Diego Gas & Electric regarding relevant topics such as technology deployment, functional operations, schedule control utilization, network performance, metrology quality, and integration with established billing practices and systems. Having the perspective of other utilities in the industry using networked lighting controls in addition to TESCO's in-depth knowledge of current metrology industry testing standards and practices, and in conjunction with conversations with other industry representatives directly involved with the ongoing development of industry metrology standards associated with the developing node technology, helped assist in establishing the testing protocols adopted for the Pilot. The determination of acceptable industry testing protocols finalized the testing requirement criteria necessary to complete the design and fabrication of the test panels used in the controlled testing environments.

1.1. Bench Testing (Stage 1-Phase 1)

The laboratory metrology testing focused on the meter reading performance of the integrated circuit metrology technology (chip) used within each vendor's node. The testing protocols administered during this testing phase adhered, when applicable, to industry accepted meter testing standards defined by ANSI C12.20. The scope of several defined testing protocols was expanded to increase or decrease the various critical test criteria in an effort to observe the integrated circuit metrology performance when exposed to certain extreme circumstances. The benefits of the expanded application included the exposure and awareness of important considerations and specification criteria to be addressed by consumers at the time of network lighting control system procurement. Throughout the laboratory and meter farm testing phases, the accessibility of metrology data through the network service provider's head-end software proved challenging and often required individual network service provider data exchange and/or alternate data interface devices.

1.2. Meter Farm Testing (Stage 1-Phase 1)

The meter farm testing simulated the operation experience and functionality of the entire network control system managing multiple node's operating under different usage schedules. The meter farm testing protocols incorporated the use of various LED street light luminaires to facilitate true electrical load applications under defined operating conditions to assimilate schedules stated in the present S-05 Tariff. Additional testing was performed to assess actual power consumption characterization of various LED luminaires based on a linear dimming output/power profile. A number of observations throughout the meter farm testing identified a variety of meter data reporting concerns that would need to be addressed through a meter data management system to assure proper data corrections are made and/or analytic solutions are instituted. Additionally, based upon the nonlinear power consumption curves exhibited by the test LED luminaires at varied dimming rates, an industry accepted 0-10 volts (V) driver algorithm adjustment should be established, as appropriate, for defining unmetered billable wattage for use within the utility industry.

1.3. Field Application Testing (Stage 1-Phase 2)

The parties involved in the Pilot deemed RIDOT as an acceptable alternative to the selection of several municipalities meeting specific in-service technology requirements. Significant delays occurred during the work with RIDOT, including a lengthy delay in RIDOT providing the Memorandum of Understanding necessary to move forward with the project and changes in RIDOT's retrofit lighting and network control program technology and deployment schedule. The approximate 19 month schedule impact (August 2015-March 2017) resulted in increased project costs and added challenges with implementing the test node technology at RIDOT field sites. However, RIDOT provided value as a program partner through its existing statewide retrofit program to deploy and operate LED luminaires in addition to an installed and operating network lighting control system. Final testing implemented a rotational approach utilizing the various vendors' nodes and applying several different operating schedules from which comparisons could be made against the meter farm testing results. Additionally, RIDOT has specific street lighting locations that provided standard metered circuitry, which allowed the comparison of node meter data with standard meter data.

1.4. Information System Integration (Stage 2-Phase 1)

The implementation of the Pilot required National Grid to determine how information collected from the metering devices and associated systems could be accurately and securely integrated into National Grid's Information Systems; namely, its data management and billing systems. The purpose of the Information Systems aspect of the

Pilot was to ensure that the new street light metering technology can be incorporated into National Grid's existing Information Systems by identifying the work that will need to be done to facilitate integration. Following the assembly of the appropriate National Grid Information Systems personnel, early stages of the Information Systems interface assessment indicated that a larger and more diverse scope of National Grid's computer systems would be involved than originally anticipated. Moreover, the Information Systems requirement evaluation and the increasing awareness of meter data management issues also identified a more complex and time consuming study scope than originally anticipated. The expanding scope of the Information Systems integration caused increased delays and costs that would have resulted in a substantial increase in total project costs and schedule extension. National Grid identified these issues in Status Report No. 2 dated December 21, 2016 and in a joint report submitted with the participating municipalities dated February 17, 2017. Consequently, in March 2017, the PUC suspended the Information Systems portion of the Pilot pending the results of the network lighting control testing in Stage 1 of the Pilot.

1.5. Comparative Billing Analysis (Stage 2-Phase 2)

Upon completion of the compiled node and standard meter data results, a manual calculation of unmetered energy consumption was performed for the same luminaires and associated operating schedules. The unmetered energy calculations were then compared with both the node meter data and standard meter data captured during the RIDOT field application testing.

2. Pilot Program Background

Illumination of streets and other public spaces has existed for centuries. Until the development of the current wireless network lighting controls, the nature of street lighting having numerous and random locations, in addition to the evolution of lighting technologies utilizing combustible fuels to various electric voltages for different lighting sources, has promoted the long-standing and customer accepted unmetered approach for energy consumption measurement. The recent development of energy efficient LED, organic LED, and polymer LED solid state lighting sources provides the greatest opportunity to use alternate means to measure the decreasing energy consumption. However, the entities that provided the lighting service were responsible for establishing a reasonable cost recovery methodology to compensate for all aspects of the service, including the measurement of the energy source. In all previous lighting solutions, the measure of energy use was a relatively simple volumetric standard utilizing pre-established consumption rates for the usage period. Although each measure was recognized as an estimate, each was considered rational in contrast with any alternate methods or costs to provide a more accurate measure. The present and future market of solid state and other lighting technologies yet to be unveiled are realizing exceptional efficacy with capabilities to achieve greater efficiencies through variable output and instant on/off operation. An industry question that persists today is whether new metering technology available through the wireless network control systems is economical and/or warranted to provide a more accurate energy consumption measure in comparison with the established unmetered application.

2.1. Pilot Testing Program Justification

The recent exponential innovation in nanotechnology solid state lighting sources and varied forms of wireless communication have advanced the ability to remotely control lighting with the additional capability to meter the energy consumption. Although these advancements have received significant market notoriety from early adopters, qualification standards have not kept pace with the increasing consumer adoption. It is the purpose of this pilot program to evaluate the various metering, communication and data management functions of the current technology by performing testing under controlled conditions and in conformance with established standards.

Following the enactment of the Act and the subsequent implementation of the unmetered S-05 Tariff to accommodate the billing of municipal-owned street lights, third-party stakeholders opined that the proposed unmetered billing tariff did not insufficiently provide an accurate representation of the consumed energy relative to the use of new LED luminaire technology. Municipalities emphasized the current ability of the customer to provide National Grid with an aggregated meter reading from which an accurate bill could be rendered. The PUC found that the S-05 complied with the enacted legislation and was consistent with the long-standing unmetered approach for energy consumption billing of street lights. Additionally, the use of customer-owned metering was considered inconsistent with all current regulations established to maintain quality and assurance of revenue-grade meter performance for the purpose of providing accurate energy consumption billing. Throughout the PUC open sessions and collaborative discussions between all parties, no factual evidence was provided to assert proof of the integrated circuit meter accuracy used in the street lighting control networks or solutions to address problematic meter read anomalies. National Grid also presented concerns regarding the inability to manage the proposed street light meter reads from customers using the current meter billing functions within all related information systems. In response to the municipalities' request for a tariff that recognized the energy savings associated with variable operating schedules, including dimming and part-night operation of the LED luminaires, National Grid incorporated two unmetered annual operating schedules in addition to the original continuous and dusk-to-dawn schedules. National Grid collaborated with the municipalities to develop the new schedules to address anticipated "typical" operating performance models and account for the associated energy savings in the bill.

In an effort to provide a well informed decision on the street light metering matter, the PUC ordered National Grid to perform the street light metering pilot to ascertain factual information regarding the accuracy and performance reliability of the proposed nodes and network communication systems for energy consumption metering irrespective of meter ownership.

2.2. Network Technology Status

The node and network communication technology continues to advance, promoting more reliability, consistency, and accuracy related to energy consumption measurement and the secure transmission of the collected data. However, the lack of approved industry testing and performance standards in addition to the proprietary nature of the system communication configuration, data management architecture, and overall economics continues to present significant barriers to widespread adoption. Assurance of meter data quality, consistent read applications, and the establishment of an accepted uniform data transmission model is necessary before utilities incur considerable costs to facilitate the billing of street light energy consumption based on network lighting control meter read information.

3. Pilot Testing Program Development

The PUC's order to conduct the Pilot set forth an effort to establish a baseline of facts related to the current status of the developing integrated circuit meters and the associated node and network systems. The Pilot, as proposed by National Grid, incorporated independent testing applications for each functional segment of the system. Testing of the various individual integrated circuit meters within different vendors' nodes would identify the present state of the metering accuracy, operational capabilities, and any variances that would represent a cause for instituting industry standards for consistency. A testing phase which addresses the incorporation of multiple nodes utilizing a single communication network in a controlled environment would provide information relative to the ability of the system to achieve consistent data collection and transmission performance. The final phase would be to assess the network lighting control accuracy and consistency performance of multiple vendor nodes utilizing a single communication network in a real-world environment. The development of the pilot had to address financial and schedule constraints in addition to experiencing inherent technology limitations caused by the lack of device interoperability due to the use of proprietary systems. National Grid made significant efforts to determine and create project partnerships that would allow for the collaboration of multiple product vendors that could function together on a single network platform, facilitating a level of testing efficiency that positively impacted both cost and schedule project parameters.

3.1. Network Lighting Control Selection

The selection of the node vendors used in the testing program was determined by default, based on existing alliance agreements at the time for each of the network communication service providers being considered. The proprietary nature of the communication networks requires an individual node vendor to accommodate the distinct communication network integrated circuit board and antenna within the node's form factor. The hardware integration also requires additional programming and firmware collaboration to facilitate the compatibility of all functional elements of the various technologies. This mutual integration collaboration defined which nodes were compatible and, therefore, which respective integrated circuit meter chips would be tested. Each of the node vendors used a different manufacturer's integrated circuit meter chip for the metering function within their node. National Grid provided other technical specifications, including the desired meter accuracy rating for the respective nodes to be tested to each vendor.

3.2. Testing Vendor Selection

At the outset of the Pilot, National Grid's research found only a minimal amount of independent laboratories that had the requisite experience, proficiency, and the necessary equipment to provide the desired standard metrology testing of the new nodes. National Grid contacted numerous testing firms that expressed little or no experience with the network lighting control meters and often appeared to have only negligible awareness of the technology. National Grid performed an in-depth evaluation of eight United States and international independent metrology testing laboratories, with most demonstrating limited comprehension regarding the establishment of a suitable testing protocol and test environment. One vendor, TESCO, exhibited knowledge of the technology, expertise to develop a comprehensive testing protocol, and the capacity and capability to perform the testing. Accordingly, National Grid selected TESCO as its vendor for the Pilot. To further substantiate the selection of TESCO as the independent laboratory having the most relevant metrology testing experience and qualifications to conduct the necessary testing, TESCO's response to National Grid's Request for Information (RFI), entitled "RI Street Light Metering Pilot Project - IC Meter Testing", is attached hereto as Attachment 1.

TESCO provided added value through its experience assisting numerous utilities with their advanced metering infrastructure deployment planning and implementation. This application involved setting up certification testing protocols as well as advanced metering infrastructure functional testing protocols. TESCO has experience working with meters from L+G, Itron, Sensus, Aclara and Honeywell at over two dozen electric utilities. In addition to its electric advanced metering infrastructure experience, TESCO has evolving familiarity associated with natural gas advanced metering infrastructure meter projects. Some of TESCO's advanced metering infrastructure work involved both traditional and non-traditional testing, such as "Hot Socket" evaluation to determine the new advanced metering infrastructure meter capacity to withstand a hot socket condition compared to the non-advanced metering infrastructure installed meter population.

4. Pilot Program Testing and Results (Stage 1-Phase 1)

The Stage 1-Phase 1 portion of the testing program evaluated the functional performance of the individual node components for accuracy and the complete communication network system operating within a controlled environment tested to industry accepted standards. The scope of the Phase 1 testing had been subdivided into two testing plans, identified as (a) laboratory, or "bench", testing; and (b) meter farm, or "end-to-end", testing. The performance results of each testing plan is presented below.

4.1. Bench Testing (Stage 1-Phase 1)

The laboratory, or "bench", testing qualified all of the nodes through meter accuracy testing to confirm the individual node metrology meets the respective integrated circuit manufacturer and node vendor specifications.

4.1.1. Test Specification Development

National Grid and TESCO created the test specification protocol for the bench testing phase in accordance with accepted industry testing standards and in collaboration with Pacific Northwest National Laboratory to clearly define the testing plan that TESCO would perform and ensure its acceptance by all involved parties, including National Grid and the node vendors.

4.1.1.1. Draft Specification

The first draft of the bench testing specification defined (i) the required testing, (ii) the procedure by which the testing would be performed, and (iii) the equipment required to perform the testing. TESCO and National Grid agreed on the original statement of work. However, as the test plan continued to develop, TESCO revised the statement of work by providing detailed testing methods and specifications based on its experience at testing standard revenue-grade meters in compliance with accepted industry standards. In addition, the first draft detailed the test equipment that TESCO planned to use during the laboratory testing phase. The various test equipment regularly used by TESCO in the performance of revenue grade meter testing is calibrated and certified in compliance with the National Institute of Standards and Technology.

4.1.1.2. Adherence to Accepted Standards

TESCO based all of its testing on the industry accepted meter testing standard American National Standards Institute (ANSI) specification C12.20. The ANSI C12.20 industry standard is the widely accepted specification used to qualify and test revenue grade metering. Considering that the nodes' metrology would be used for billing purposes, the qualification testing followed the same rigorous industry metrology testing standards as other revenue grade standard meter applications.

ANSI C12.20 is generally intended for testing of revenue grade meters with quoted accuracies of 0.1% through 0.5%. Therefore, the testing specifications used accuracy limits commensurate with meter devices of that intended accuracy level. In the case of the nodes tested, National Grid and TESCO specified the three meter accuracy ranges at 0.5%, 1.0%, and 2.0%. In addition, the existing specifications refer to voltage and current limits, under which the tests are to be conducted outside of the advertised operating range of the nodes as defined by each of the three vendors. Because of the foregoing two issues, TESCO and National Grid based the Laboratory Testing Specification on ANSI C12.20, but modified it to allow for the differences associated with the types of integrated circuit meter devices that would be tested.

4.1.1.3. Alternate Utility Experiences

As part of the test procedure development, National Grid and TESCO contacted three other utilities that had programs using network lighting control devices for metering purposes similar to the Pilot. Through such communications, National Grid and TESCO inquired and learned about the testing protocols and application programs adopted or used by other utilities.

- **Florida Power and Light –Principal Engineer, Street Lights (January 14, 2016)**

  At the time of its meeting with National Grid and TESCO, Florida Power and Light had installed 95,000 out of a proposed 505,000 "smart nodes" on street lights using Florida Power and Light's current advanced metering infrastructure network, which was compatible with the selected nodes. Florida Power and Light did not use the nodes' metering capabilities and, therefore, had not integrated the available meter data into their meter data management or billing systems. The main functional purpose of the nodes in Florida Power and Light's street lighting system is to monitor high intensity discharge lamp performance (i.e., outages and day-burners) and other maintenance-related electrical system diagnostics. Florida Power and Light's existing work management system for maintenance automatically dispatches service personnel and generates service tickets based on abnormal voltage, current, or wattage readings as reported by the nodes. Florida Power and Light relies on the manufacturer to perform any required product testing and provide certified compliance reports. Additionally, Florida Power and Light reported that it has experienced problems with the nodes exhibiting an "unsearchable" condition, meaning the nodes would not communicate with the head-end system. Florida Power and Light also experienced early manufacturer production quality problems associated with the ultrasonic welds on integrated circuit component connections within the nodes.

- **San Diego Gas and Electric – Principal Engineer (February 18, 2016)**

  San Diego Gas and Electric had experienced the impacts of a major network control system deployment associated with street lighting owned by the City of San Diego. At the time of its meeting with National Grid and TESCO, San Diego Gas and Electric was investigating the capabilities of street light nodes for lighting controllability and revenue grade metering. San Diego Gas and Electric had been experiencing pressure from some municipalities that were converting to LED luminaires and wanted to bill the energy based on the network lighting control metering. San Diego Gas and Electric had started testing nodes with real loads (i.e., LED luminaires) to determine the actual energy consumption when utilizing the dimming capabilities. San Diego Gas and Electric expressed observations that at low dimming levels, the power factor and total harmonic distortion of the luminaires tested began to produce significant negative results. The meter accuracy testing performed was best described as a comparative timed test, comparing the Watt-hours collected by a known reference standard to that reported by the node during a defined time period and under a specified electrical load. The testing read the starting Watt-hours from the node and the reference meter standard, then applied a phantom load current for a period of time, reading the ending Watt-hours from the reference meter standard and the node. San Diego Gas and Electric used ANSI C12.20 as the acceptance criteria for San Diego Gas and Electric's accuracy testing for 0.5% rated class 10 meters at full load, light load, and power factor. The metering validation only assured the use of the reported energy consumption meter values. San Diego Gas and Electric did not integrate these values into its meter data management or billing systems. San Diego Gas and Electric used the meter values in conjunction with an established energy consumption operating schedule table to assign the pre-determined billing metrics to achieve the energy billing of the customer-owned street lights within its current billing system.

- **Georgia Power/Southern Company – Lead Project Engineer – Lighting & Other Lead Lighting Personnel, (February 25, 2016)**

  Georgia Power/Southern Company (Georgia Power) performed prequalification testing of selected nodes within its meter test facility. The nodes tested did not include any manufacturers selected for the Pilot due to the different proprietary network service providers used by each company. The nodes and associated proprietary communication network being tested was planned to be used solely for Georgia Power's unregulated outdoor lighting business. Georgia Power is primarily considering the node as a meter and will treat each device as it would any other standard revenue grade meter. Although it expressed a need to perform more meter accuracy testing, Georgia Power plans to use the nodes for dimming control and time-of-use metering. Georgia Power also recognizes the specific non-conformance issues with the meter testing specification in ANSI C12.20, but continues to use the standard until an alternative meter standard is approved for this type of device. Georgia Power indicted that test results and general observations were "fairly accurate" up to 10 amps, with no further details provided. Georgia Power and National Grid agree that meter accuracy should be sustained up to 15 amps in order to accommodate larger electrical loading conditions in the field. Georgia Power described its initial observations of meter accuracy at the 15 amp level as "somewhat dismal," with no further details provided. Similar to National Grid, Georgia Power also requested independent metrology accuracy testing reports and certification from the node manufacturers, as is standard with other revenue grade meters, but had never received any testing or qualification documentation. Based upon its meter testing experiences, Georgia Power indicated that all nodes should have infrared metering test pulse capability to better facilitate end-user testing. Georgia Power expressed additional concerns regarding the use of the wireless communications network to perform its accuracy testing and the problems encountered with the communication network causing excessive time requirements to observe the final test results.

4.1.1.4. Network Lighting Control Test Quantity Criteria

The following criteria determined the quantity of nodes that would be laboratory bench tested: the time to acquire the data, the time to perform all of the required tests as defined by the test specification details (see below), and the number of nodes made available to TESCO. The project schedule allocated approximately three months of laboratory bench testing time. The testing performance estimate based on National Grid required testing would consume approximately 1.5 weeks for every 4 nodes. Therefore, it was determined to test 10 nodes from each of the 4 vendors for the “Main Tests” section of the bench testing, and 4 nodes from each of the 4 vendors for the “Optional Tests” sections of the laboratory bench testing. Also, if a vendor provided more than one accuracy class of node, National Grid and TESCO tested the most accurate version of each node.

4.1.1.5. Test Parameters

In general, as stated in Section 4.1.1.2 (Adherence to Accepted Standards), above, the testing parameters and protocols would adhere as closely as possible to those presented in the most recent version of ANSI C12.20. However, the requirements were modified to (i) promote more relevant testing of parameters most useful for this Pilot, and (ii) conform the test parameters more closely to the vendor’s stated node specifications.

4.1.1.6. Test Duration

As stated in Section 4.1.1.4 (Network Lighting Control Test Quantity Criteria), above, the testing time for four nodes utilizing the full capacity of the test equipment was approximately three weeks. For reference, the testing time of standard revenue grade meters is much shorter due to the requirement that standard revenue grade meters have an electronic circuit on-board that produces an infrared pulse corresponding to a few Watt-hours. Additionally, because the reference standard is accurate to 0.00001 Watts (W), the infrared pulse is required by ANSI to be at least as accurate as the meter registers. Based on this test feature and criteria, a typical standard revenue grade meter test lasts just a few seconds. Therefore, standard revenue grade meter testing need only apply energy to the meters for the length of time it takes the meter to produce just a few infrared pulses. For three of the four node types tested, there was no infrared pulse output available for testing. TESCO and National Grid performed all bench testing without the use of the infrared pulse, so that all results from the four node types would correspond to the same test method. Considering the aforementioned decision, each of the testing methods required the local querying of the individual node Watt-hour registers at the start and end of each test time. The test results were determined by comparing the difference in node Watt-hour registers to the difference in the amount of Watt-hours measured by the reference standard.

In order to obtain the proper number of significant digits required to determine whether the nodes met the stated accuracy metric, the duration of the test had to produce at least four significant digits in the results from the node. As each node was only capable of reporting back full Watt-hours, each test was required to run until at least 1,000 Watt-hours (Wh) passed through the node and the reference standard. For example, for a node being tested at 120 volts (V) and 10 amperes (A), it would take 50 minutes to collect 1,000 Wh.

4.1.1.7. Load Current

Although ANSI C12.20 defines three classes of load testing current for standard revenue grade meters at the respective amperages – 2.5A (Class 10), 30A (Class 200), and 50A (Class 320) – National Grid specified that the nodes would be tested to the limits of the vendors stated accuracy.

The advertised current limit of each node tested was approximately 10A, based on vendor specifications stating a power rating of 1,800 volt-amperes (VA) at the time of testing. This prescribed current limit became the "Full Load" current rating used for the laboratory bench testing. A secondary justification for the 10A Full Load current rating was that National Grid believed that the nodes can and will be used in the future to meter more than just LED luminaires, including for a wide range of pole-mounted ancillary equipment.

4.1.1.8. Physical/Mechanical Tests

Due in large part to project time restrictions, the physical and mechanical testing of the nodes defined in ANSI C12.20, (i.e., tests 25 through 37) could not be performed as part of this Pilot. Such tests included, but were not limited to, vibration, temperature, and environmental (salt spray) conditions not considered critical to the meter accuracy qualifications in consideration of the established Pilot constraints.

4.1.1.9. Network Lighting Control Vendor Input

The following node specification table provides a summary of the specifications as listed in the node vendor's technical product documentation.

Table 1

Summary of Node Specification Sheets

	Vendor A	Vendor B	Vendor C	Vendor D
Voltage Range	85-264VAC. 50/60Hz (305V and 480V available)	85-264VAC. 50/60Hz (305V and 480V available)	90-320VAC (48-62Hz)	105-305VAC
Power Range	1200W/1800VA	1200W/1800VA	1200W/1800VA	1000W/1800VA
Accuracy Rating	2% (Optional 0.5%)	2% (Optional 0.5%)	1% Energy, 2% VRMS, IRMS	2% (Optional 0.5%)
Network	Service Provider 1	Service Provider 2	Service Provider 2	Service Provider 2
Control Signal Interfaces	0-10VDC, PVM, or DALI	0-10VDC, PVM, or DALI	0-10VDC or DALI	0-10VDC or DALI
Temperature Rating	-22F to +158F	-22F to +158F	-40F to +158F	-40F to +158F
Switching Capacity Max	15A	15A	10A	Not Listed
Rated Power Consumption	Not Listed	Not Listed	< 2W Average Power	< 2W
IR Metering test pulse output	NO	NO	NO	YES
Metered values	Current, Voltage, Frequency, Power Factor, kW, kWh	Current, Voltage, Frequency, Power Factor, kW, kWh	Current, Voltage, Frequency, Power Factor, kW, kWh	Current, Voltage, Frequency, Power Factor, kW, kWh

When qualifying new automatic meter reading revenue grade meters for deployment, the meter vendors being considered put their meters through full ANSI C12.20 testing by an independent testing laboratory and create a complete documentation package tabulating the results of those tests. This documentation is typically provided to the utility with sample meters to consider as an option for deployment. The utility would then perform its own ANSI testing as a validation of the test results provided in the vendor's documentation package.

As part of the Bench Test Specification development, National Grid and TESCO contacted all of the vendors on numerous occasions. The first such communication was in regard to obtaining any meter accuracy test documentation. At the time of these discussions, none of the vendors had performed any third party testing and, therefore, had no documented meter quality references. The node vendors offered documentation consisting of only the technical specification sheets available from the integrated circuit meter chipset manufacturer used in the respective nodes.

After the testing, National Grid learned that Vendor D performed accuracy testing in its own laboratory and provided its standard testing documentation. Vendor D used meter testing equipment consistent with and qualified by the National Institute of Standards and Technology, but did not necessarily follow any ANSI C12.20 standards or procedures during its testing.

National Grid and TESCO extended additional communications to each vendor after submission of the initial written specification. All vendors were given the opportunity to suggest changes to the test specification. National Grid received only a single response, from Vendor D, who recommended an adjustment be made to raise the full load current specification to 15A, upon which Vendor D indicated that its nodes would hold tolerance at that level. When queried, Vendors A through C did not believe that their nodes would hold tolerance at the increased level.

4.1.2. Final Test Specification

On September 19, 2016, National Grid approved the completion of TESCO's final bench testing specification plan. The final bench test specification is referenced as Attachment 2. The changes from the draft specification are as follows:

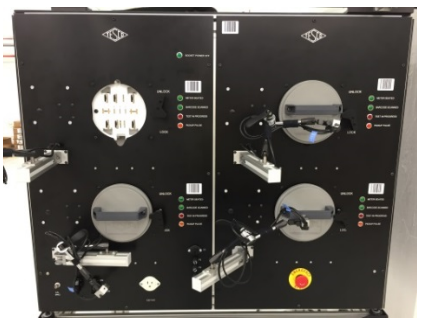
- Added tests for full load amperage at 15A, in addition to the 10A tests.
- Added tests for light load amperage at 0.5A, in addition to the 1A tests.
- Added tests for expanded voltage testing at +/- 15% rated voltage and +/- 20% rated voltage. This requirement was requested by National Grid as a check to address voltage variance ranges that may exist at locations where the nodes could be installed.

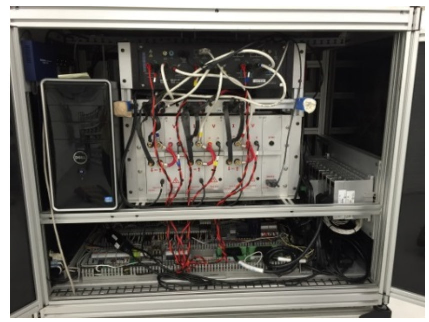
4.1.3. Test Setup

4.1.3.1. Equipment Used

- TESCO Meter Test Board (also referred to as a MTB in Diagram 1, below) (Catalog No. 2450) – The TESCO Meter Test Board is a four socket unit capable of simultaneously testing four meters. The Meter Test Board complies with ANSI C12.20 and uses a traceable three phase reference standard qualified by the National Institute of Standards and Technology.

Diagram 1

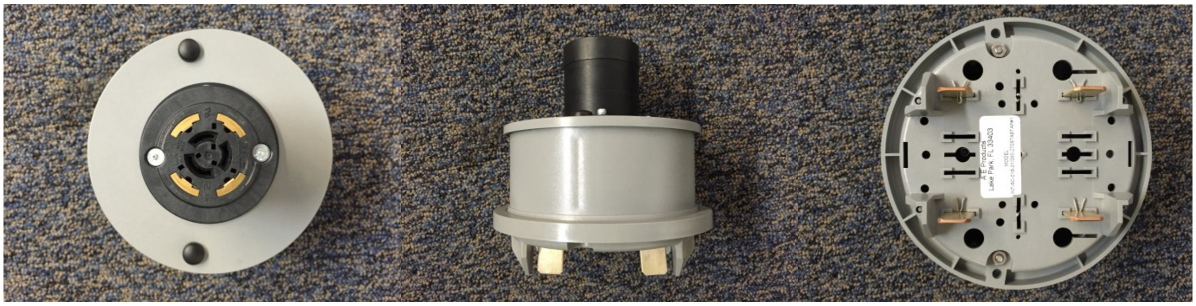




4 Position MTB Test Panel   Complete MTB Unit   MTB Rear View

- The main components of the Meter Testing Board are as follows:
  - Digital Power Supply – Digital Power Technologies DPT 024 Series 3 phase source.
    - Frequency Accuracy – +/-0.02Hz
    - Voltage Set point accuracy - 0.5%
    - Total Harmonic Distortion - less than 0.5% Linear load
    - Phase Resolution - 0.01 degree
    - Current Accuracy - 0.5%
  - Reference Standard – Radian Dytronic RD-30-201
    - 0.04% accuracy class
    - Serial Number 301510
    - Calibration date: April 20, 2015
  - Programmable Logic Controller – Automation Direct, Productivity 3000 series.
  - Main Unit Controller – Responsible for setting up the power supply, monitoring voltages and currents, and counting reference standard energy pulses.
- Socket Adapter – by TESCO (Diagram 2, below)
  - This assembly adapts a seven pin standard photocell socket (top) to a four lug standard revenue grade metering socket (bottom).

Diagram 2



Top View Profile Bottom View

- Personal Computer
  - Used to interface to TESCO Meter Testing Board and Service Provider 2 communication adaptor.

- Service Provider 1 Handheld Configurator (Diagram 3, below)
  - Communication adapter used between Service Provider 1 / Vendor A nodes and the Personal Computer.

Diagram 3

- Service Provider 2 Field Service Unit (FSU) (Diagram 4, below)

- Communication adapter between Personal Computer and Service Provider 2 compatible nodes.

Diagram 4

Service Provider 2 Field Service Unit

4.1.4. Test Methods Used

4.1.4.1. Service Provider 1 Communication Method

All Vendor A nodes fitted with the Service Provider 1 communication hardware used the Service 1 Communication Method for all tests listed in Sections 4.5 and 4.6 of the Bench Test Specification (Attachment 2).

- Each test was performed on the TESCO Meter Testing Board, four nodes at a time.
- Each node was energized with potential only.
- Each node was registered through the Service Provider 1 network using Vendor A's Software.
- An initial Watt-hour query was completed on each node and recorded in the data collection spreadsheet.
- The testing parameters were then set in the Meter Testing Board. The Meter Testing Board was set to run a Demand test, with the interval set to a value that should register at least 1,000Wh on both the node and the reference standard (i.e., for 120V, 1.00 Power factor, 10A test, the time interval will be set to (1,000 x 60)/(120 x 10) = 50 minutes).

- At the end of the interval, the number of Watt-hours from the reference standard was recorded, along with the ending Watt-hour readings from each of the four nodes.
- The percent accuracy was then determined by the ratio of node Watt-hour/reference standard Watt-hour.

4.1.4.2. Service Provider 2 Communication Method

All nodes used the Service Provider 2 Communication Method for all tests listed in Sections 4.5 and 4.6 of the Final Bench Test Specification Plan (Attachment 2).

- Each test was performed on the TESCO Meter Test Board, four nodes at a time.
- Each node was energized with potential only.
- Each node was registered through the Service Provider 2 network using Service Provider 2's Communication Test software (version 6.10.25413).
- An initial Watt-hour query was completed on each node and recorded in the data collection spreadsheet.
- The testing parameters were then set in the Meter Testing Board. The Meter Testing Board was set to run a Demand test, with the interval set to a value that should register at least 1,000 Wh on both the node and the reference standard, (i.e., for 120V, 1.00 Power factor, 10A test, the time interval will be set to (1,000 x 60)/(120 x 10) = 50 minutes).
- At the end of the interval, the number of Watt-hours from the reference standard was recorded, along with the ending Watt-hour readings from each of the four nodes.
- The percent accuracy is determined by the ratio of node Watt-hours/reference standard Watt-hours.

4.1.4.3. Meter Pulse Method

- Nodes with a metering infrared pulse output used the Meter Pulse Method on all the tests listed in Sections 4.5 and 4.6 of the Final Bench Test Specification Plan (Attachment 2) in addition to the method described in Section 4.1.4.2 (Service Provider 2 Communications Method), above. Each test was performed on the TESCO Meter Testing Board, four nodes at a time.
- Each node was energized with potential and load current so that the metering pulse would be activated.
- Each node's metering pulse pickup assembly (part of the Meter Testing Board) was aligned with the metering pulse output.

- The testing parameters were then set in the Meter Testing Board. The Meter Testing Board was set to run a Full Load, Light Load, or Power Factor test, depending on the requirements of the test.
- At the end of the test, the registration value was read directly from the Meter Testing Board.

4.1.5. Equipment Calibration and Traceability Documentation

- Meter Testing Board Calibration
  - The Meter Testing Board was calibrated with an external National Institute of Standards and Technology traceable transfer standard once per year. The tolerance for the Meter Testing Board is +\- .05% from reference.
  - The Meter Testing Board used in these tests became due for calibration during the testing, so there are two sets of data attached to this document detailing the results of those calibrations. Reference Attachment 3 (MTB Calibration Report - 4/21/2015) and Attachment 4 (MTB Calibration Report - 4/20/2016).

- External Reference Standard
  - The External Reference Standard used to calibrate the Meter Testing Board was a Radian RD-30-201 (Serial Number 301563) Dytronic Portable Standard.
  - The calibration data and National Institute of Standards and Technology traceability information for this standard is provided in Attachment 5 (Radian Research Inc. Certificate of Calibration).

4.1.6. Test Results and Analysis

4.1.6.1. Test Conditions

- Temperature: 23°C, +/- 2°C
- Rated voltage (120 volts alternating current (VAC)): +/- 1% VAC
- Rated frequency (60 cycles per second (Hz)): +/- 1Hz
- Test Amperes (1.5/10 amps alternating current (AAC)): +/- 1% AAC
- Unity Power factor (0°): +/- 2°
- Nodes will be temperature stabilized before testing

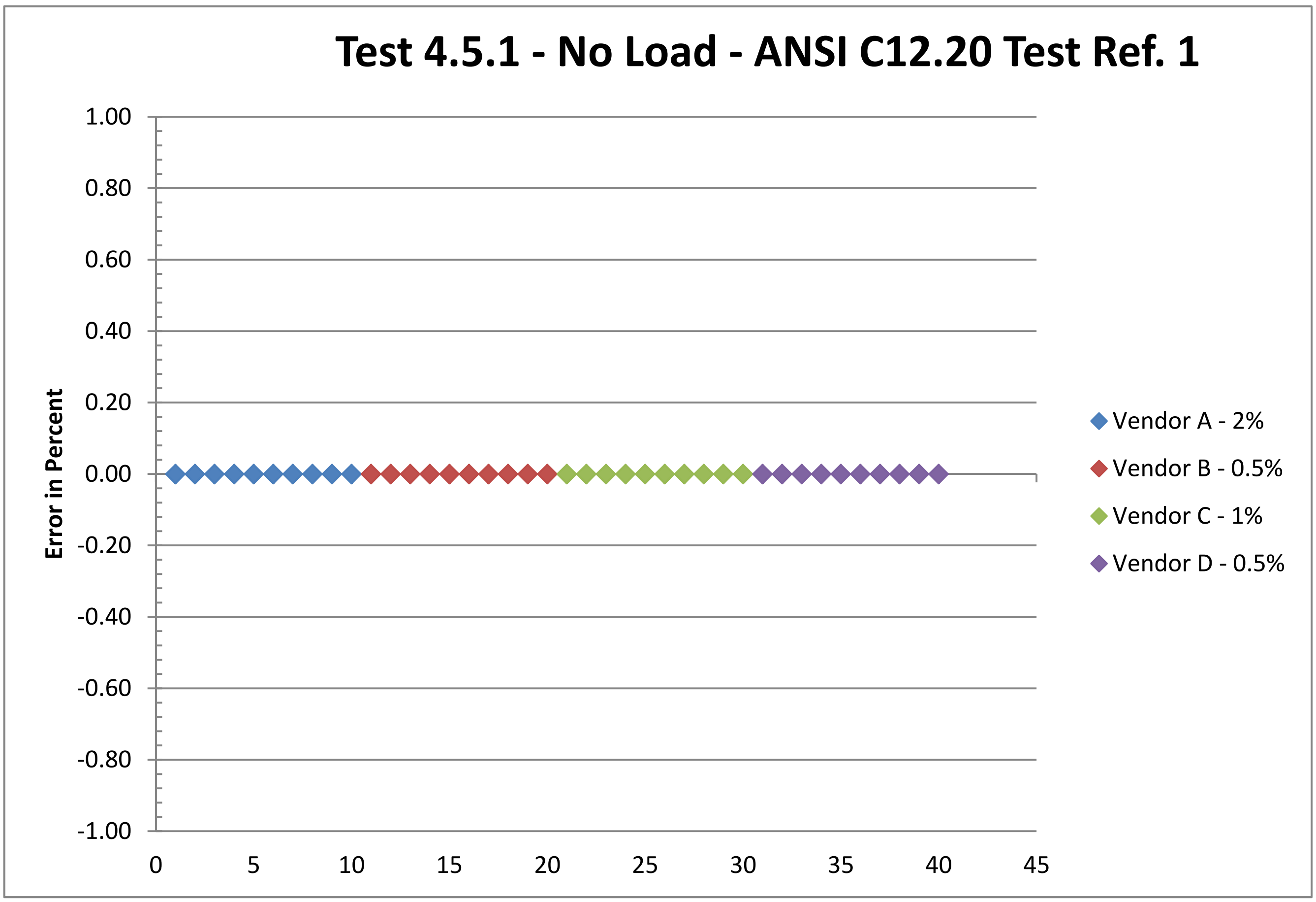
4.1.6.2. Data / Results

- Reference Attachment 2 (Final Bench Test Specification Plan) for a detailed explanation of test conditions and individual test methods. The bench test summary results are presented below.

4.1.6.2.1 Load Tests

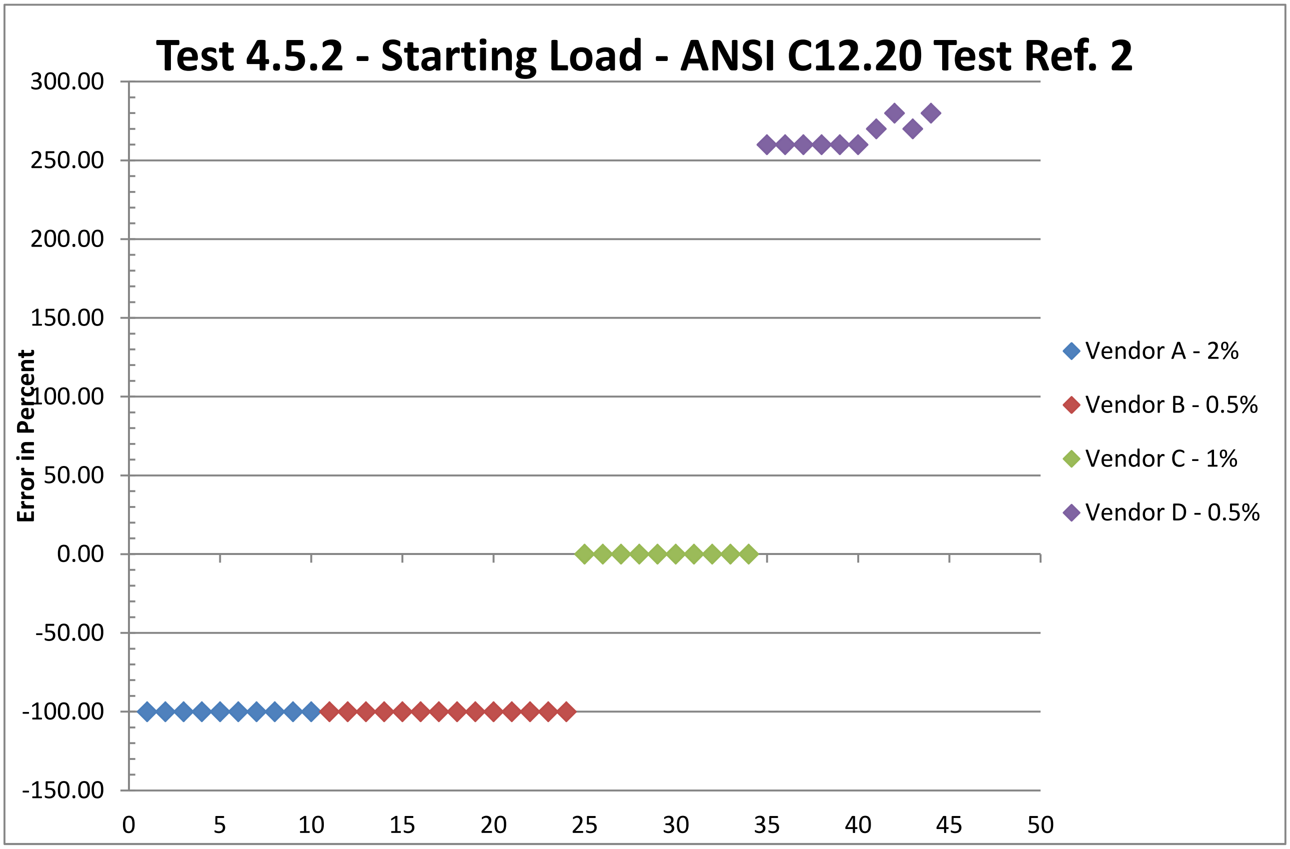
- Test 4.5.1 – No Load
  - Conditions
    - Voltage – 120VAC
    - Current – 0A
    - Power factor – 1.00
    - Frequency – 60Hz
  - Results (Graph 1, below)
    - All nodes from all Vendors passed this test without issue

Graph 1



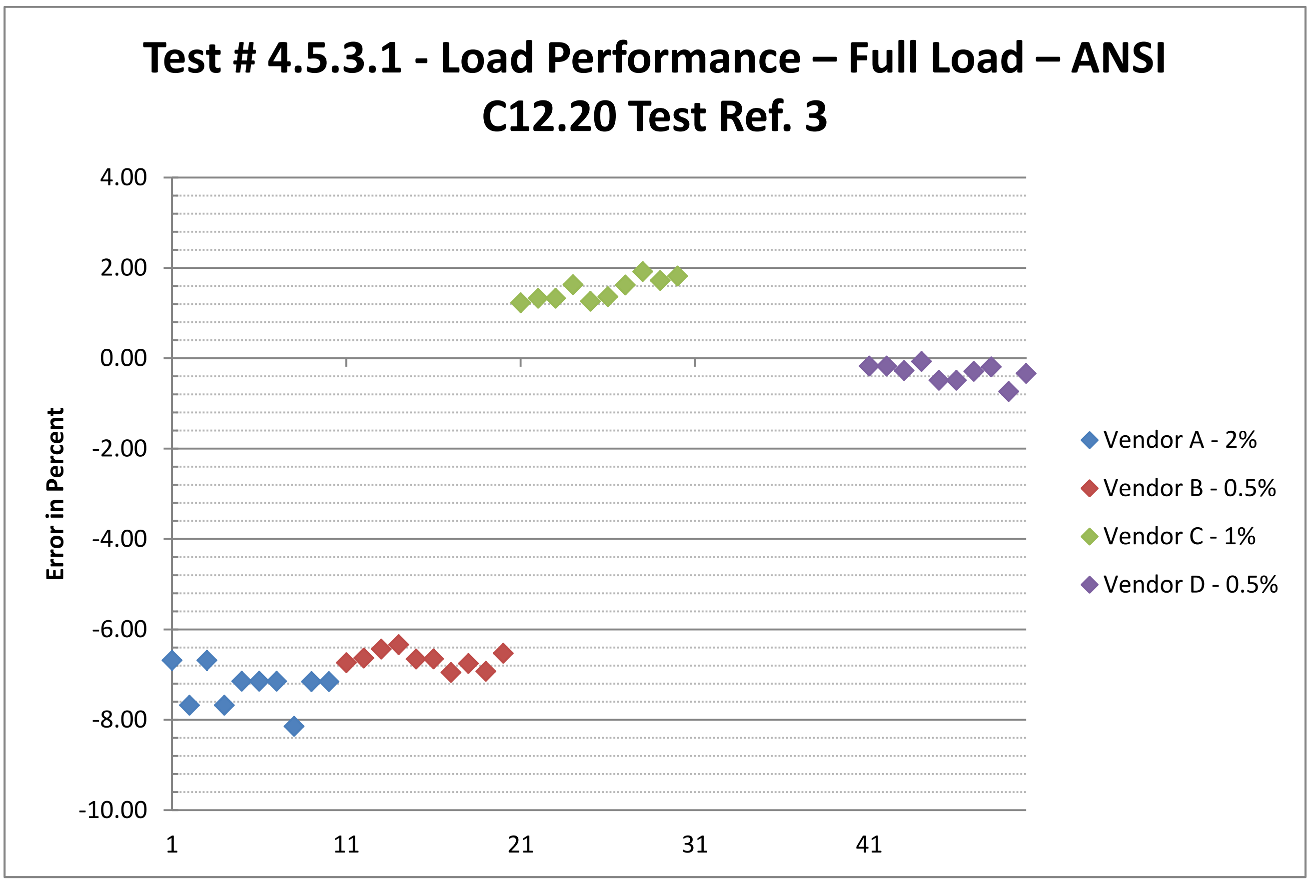
- Test 4.5.2 – Starting Load
  - Conditions
    - Voltage – 105VAC
    - Current – 0.01A
    - Power factor – 1.00
    - Frequency – 60Hz
  - Results (Graph 2, below)
    - Only Vendor C nodes passed this test.
    - Vendors A and B reported no current or Wattage readings.
    - Vendor D reported readings far higher than expected.

Graph 2



- Test 4.5.3.1 – Load Performance – Full Load
  - Conditions
    - Voltage – 120VAC
    - Current – 10A
    - Power factor – 1.00
    - Frequency – 60Hz
  - Results (Graph 3, below)
    - Vendors A through C failed all 10 nodes.
    - Vendor D met its stated specifications in 7 of the 10 nodes tested.

Graph 3

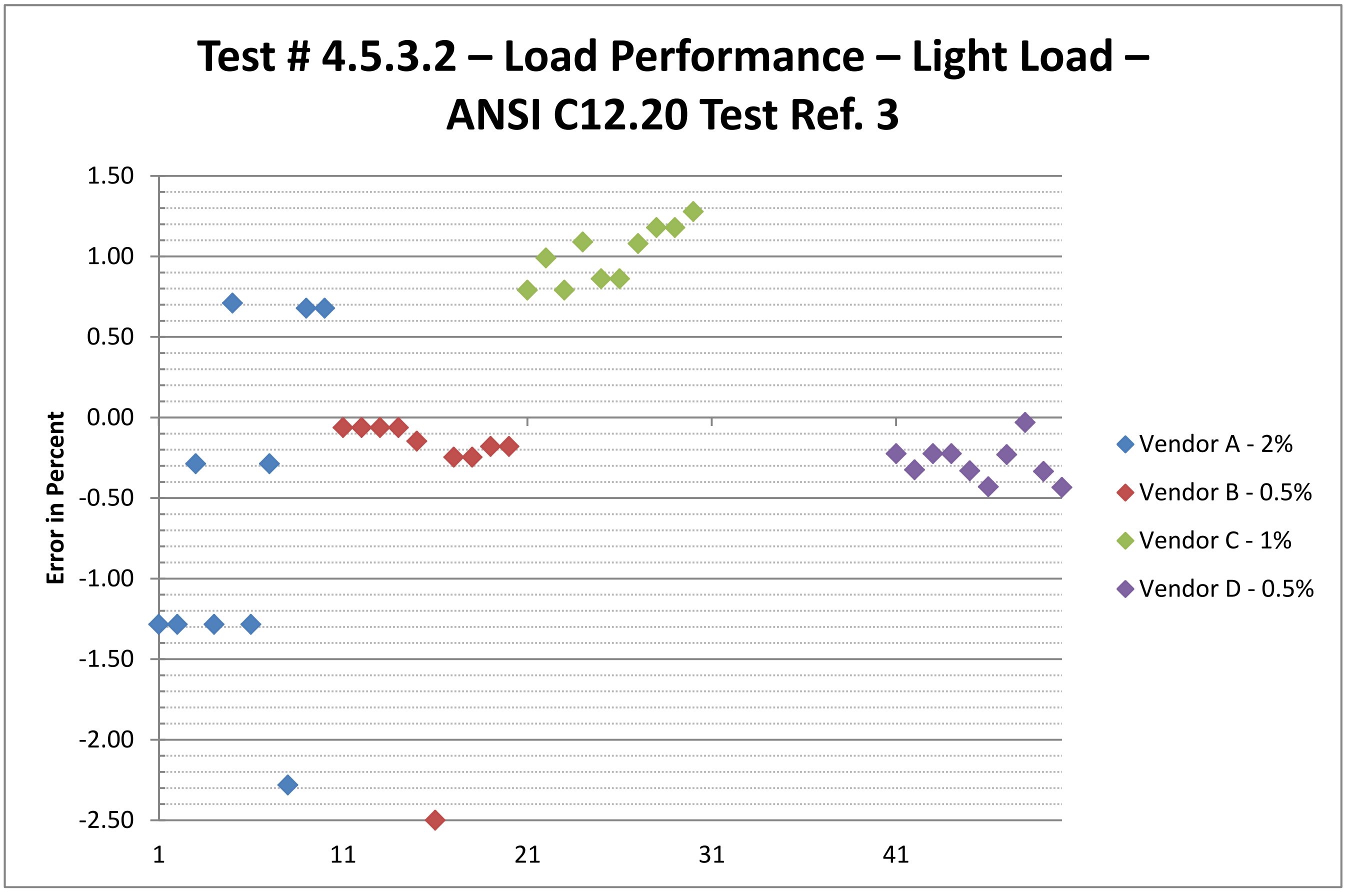


Test 4.5.3.2 – Load Performance – Light Load

- Conditions
  - Voltage – 120VAC
  - Current – 1A
  - Power factor – 1.00
  - Frequency – 60Hz

- Results (Graph 4, below)
  - Vendors A and B met their stated specifications in 9 of 10 nodes tested.
  - Vendor C met its stated specifications in 5 of 10 nodes tested.
  - Vendor D had all 10 nodes pass this test.

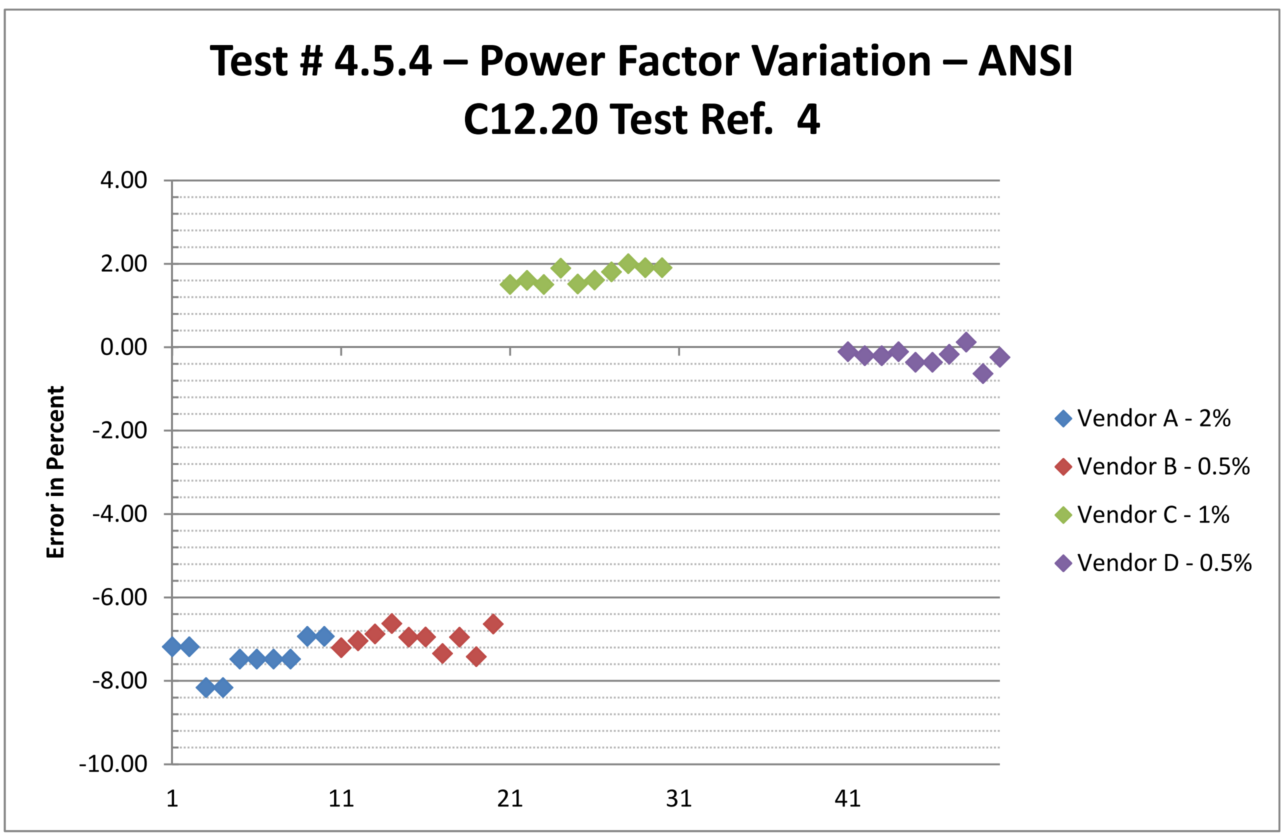
Graph 4



4.1.6.2.2. Power Factor Variation Test

- Test 4.5.4 – Power Factor Variation
  - Conditions
    - Voltage – 120VAC
    - Current – 10A
    - Power factor – 0.50
    - Frequency – 60Hz
  - Results – Similar to the Full Load testing (Graph 5, below).
    - Vendors A through C failed all 10 nodes.
    - Vendor D met its stated specifications in 9 of the 10 nodes tested.

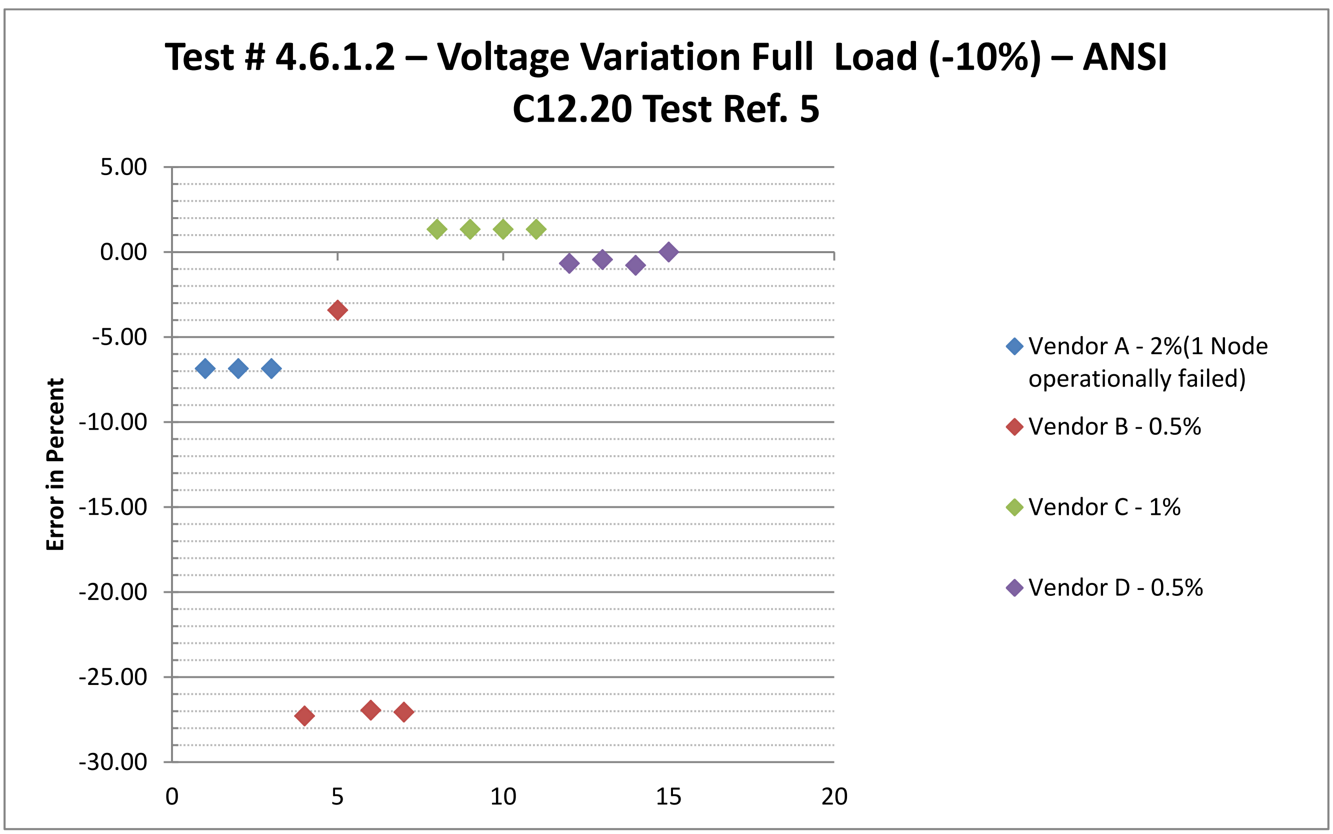
Graph 5



4.1.6.2.3. Voltage Variation Tests

- Test 4.6.1.2 – Voltage Variation – Full Load (-10%)
  - Conditions
    - Voltage – 108VAC
    - Current – 10A
    - Power factor – 1.00
    - Frequency – 60Hz
  - Results – Similar to the Full Load testing (Graph 6, below).
    - Vendors A through C failed all four nodes.
    - Vendor D met its stated specifications in two of the four nodes tested.
    - Vendor A also had one of the four nodes assigned to this test operationally fail during this test. That node was replaced by another of equal rating from Vendor A for the remainder of the Bench Testing.

Graph 6

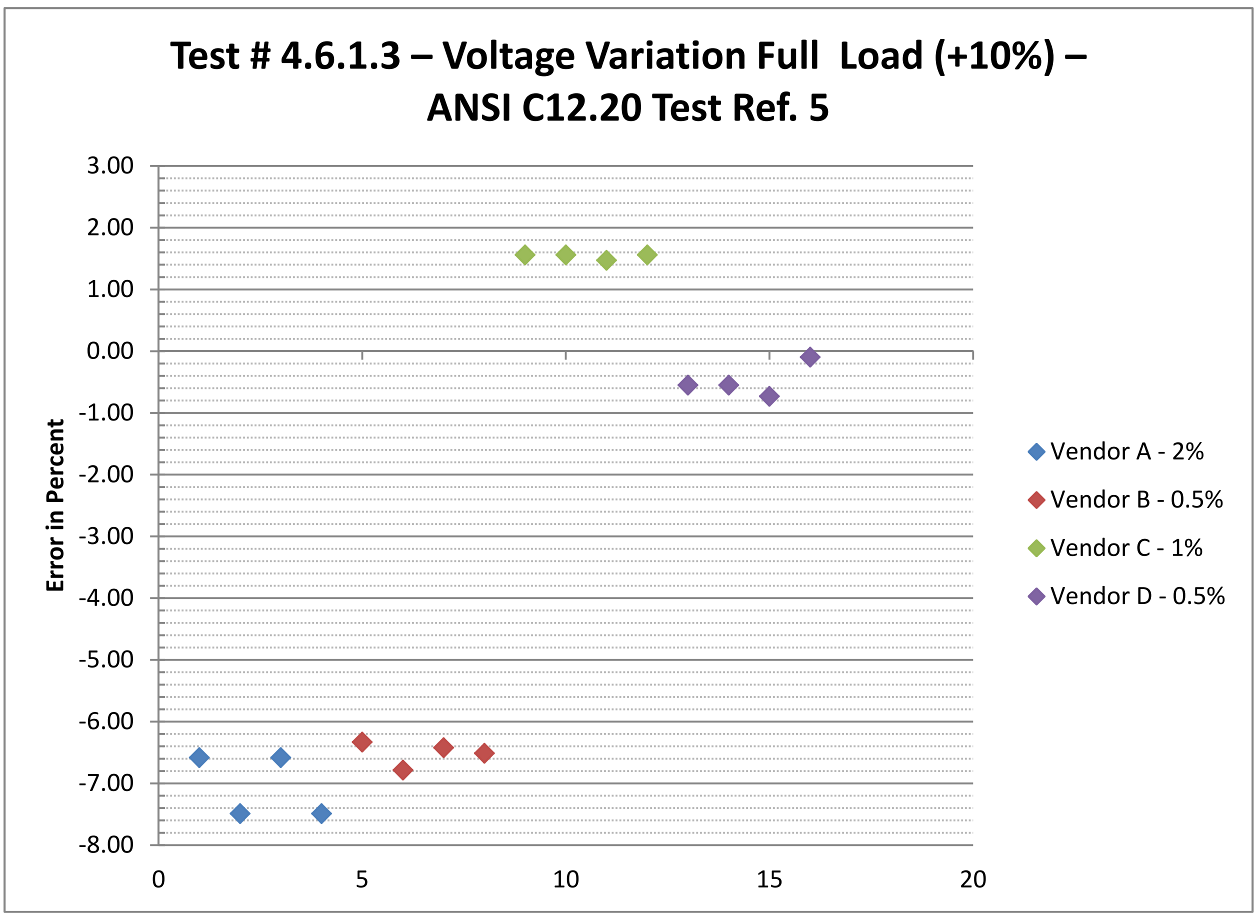


- Test 4.6.1.3 – Voltage Variation – Full Load (+10%)

  - Conditions
    - Voltage – 132VAC
    - Current – 10A
    - Power factor – 1.00
    - Frequency – 60Hz

  - Results – Similar to the Full Load testing (Graph 7, below).
    - Vendors A through C failed all four nodes.
    - Vendor D met its stated specifications in one of the four nodes tested.

Graph 7

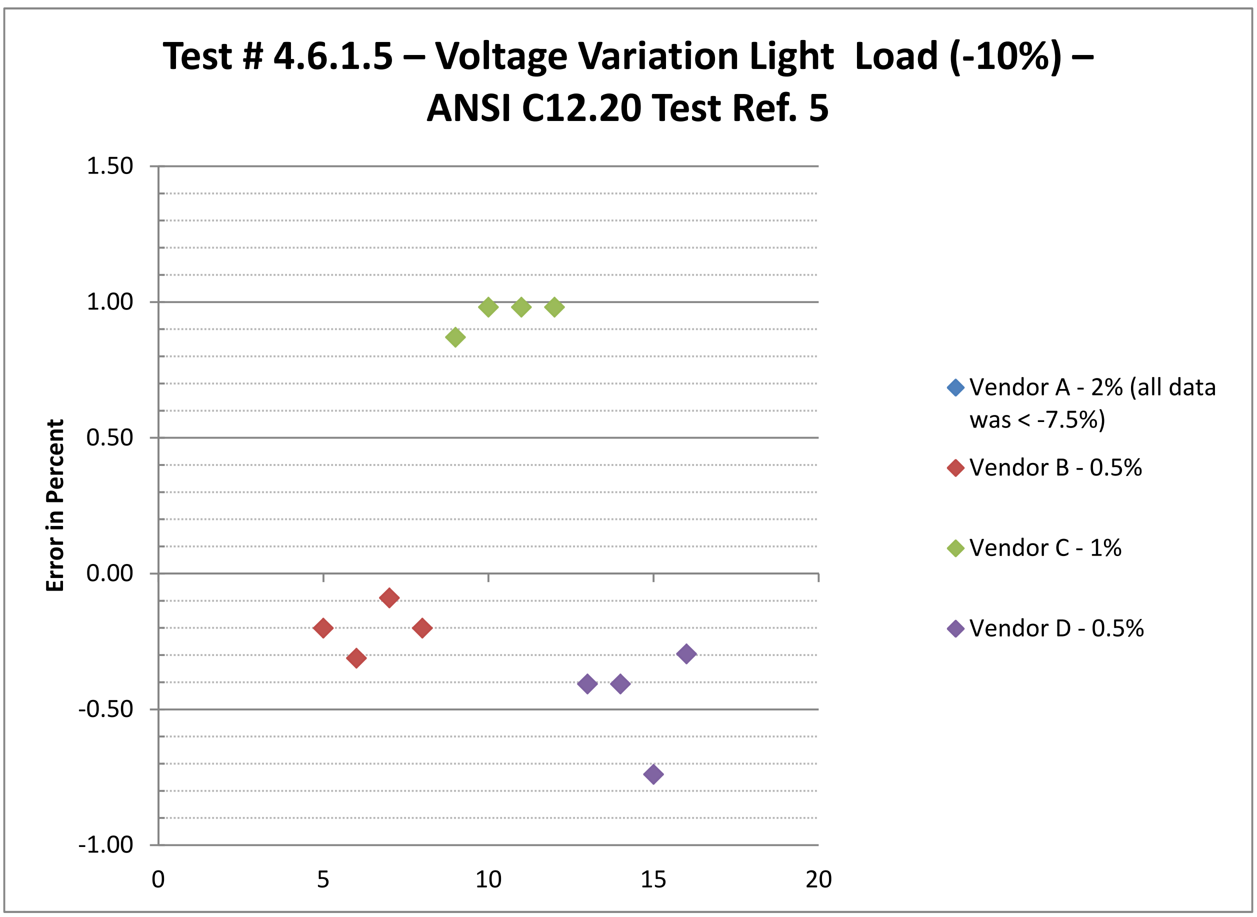


- Test 4.6.1.5 – Voltage Variation – Light Load (-10%)

  - Conditions
    - Voltage – 108VAC
    - Current – 1A
    - Power factor – 1.00
    - Frequency – 60Hz

  - Results (Graph 8, below)
    - Vendor A failed all four nodes with less than -7.5% error and is not presented on the graph.
    - Vendor B and C met their stated specifications in all four nodes.
    - Vendor D met its stated specifications in three of the four nodes tested.

Graph 8

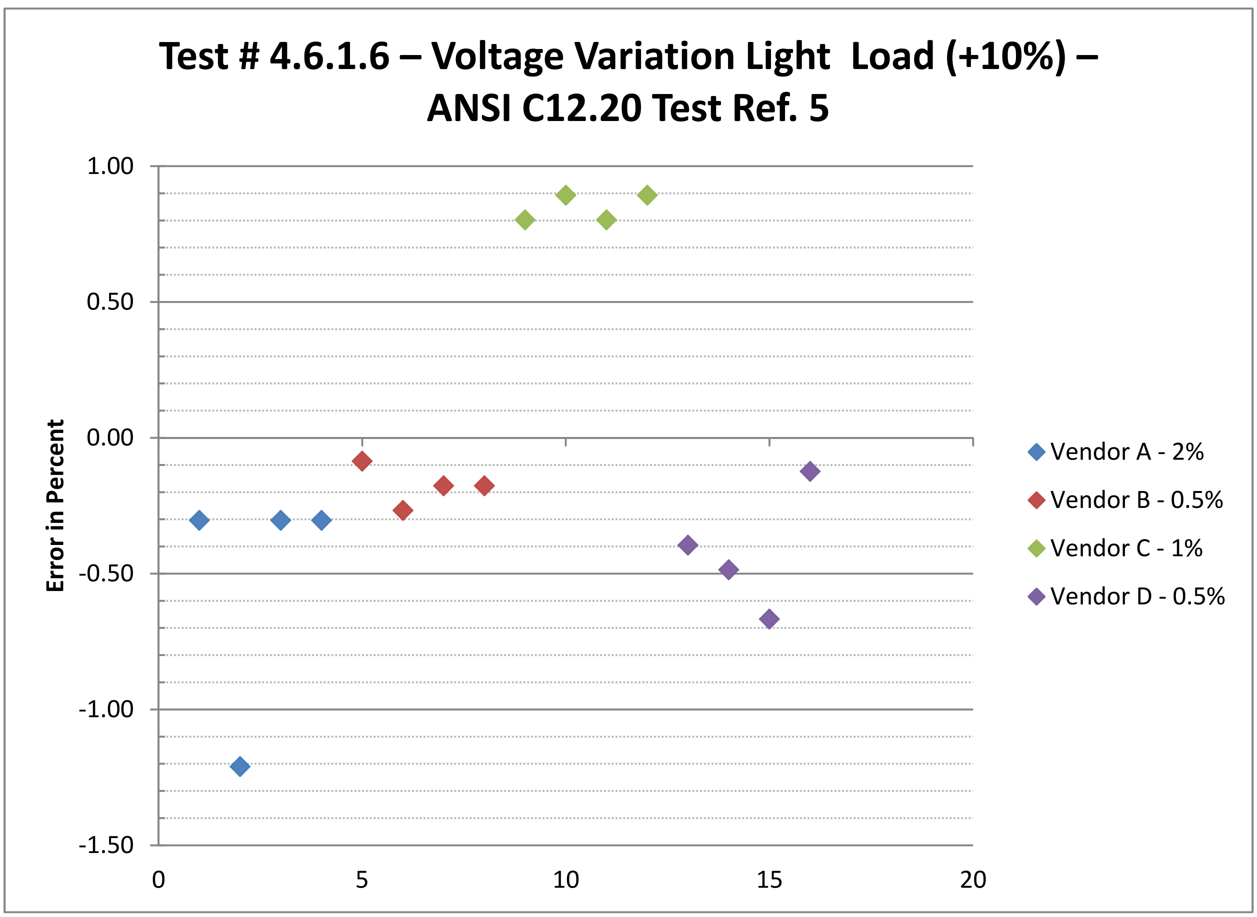


- Test 4.6.1.6 – Voltage Variation – Light Load (+10%)

  - Conditions
    - Voltage – 132VAC
    - Current – 1A
    - Power factor – 1.00
    - Frequency – 60Hz

  - Results (Graph 9, below)
    - Vendor A met its stated specifications in three of four nodes tested.
    - Vendors B and C met their stated specifications in all four nodes tested.
    - Vendor D met its stated specifications in three of four nodes tested.

Graph 9

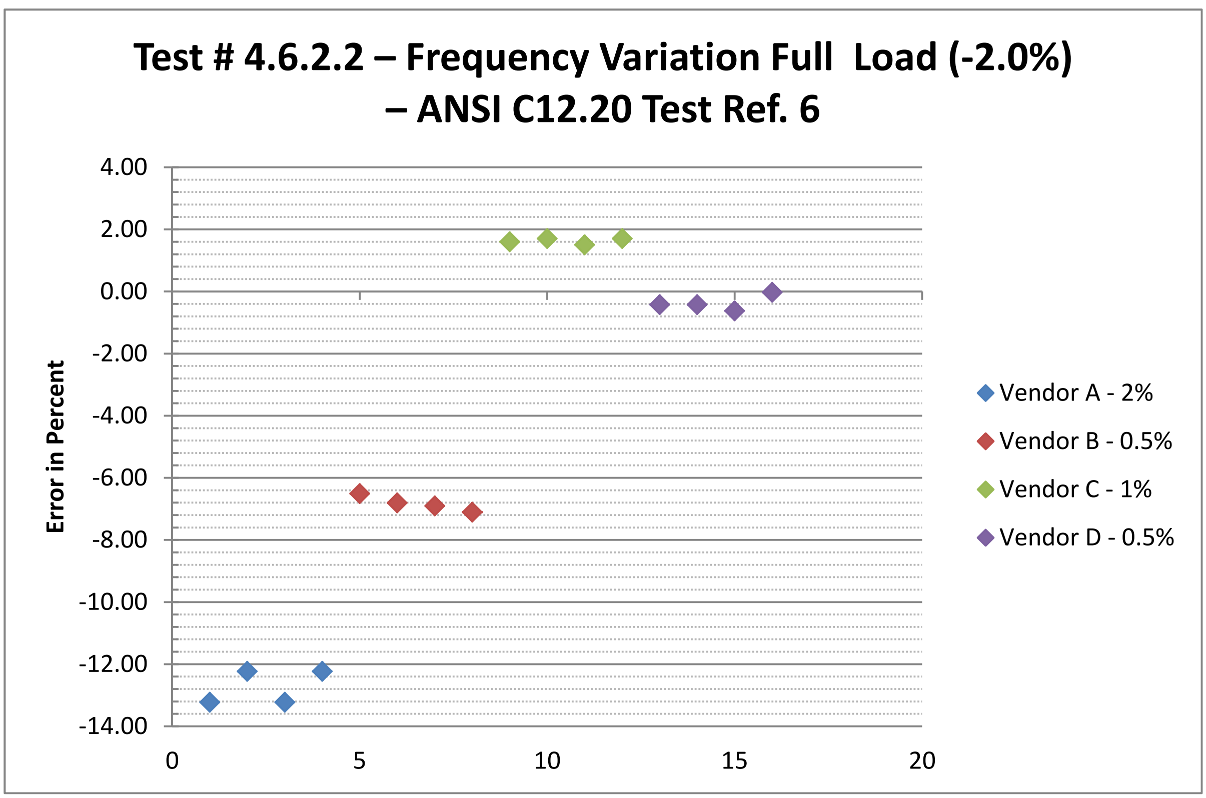


4.1.6.2.4. Frequency Variation Tests

- Test 4.6.2.2 – Frequency Variation – Full Load (-2%) Conditions
  - Voltage – 120VAC
  - Current – 10A
  - Power factor – 1.00
  - Frequency – 58.8Hz

- Results – Results are somewhat similar to all previous high-amperage tests (Graph 10, below).
  - Vendors A through C failed to meet their stated specifications in all four nodes tested.
  - Vendor D met its stated specifications in three of the four nodes tested.

Graph 10

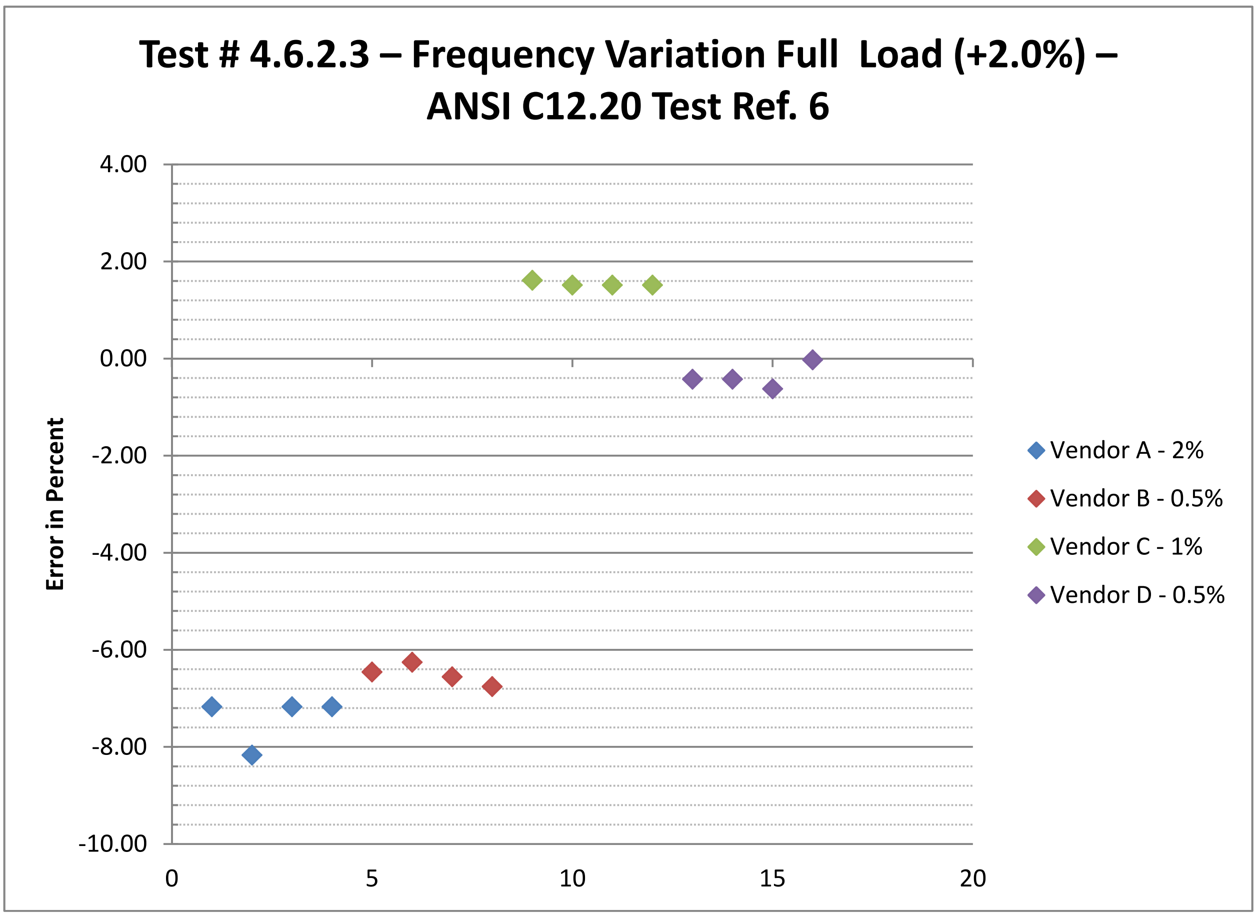


Test 4.6.2.2 – Frequency Variation – Full Load (+2%)

- Conditions
  - Voltage – 120VAC
  - Current – 10A
  - Power factor – 1.00
  - Frequency – 61.2Hz

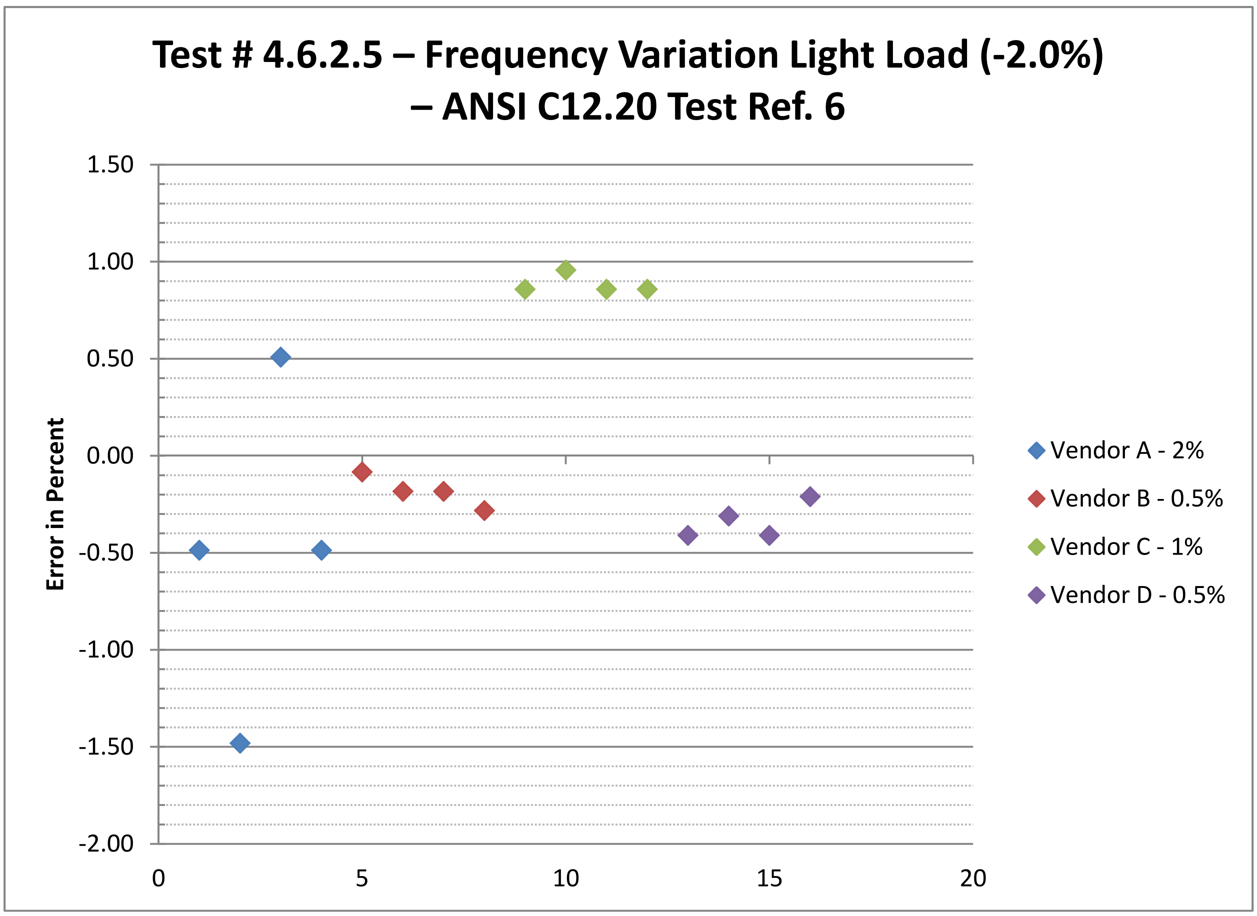
- Results – Similar to the previous test (Graph 11, below).
  - Vendors A through C failed to meet their stated specifications in all four nodes tested.
  - Vendor D met their stated specifications in three of the four nodes tested.

Graph 11



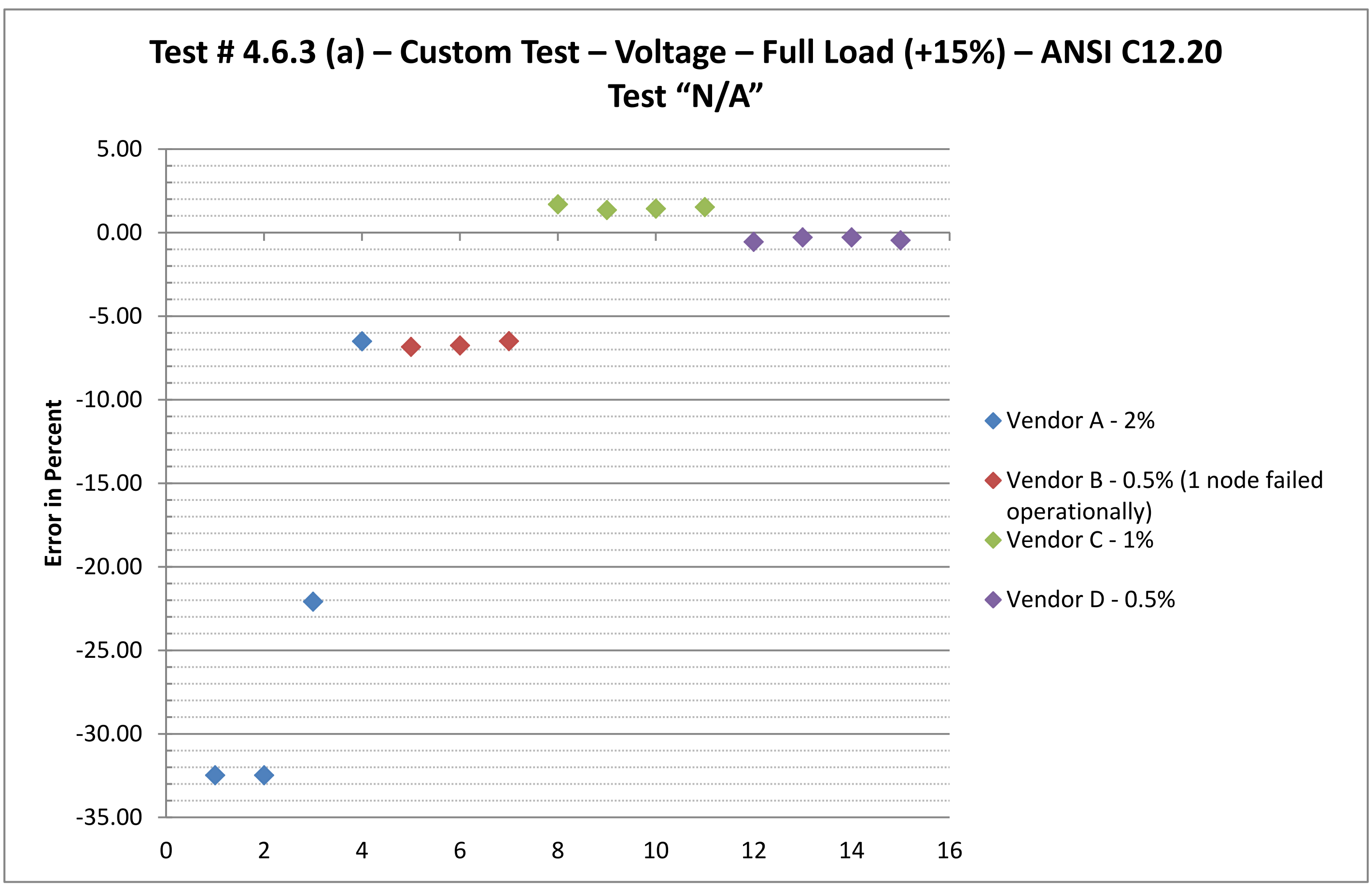
- Test 4.6.2.2 – Frequency Variation – Light Load (-2%)
  - Conditions
    - Voltage – 120VAC
    - Current – 1A
    - Power factor – 1.00
    - Frequency – 58.8Hz
  - Results (Graph 12, below)
    - Vendor A met its stated specifications on three of the four nodes tested.
    - Vendors B through D met their stated specifications in all four nodes tested.

Graph 12



- Test 4.6.2.2 – Frequency Variation – Light Load (+2%)
  - Conditions
    - Voltage – 120VAC
    - Current – 1A
    - Power factor – 1.00
    - Frequency – 61.2Hz
  - Results (Graph 13, below)
    - Vendor A met its stated specifications on all four nodes tested.
    - Vendors B met its stated specifications on one of the four nodes tested. Note: Vendor B had one node fail operationally during this test and that node was removed from the remaining tests.
    - Vendor D met its stated specifications on three of the four nodes tested.

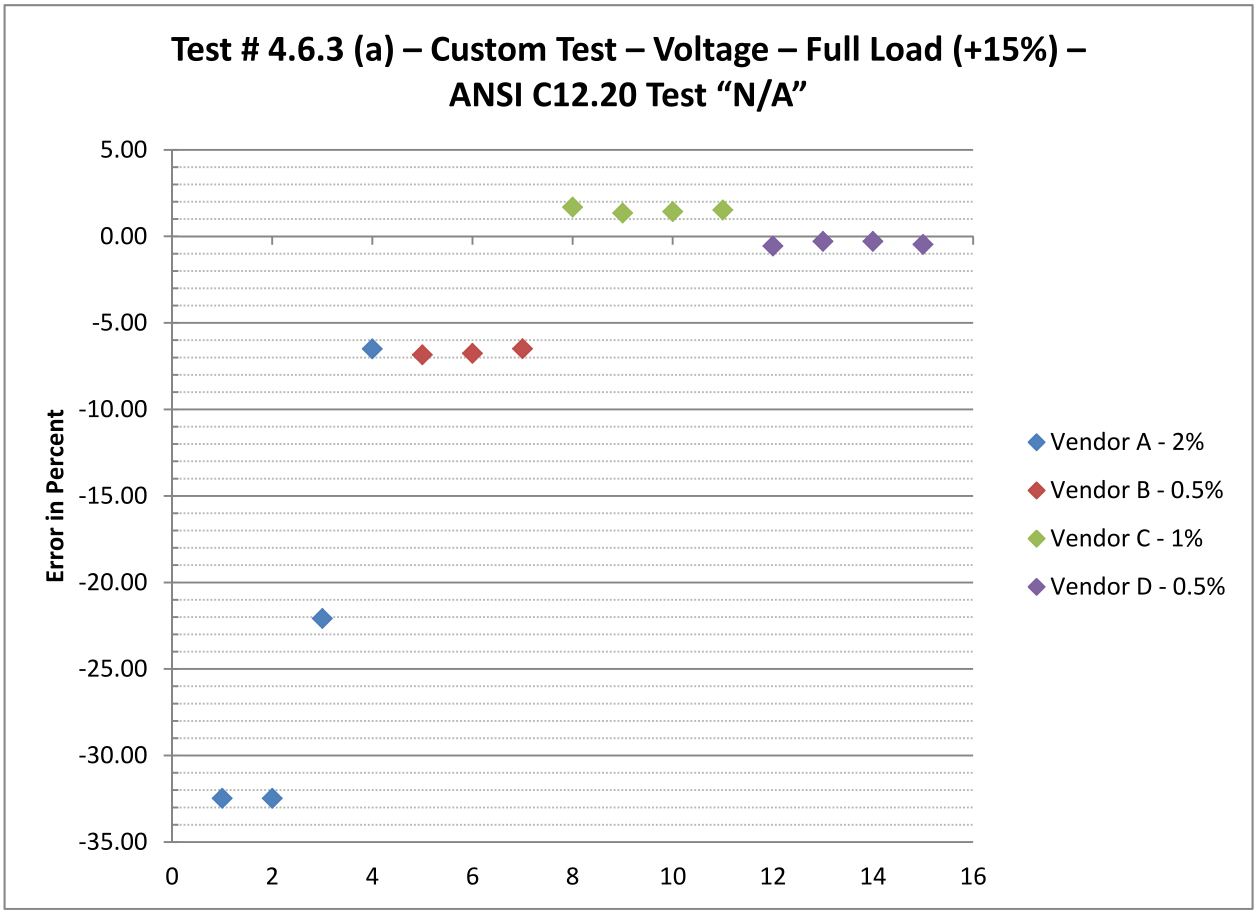
Graph 13



4.1.6.2.5. Custom Tests – Voltage

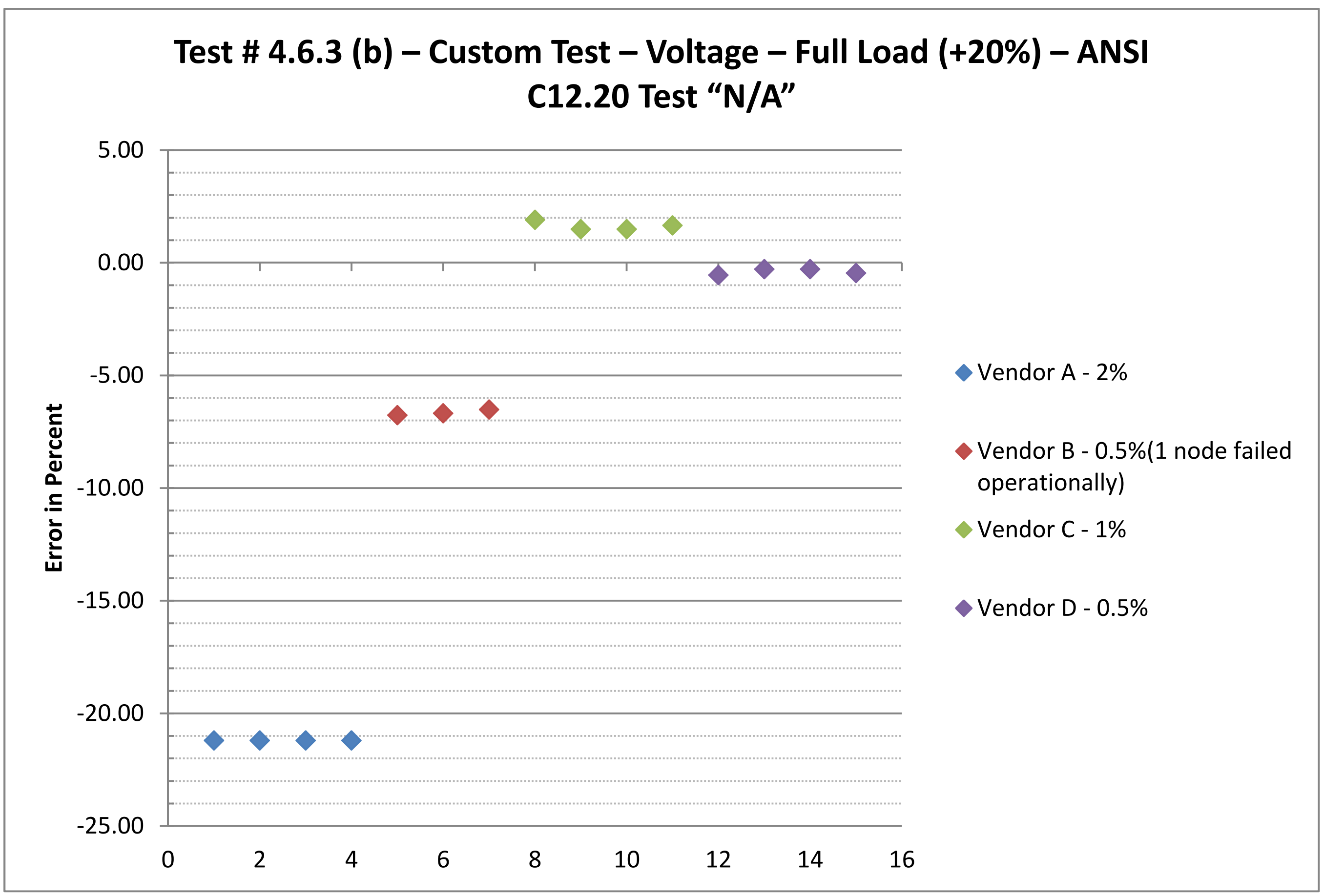
- Test 4.6.3 (a) – Custom Test – Voltage – Full Load (+15%)
  - Conditions
    - Voltage – 138VAC
    - Current – 10A
    - Power factor – 1.00
    - Frequency – 60Hz
  - Results (Graph 14, below)
    - Vendors A through C failed to meet their stated specifications on any of the four nodes tested.
    - Vendor D met its stated specifications on three of the four nodes tested.

Graph 14



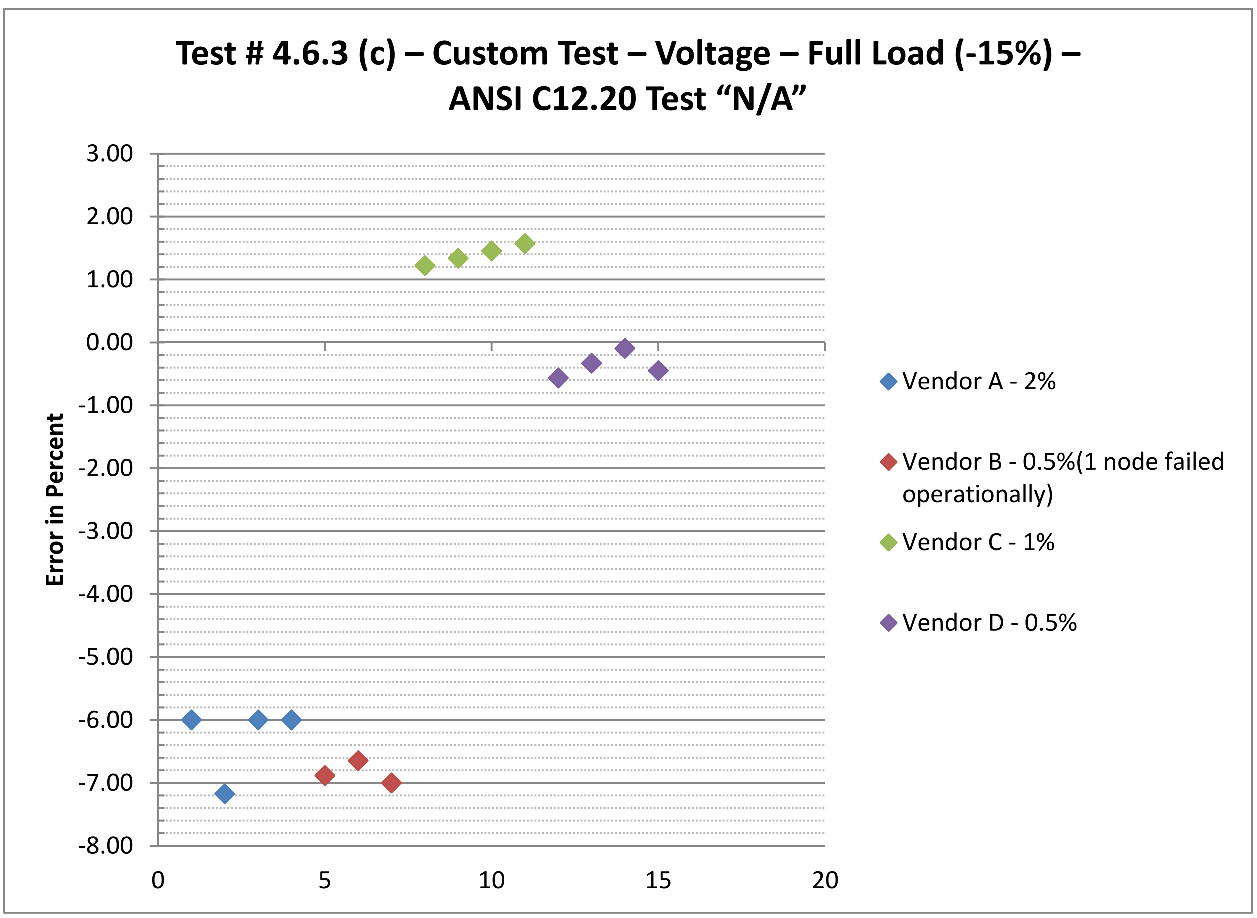
- Test 4.6.3 (b) – Custom Test – Voltage – Full Load (+20%)
  - Conditions
    - Voltage – 144VAC
    - Current – 10A
    - Power factor – 1.00
    - Frequency – 60Hz
  - Results (Graph 15, below)
    - Vendors A through C failed to meet their stated specifications on any of the four nodes tested.
    - Vendor D met its stated specifications on three of the four nodes tested.

Graph 15



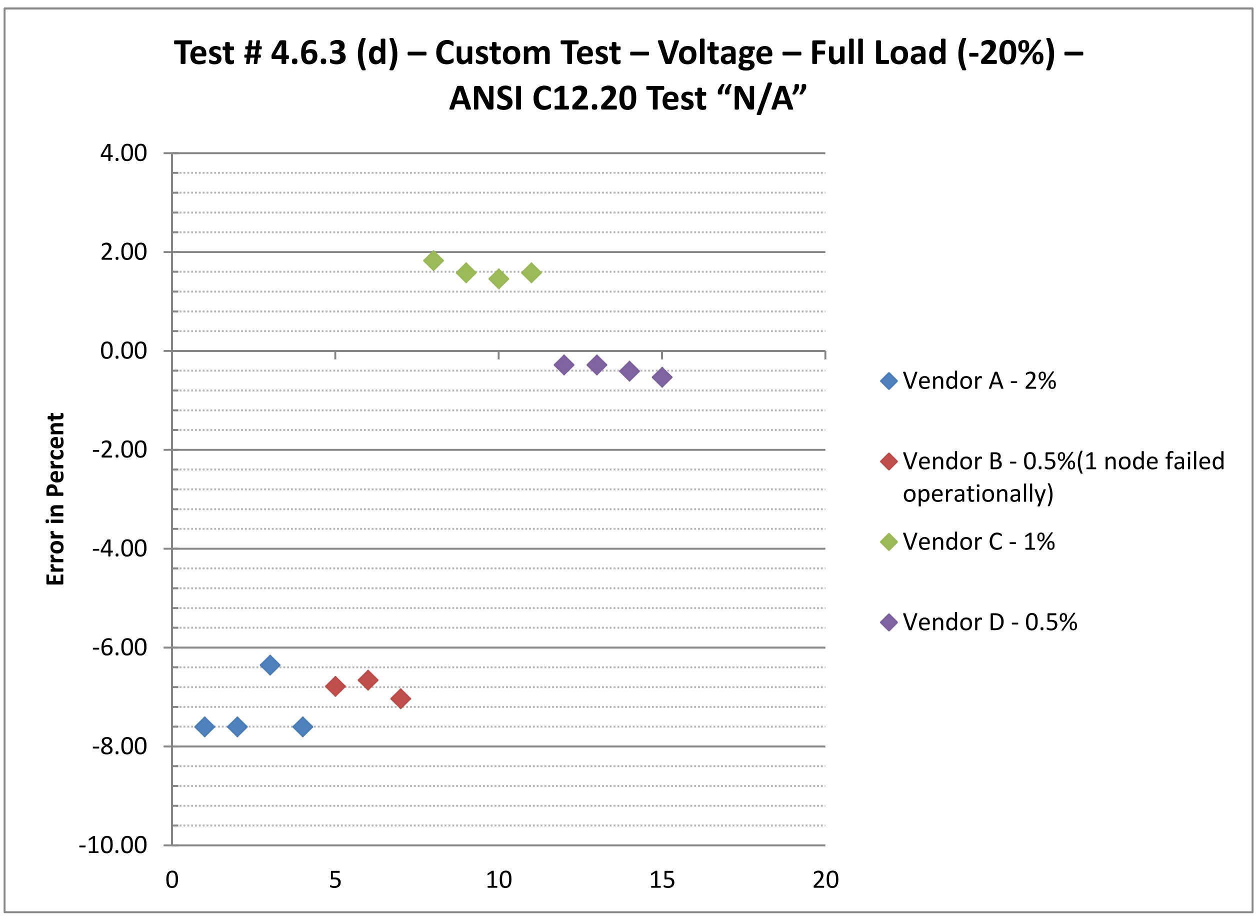
- Test 4.6.3 (c) – Custom Test – Voltage – Full Load (-15%)
  - Conditions
    - Voltage – 102VAC
    - Current – 10A
    - Power factor – 1.00
    - Frequency – 60Hz
  - Results (Graph 16, below)
    - Vendors A through C failed to meet their stated specifications on any of the four nodes tested.
    - Vendor D met its stated specifications on three of the four nodes tested.

Graph 16



- Test 4.6.3 (d) – Custom Test – Voltage – Full Load (-20%)
  - ➢ Conditions
    - Voltage – 96VAC
    - Current – 10A
    - Power factor – 1.00
    - Frequency – 60Hz
  - ➢ Results (Graph 17, below)
    - Vendors A through C failed to meet their stated specifications on any of the four nodes tested.
    - Vendor D met its stated specifications on three of the four nodes tested.

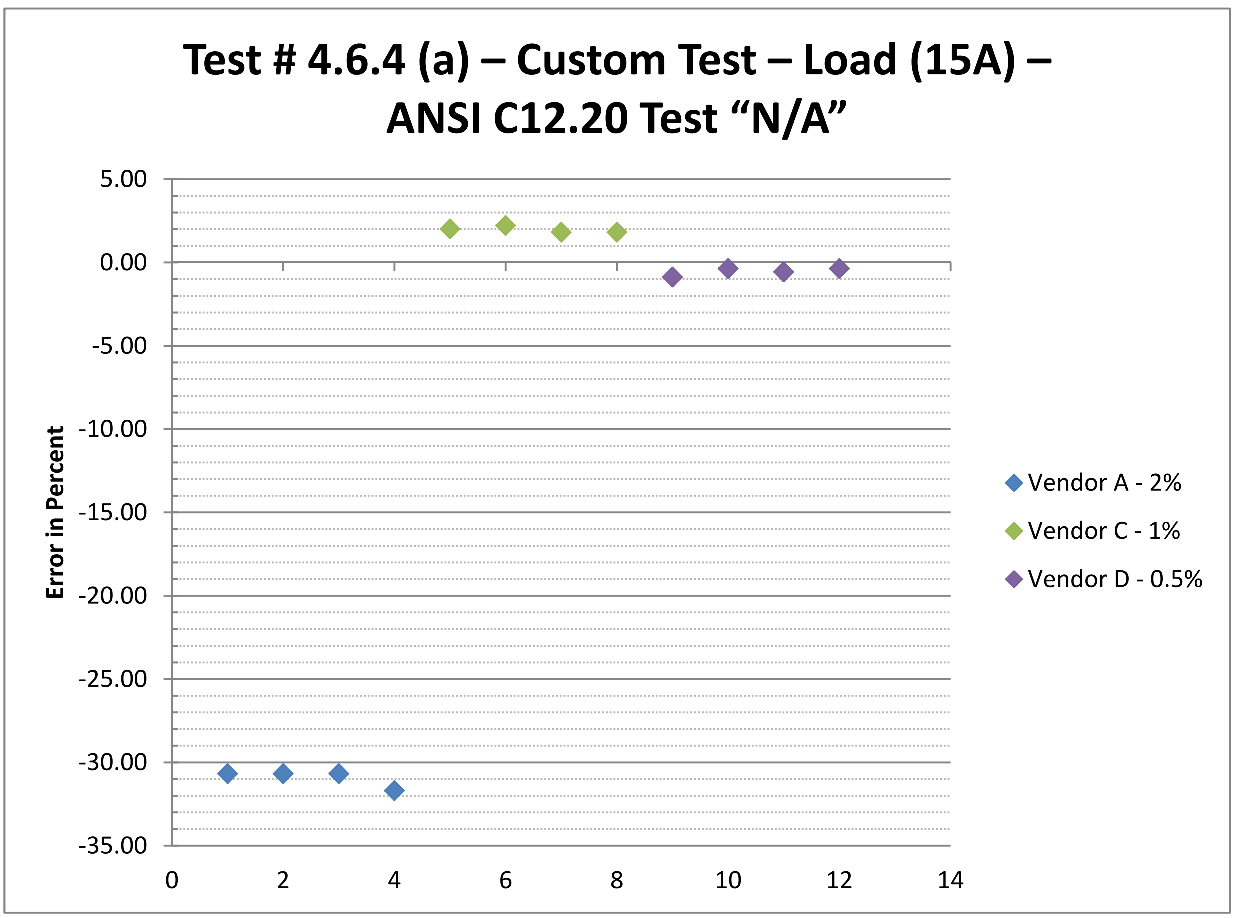
Graph 17



4.1.6.2.6. Customer Tests – Load

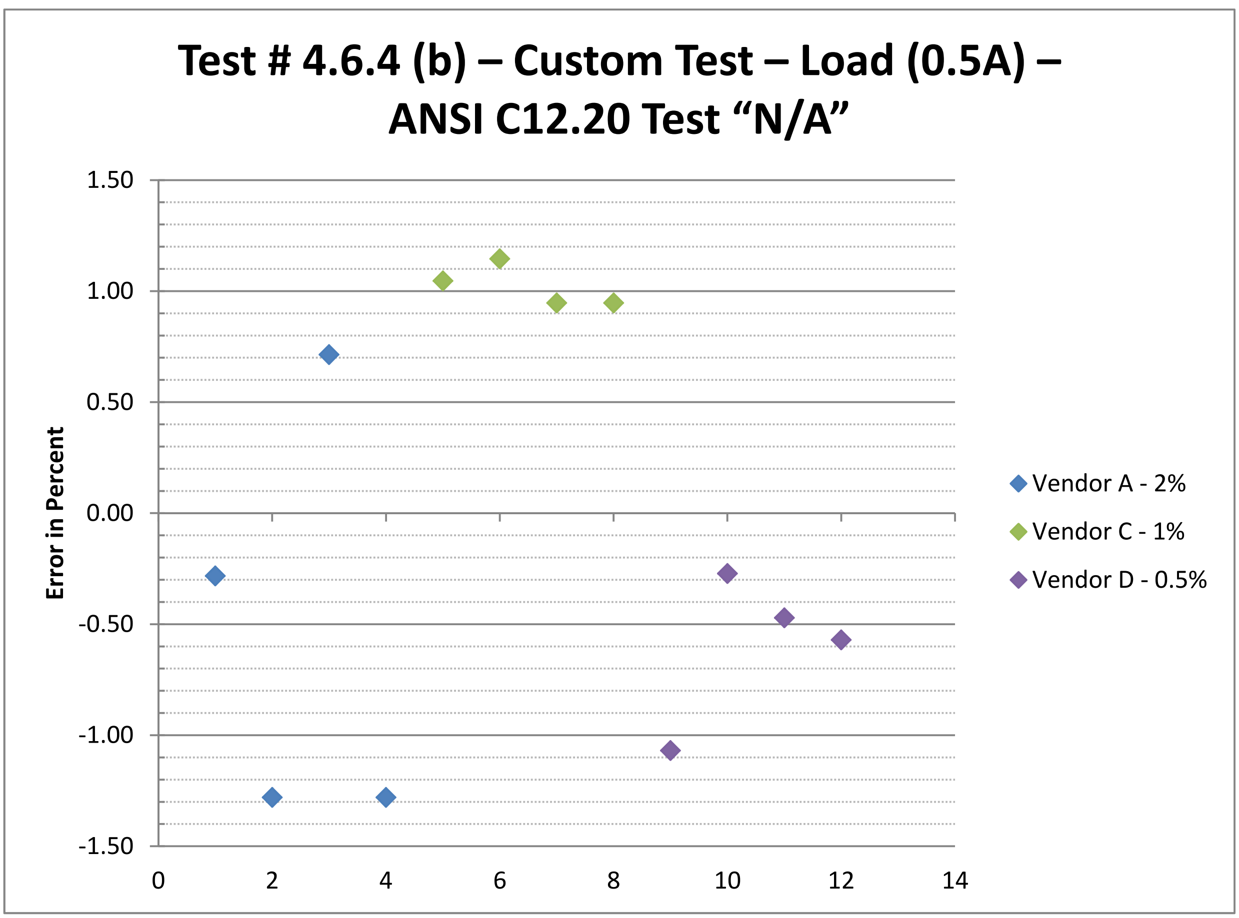
- Test 4.6.4 (a) – Custom Test Load (15A)
  - Conditions
    - Voltage – 120VAC
    - Current – 15A
    - Power factor – 1.00
    - Frequency – 60Hz
  - Results (Graph 18, below)
    - Vendors A through C failed to meet their stated specifications on any of the four nodes tested.
    - Vendor D met its stated specifications on two of the four nodes tested.
    - Vendor B could not be tested because of time constraints.

Graph 18



- Test 4.6.4 (b) – Custom Test Load (0.5A)
  - Conditions
    - Voltage – 120VAC
    - Current – 15A
    - Power factor – 1.00
    - Frequency – 60Hz
  - Results (Graph 19, below)
    - Vendor A met its stated specifications on all four nodes tested.
    - Vendors C and D met their stated specifications on two of the four nodes tested.
    - Vendor B could not be tested because of time constraints.

Graph 19



4.1.6.2.7. Customer Tests – Parasitic Load

- Additional Test – Parasitic Load
  - During the bench testing, National Grid requested that TESCO test each of the Vendors' nodes to determine their "Parasitic Load" or the amount of energy it takes to operate the nodes.
  - Results - According to ANSI C12.20, the Voltage Loss (parasitic load) must be less than 20VA. All of the nodes passed this requirement.
    - Vendor A – Average 0.839 VA
    - Vendor B – Average 0.918 VA
    - Vendor C – Average 0.832 VA
    - Vendor D – Average 0.835 VA

4.1.7. Observations

- For the majority of the tests run at the high end load current, Vendors A through C performed very poorly with respect to their stated specifications. Vendor D performed much better, but still had a number of failures.

- Two nodes became completely inoperable during the testing. The cause of the fault remains unknown.

- All Vendor B nodes shipped to TESCO were incorrectly programed to Service Provider 2 network ID1341, rather than the correct network ID1421. This error caused additional time to elapse from the test schedule due to the delay associated with shipping and reprogramming the network ID in all nodes.

- It takes a few minutes for any of the nodes to come back online after even a brief (less than 10 seconds) power outage. This delay may become an issue if these nodes are deployed into the field.

- All of the Service Provider 2 Network equipped nodes continue to communicate for a period of time after they have been powered down. The vendor subsequently provided information indicating that this condition is a configuration setting on the nodes and is used to keep network communications working to the node for a period of time after an outage occurs so that node can notify the head-end system of the outage.

- As noted earlier in this report, only Vendor D nodes were equipped with a test infrared pulse output. Although the pulse output worked well, it was very difficult to set up the sensor to pick up the pulse. A design recommendation would be for the node to have some indicator on the housing to better align the infrared pulse sensor.

- Vendor A nodes seem to require longer time to boot and respond to the handheld configurator. Repetitive actions were required to query each node. This too may become an issue if these units are deployed and require commissioning.

- Vendor A nodes only have 10Wh resolution. This would have caused testing to be much slower. Rather than losing additional testing schedule time, TESCO elected to test these nodes for the same time as all other nodes and forego the required resolution.

- The Meter Testing Board had to be re-calibrated during the bench testing. The calibration certification had expired on April 21, 2016 and the unit was re-calibrated on April 20, 2016.

- On some Vendor A nodes, the end Watt-hour reading was greater than the start Watt-hour reading for the next test. This condition indicates that the Watt-hour reading had been reduced, possibly during power cycles. This loss of energy readings could be significant over long periods of time.

- Vendor A explained to National Grid that all of its nodes were calibrated at 8.5A and, thus, a great deal of error outside the 8.5A calibration point would be expected. Vendor A also noted that the tests they ran within the calibration limits fared much better (in some cases a 90% pass rate) than their overall results. Also, Vendor A mentioned that its nodes come with a hardcoded firmware setting for minimum current recognition. The algorithm is such that the minimum creep limit is set to 10% of the measured full load that node will see, within a band of 30 to 100 milliamps (mA). Therefore, when testing nodes below 30mA one should expect to see exactly what the data shows. As noted earlier, National Grid provided the test specification to all vendors prior to the testing, and all vendors had the opportunity to comment or request revisions. Only Vendor D took the opportunity to provide feedback to National Grid.

4.2. Meter Farm Testing (Stage 1-Phase1)

The purpose of the meter farm testing phase was to prove out the operational capabilities of the nodes and to confirm the data flow from the nodes to the head end system under varying conditions.

4.2.1. Test Specification Development

The test specification for the meter farm testing was created in order to ensure that the third party testing was clearly defined and accepted by all involved parties, including National Grid and the node vendors.

4.2.1.1. Draft Specification

The initial draft of the meter farm testing specification defined the required testing, the method by which the testing would be performed, and the equipment required to perform the testing. The initial draft was mainly an adaptation of the statement of work. TESCO provided greater detail to the testing methods and specifications based on the requirements established for this phase as directed by National Grid. In addition, the draft detailed the test equipment that TESCO planned to build for use during the meter farm testing phase. This equipment was custom built for the project and will be transferred to National Grid at the completion of testing. See Attachment 6 (Photocell Node Meter Farm Testing – Project 8594) for the Meter Farm testing specification.

4.2.1.2. Test Quantity Criteria

The number of nodes to be tested was based on the meter farm panel design. A minimum of 18 nodes from each vendor would be tested in this phase.

4.2.1.3. Network Service Provider Software Training

Two different network communication systems and associated data retrieval software programs would be used to perform the meter farm testing. First, Service Provider 1 created and used the native system that interfaced with nodes provided by Vendor A. Second, Service Provider 2 created and used a program that functioned with nodes provided by Vendors B through D. Prior to the performance of the testing, both TESCO and National Grid requested the two service providers review the use and background programming of their software and provide insight as to the requirements and action necessary to obtain the metering information from the applicable nodes using their software.

On June 2, 2016, a Service Provider 1 Applications Engineer reviewed all operations of the Service Provider 1 software and made recommendations on report formatting and automation.

On May 11, 2016, the Director of Smart City Business Development for Service Provider 2 conducted the review of their software and presented an overview of its "Smart City" vision and initiatives. The review provided instructions on end-user use and functions available through the software. Following a more detailed discussion, Service Provider 2 provided notification that the present interface software was not adequate for the proposed access of the meter testing data due to user access limitations of the core metering information database. Additionally, Service Provider 2 utilizes two software programs to manage street light meter information. The first represents interface software, which is intended to functionally manage the control and setup of the nodes. The second software program represents the data backbone of the network head-end system, which also manages the revenue metering data collection that is often marketed by Service Provider 2 to its clients. Neither National Grid nor TESCO could gain access to Service Provider 2's database software meter data because the established accounts associated with the Pilot did not qualify for such level of data access. TESCO resolved the direct access problem when Service Provider 2 agreed to provide the desired meter data information on a weekly basis to TESCO in an acceptable database file format.

4.2.1.4. Additional Specification Requirements

The conceptual meter farm test plan called for TESCO to simply create different physical conditions (i.e., dimming or part-night) with the nodes on the meter farm panels at different dates and times. The resulting meter read data retrieved from the head-end system software would then be analyzed against calculated energy consumption based on the defined physical operating conditions tested. This process assessed the functionality of the network lighting control metering and associated network operations to simulate data accessibility and compatibility for the potential integration into National Grid's meter data management and billing systems.

This plan was modified to allow TESCO to establish the test conditions, data collection, and review of the metering data information from the nodes and provide the results to National Grid. National Grid added a section into the meter farm testing plan to directly connect LED luminaires into the meter farm panels so the nodes would actually experience realistic operating electrical load conditions. This testing of real load conditions facilitated the ability to achieve comparative metered and unmetered billing analysis. Each meter farm panel would have an individual, unique LED luminaire directly connected to each of the six node positions. This configuration allowed for the programming of individual operating conditions for each node position per test panel. The flexibility of this configuration allowed all nodes assigned to each test panel to function under each of the four operating schedules on each of the connected LED luminaires for one full day each. The addition to the meter farm testing would give National Grid a representation of how well the nodes followed the schedules assigned through the head-end software. The four schedules represented dusk-to-dawn, a "part-night", and two dimming programs, each of which have a direct correlation to current unmetered billing algorithms defined in National Grid's S-05 Tariff.

National Grid also requested that TESCO perform "characterizations" of each vendor's node on a number of sample LED luminaires to determine the offset, if any, between the commanded dimming level and the actual power consumed by the luminaire as reported by the node. In addition, National Grid requested that TESCO perform a characterization of nodes from each vendor on a specific LED luminaire to determine whether, and to what extent, the offset differed for a given vendor.

4.2.2. Final Test Specification

National Grid approved the final meter farm test specification plan, including all of the above changes, as set forth in Attachment 6.

4.2.3. Test Setup

4.2.3.1. Equipment Used

- TESCO Meter Farm Panels – The Meter Farm panels and the associated wire trough assembly bottom row equipment used for this part of the testing had to be specified, designed, and built according to mutually agreed upon specifications, as demonstrated in Attachment 7 (Photo Cell Meter Test Equipment), Attachment 8 (National Grid Panel), and Attachment 9 (Wire Trough Assembly – Bottom Row). The setup consisted of a total of four panels (one for each node vendor) with three rows of six node sockets each. The first row had a constant load on each of the node positions. The second row had a simulated dimming circuit, and the third row had connections that would allow the connection of individual luminaires to be wired into each of the six node positions. The setup of the Meter Farm panels is demonstrated in Diagram 5, below.

Diagram 5

Meter Farm Test Panel

- Service Provider 2 Wireless Gateway
  - Communication adapter between head-end system and Service Provider 2 capable nodes.
- Vendor A Wireless Data Concentration Unit
  - Communication adapter between Head end system and Vendor A nodes.
- Computer
  - Used to interface to the Service Provider 1 and Service Provider 2 software.

4.2.4. Test Methods Used

The meter farm testing was performed in two groups, with each group focused on core principles of function or schedule, respectively. The functional-based testing checked the basic operations of each node by reviewing the status information on each node through each of the two software interfaces used in the testing. The schedule-based testing was performed as follows:

- The nodes tested were mounted in the bottom row of their respective Meter Farm panels.
- Each of the nodes being tested had a LED luminaire connected to it.
- The nodes were programmed to apply specific dimming values at different times during the day based on a schedule and were allowed to run for four days per luminaire.
- At the conclusion of the schedule, the load was removed.
- After operating a given schedule on a given luminaire for one day, the node was programmed for the next schedule.
- After each node ran all four schedules on a given luminaire, the node was rotated to the next position connected to a different luminaire on the Meter Farm panel.
- This process was repeated in such a manner as to test each of the defined schedules on each of the luminaires available to each node panel. See Attachment 10 (Meter Farm Testing Data Final Report – Rotation Plan).

4.2.5. Test Results and Analysis

4.2.5.1. Laboratory Conditions

The Meter Farm panels were located in an area of the TESCO facility normally reserved for equipment assembly. The temperature was not regulated, but typically varied between 70ºF and 80ºF. The panels were not exposed to high humidity, hazardous environmental elements, or other natural weather conditions. The panels were wired into unregulated 120VAC supplies and were not exposed to surges or outages for the duration of the Meter Farm testing.

4.2.5.2. Data / Results

4.2.5.2.1. Read Test Results – Service Provider 1

- Test 4.2.2.1 – Read Tests (Service Provider 1) – Read Time

- Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
- Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the 18 nodes were read from the Service Provider 1 software to obtain status and metering information. In each case of good reads, the read time was correctly displayed on all nodes. See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.2.2.2 – Read Tests (Service Provider 1) – Volts
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the 18 nodes were read from the Service Provider 1 software to get status and metering information. In each case of good reads, the voltage was correctly displayed on all nodes, as compared to the values read by the handheld communicator (local resource). See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.2.2.3.1 – Read Tests (Service Provider 1) – Constant Current
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the six nodes in Row 1 of the Meter Farm Panel were read from the Service Provider 1 software to obtain status and metering information. In each case of good reads, the current was correctly displayed on all nodes, as compared to the values read by the handheld communicator (local resource). See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.2.2.3.2 – Read Tests (Service Provider 1) – Actual Luminaire Current
  - Conditions – Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the six nodes in Row 3 were read from the Service Provider 1 software to obtain status and metering information. In each case of good reads, the current was correctly displayed on all nodes, as compared to the values read by the handheld communicator (local resource). See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.2.2.4.1 – Read Tests (Service Provider 1) – Constant Power
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the six nodes in Row 1 of the Meter Farm Panel were read from the Service Provider 1 software to obtain status and metering information. In each case of good reads, the kilowatts (kW) (i.e., power) were correctly displayed on all nodes, using the voltage and current values to calculate the estimated kW in each read. See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.2.2.4.2 – Read Tests (Service Provider 1) – Actual Luminaire Power
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing and included in the Meter Farm raw data, each of the six nodes in Row 3 of the Meter Farm Panel were read from the Service Provider 1 software to obtain status and metering information. In each case of good reads, the kW (power) was correctly displayed on all nodes, using the voltage and current values to calculate the estimated kW in each read. The values did fluctuate throughout the scheduled testing, based on commanded dimming values. The only offset seen resulted from the "characterization" described in Section 4.2.5.2.8, below, regarding the Test 4.6.1 Characterizations. See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.2.2.5 – Read Tests (Service Provider 1) – Energy
  - Conditions – Row 1– 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the 18 nodes were read from the Service Provider 1 software to get status and metering information. In each case of good reads, the kWh (i.e., energy) were displayed properly on all nodes, using the voltage, current, and time values to calculate the estimated increase in kWh in consecutive reads. The only offset seen resulted from the "characterization" described in Section 4.2.5.2.8, below, regarding the Test 4.6.1 Characterizations. See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.2.2.6 – Read Tests (Service Provider 1) – Dimming Value
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the six nodes wired to luminaires in Row 3 of the Meter Farm Panel were read from the Service Provider 1 software to get status and metering information. In each case of good reads, the dimming value was correctly displayed on all nodes. See Attachment 10 (Meter Farm Testing Data Final Report).

4.2.5.2.2. <u>Write Test Results – Service Provider 1</u>

- Test 4.2.3.1 – Write Tests (Service Provider 1) – On/Off
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-0.0A (variable).
  - Results – Each of the 18 nodes were cycled on and off through the Service Provider 1 software. After each cycle, the status was read through the Service Provider 1 software and was reported accurately on all nodes.

- Test 4.2.3.2 – Write Tests (Service Provider 1) – Dimming
  - Conditions – Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing, and specifically the schedule testing, the dimming value was written to the nodes in Row 3 of the meter farm panels. The schedule testing results reflect the responses to the write changes.

4.2.5.2.3. <u>Communication Integrity Test Results – Service Provider 1</u>

- Test 4.2.4.1 – Communication Integrity Tests – Dead Meter – No usage
  - Conditions – Row 3 – 120VAC, 60Hz, 0.0A
  - Results – During the meter farm testing, numerous nodes in Row 3 were removed from their socket and replaced. On most occasions, the first reads showed the accumulated Watt-hours. There were occasions, however, on Vendor A nodes, where the accumulated Watt-hours prior to the shutoff were greater than after the power was turned back on to the nodes. An example of this condition can be observed in Attachment 10 (Meter Farm Testing Data Final Report) at sheet 3850, rows 189 and 190.

- Test 4.2.4.2 – Communication Integrity Tests – Zero Usage – Valid – No usage
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – During the Meter Farm testing, there were multiple occasions for each node to respond to dimming values set to 0% and then back up again and the nodes responded appropriately.

- Test 4.2.4.3 – Communication Integrity Tests – 50% Actual Data
  - No data was received from Service Provider 1 for this test.

- Test 4.2.4.4 – Communication Integrity Tests – 80% Actual Data
  - No data was received from Service Provider 1 for this test.

- Test 4.2.4.5 – Communication Integrity Tests – 90% Actual Data
  - No data was received from Service Provider 1 for this test.

- Test 4.2.4.6 – Communication Integrity Tests – Simulated Gateway Loss and Recovery
  - No data was received from Service Provider 1 for this test.

- Test 4.2.4.7 – Communication Integrity Tests – Read Rate per Meter
  - This value is not available from Service Provider 1.

- Test 4.2.4.8 – Communication Integrity Tests – Total Meter Average Read Rate
  - This data was not available from the Service Provider 1 software.

4.2.5.2.4. <u>Read Test Results – Service Provider 2</u>

- Test 4.3.2.1 – Read Tests (Service Provider 2) – Voltage and Frequency
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the 54 nodes were read from the Service Provider 2 software to get status and metering information. In each case of good reads, the voltage and frequency readings were correctly displayed on all nodes. See Attachment 10 (Meter Farm Testing Data Final).

- Test 4.3.2.2.1.1 – Read Tests (Service Provider 2) – Constant Current
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing and included in the Meter Farm raw data, each of the 18 nodes on Row 1 of the Meter Farm Panels were read from the Service Provider 2 software to get status and metering information. In each case of good reads, the current was correctly displayed on all nodes, as compared to the values read by the handheld communicator (local resource). See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.3.2.2.1.2 – Read Tests (Service Provider 2) – Actual Luminaire Current
  - Conditions – Although the specification called for this reading to be done on the Row 2 nodes, the data for this test was easily obtained from the Row 3 nodes, which were connected to the luminaires. The current was fluctuating on these nodes based on the schedule testing.
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the 12 nodes from Row 3 were read from the Service Provider 2 software to get status and metering information. In each case of good reads, the current was correctly displayed on all nodes, as compared to the values read by the handheld communicator (local resource). See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.3.2.2.1.1 – Read Tests (Service Provider 2) – Constant Power
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the 18 nodes in Row 1 of the Meter Farm Panel were read from the Service Provider 2 software to get status and metering information. In each case of good reads, the kW (i.e., power) were correctly displayed on all nodes, using the voltage and current values to calculate the estimated kW in each read. The only offset resulted from the "characterization" described in Section 4.2.5.2.8, below, regarding the Test 4.6.1 Characterizations. See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.3.2.2.2.2 – Read Tests (Service Provider 2) – Actual Luminaire Power
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the 12 nodes in Row 3 of the Meter Farm Panel were read from the Service Provider 2 software to get status and metering information. In each case of good reads, the kW (i.e., power) was correctly displayed on all nodes, using the voltage and current values to calculate the estimated kW in each read. These values did fluctuate throughout the schedule testing, based on commanded dimming values. The only offset seen resulted from the "characterization" described in Section 4.2.5.2.8, below, regarding the Test 4.6.1. Characterizations. See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.3.2.2.3.1 – Read Tests (Service Provider 2) – Energy
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the 54 nodes were read from the Service Provider 2 software to get status and metering information. In each case of good reads, the kWh (i.e., energy) was displayed properly on all nodes, using the voltage, current, and time values to calculate the estimated increase in kWh in consecutive reads. The only offset seen resulted from the "characterization" described in Section 4.2.5.2.8, below, regarding the Test 4.6.1. Characterizations. See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.3.2.2.4 – Read Tests (Service Provider 2) – Brightness Value
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing, and included in the Meter Farm raw data, each of the 12 nodes wired to luminaires in

Row 3 of the Meter Farm Panels were read from the Service Provider 2 software to get status and metering information. In each case of good reads, the brightness value was correctly displayed on all nodes. See Attachment 10 (Meter Farm Testing Data Final Report).

4.2.5.2.5. <u>Write Test Results – Service Provider 2</u>

- Test 4.3.3.1 – Write Tests (Service Provider 2) – Brightness
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – Throughout the course of the Meter Farm testing, and specifically the schedule testing, the brightness value was written to the nodes in Row 3 of the meter farm panels. The schedule testing results reflect the responses to the write changes. See Attachment 10 (Meter Farm Testing Data Final Report).

4.2.5.2.6. <u>Communication Integrity Test Results – Service Provider 2</u>

- Test 4.3.4.1 – Communication Integrity Tests – Dead Meter – No usage
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – During the meter farm testing, numerous nodes in Row 3 were removed from their socket and replaced. On most occasions, the first reads showed the accumulated Wh. There were occasions, however, on Vendor B nodes, where the accumulated Wh prior to the shutoff were greater than after the power was turned back on to the nodes. Refer to the Meter Farm Testing Data Final Report, sheet 43A7, rows 90 and 91 for an example. See Attachment 10 (Meter Farm Testing Data Final Report).

- Test 4.3.4.2 – Communication Integrity Tests – Zero Usage – Valid – No usage
  - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
  - Results – During the meter farm testing, there were multiple occasions for each node where the dimming values were set to 0% and then back up again and the nodes responded appropriately.

- Test 4.3.4.3 – Communication Integrity Tests – 50% Actual Data
    - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
    - Results – No data was received from Service Provider 2 for this test.

- Test 4.3.4.4 – Communication Integrity Tests – 80% Actual Data
    - Conditions – Row 1– 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
    - Results – No data was received from Service Provider 2 for this test.

- Test 4.3.4.5 – Communication Integrity Tests – 90% Actual Data
    - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
    - Results – No data was received from Service Provider 2 for this test.

- Test 4.3.4.6 – Communication Integrity Tests – Simulated Gateway Loss and Recovery
    - Conditions – Row 1 – 20VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
    - Results – No data was received from Service Provider 2 for this test.

- Test 4.3.4.7 – Communication Integrity Tests – Read Rate per Meter
    - Conditions – Row 1 – 20VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
    - Results – This data was not available from the Service Provider 2 software.

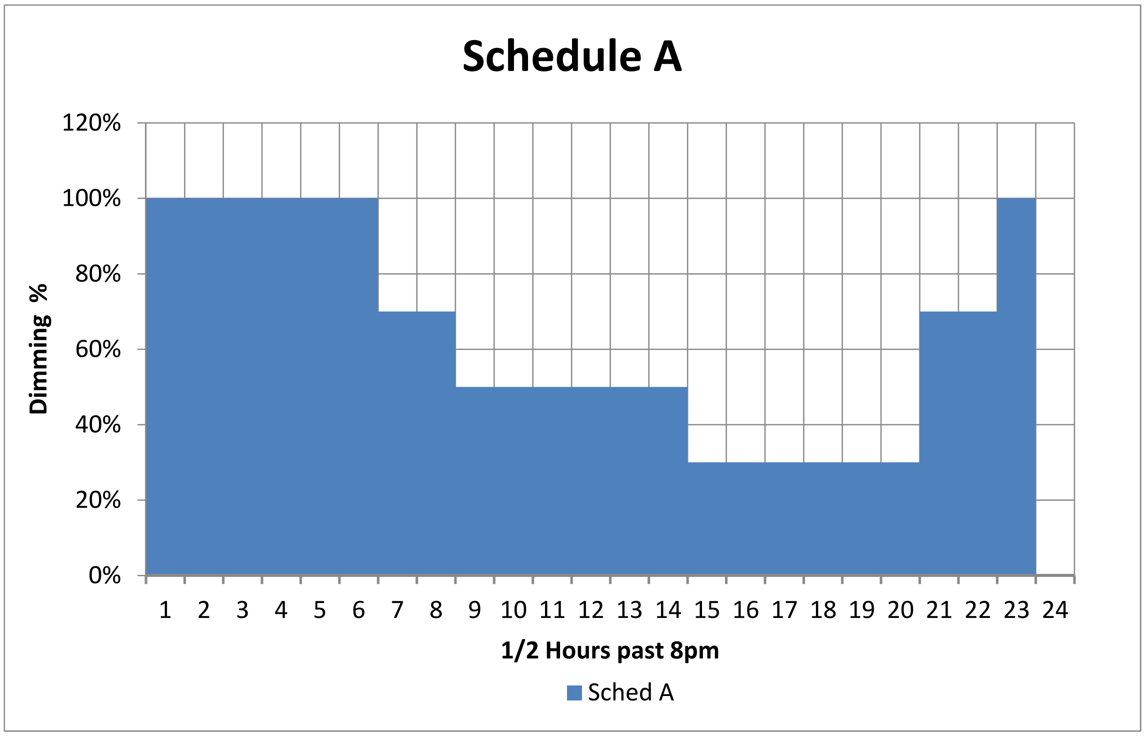
- Test 4.3.4.8 – Communication Integrity Tests – Total Meter Average Read Rate
    - Conditions – Row 1 – 120VAC, 60Hz, 0.5A (constant); Row 2 – 120VAC, 60Hz, 0-1.5A (variable); Row 3 – 120VAC, 60Hz, 0-10.0A (variable).
    - Results – This data was not available from the Service Provider 2 software.

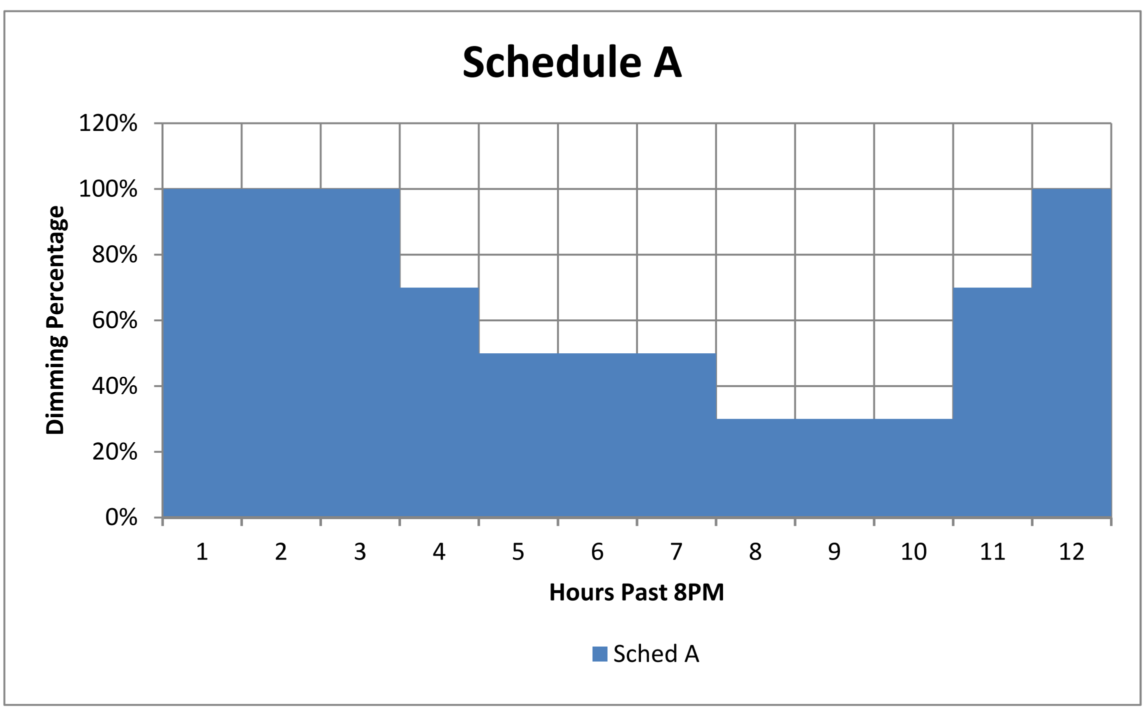
4.2.5.2.7. Variable Schedule Analysis – Both Service Provider Networks

The Variable Schedule tests represent an analysis of the operation of the luminaires while running the prescribed schedules. Originally, such tests were intended to result in the analysis of comparative metered billing. However, that analysis was better suited for the field testing, as presented later in this report, as the field installations had the ability to compare each node to a qualified revenue-grade meter as well as the standard billing algorithm. Any comparison that could be completed on the Meter Farm nodes would have to use the metrology of the node to perform a comparison calculation, which would only end up proving that the nodes were able to do a simple math calculation, which was already tested during the bench testing.

Operating Schedule A

Graph 20





- **Vendor A Test**
  - Conditions – Nodes: 3850, 4028, 4030, 4068, 4094.
    Luminaires: 18, 7, 12, 17, 16.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – All nodes reported data at 5:00 a.m., except for node 4094, as seen in coordinate E5. The chart at coordinate E5 returned data as presented because of a faulty install that was later fixed. All nodes, except node 4094 in coordinate E5, reported double data at midnight. Three of four days that this schedule ran on node 3850 had missing data at 6:00 a.m., while node 4028 had missing the same data on all four days; node 4030 had missing the data in three of the four days; node 4068 had missing the data on all four days; and node 4094 had missing the data in three of the four days. All nodes, except node 4094 at coordinate E5, are missing data from 3:30-5:00 a.m. All nodes, except node 4094 in coordinate E5, are missing data at 8:00 p.m., 9:00 p.m., and 9:30pm. Charts at coordinates A3, B4, C2, and D4 are all missing data or show 0% power until midnight due to a scheduling error on the first day of testing.

- **Vendor B Test**
  - Conditions – Nodes: 43A7, 3866, B4DB, 327C.
    Luminaires: 5, 1, 14, 8.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – Data was not reported for node 43A7 on June 20-21 and 27-28, 2017. Data was consistently 0% power at 6:00-7:00 a.m., except for the following instances noted due to an uncertainty as to what happened: one of the two days that this schedule ran on node 43A7; two of the four days that this schedule ran on node 3866; one of the four days that this schedule ran on node B4DB; and one of the four days that this schedule ran on node 327C. 100% dimming power (i.e., full power) did not always stay at 100% and is noted to have occurred one of the two days this schedule ran on node 43A7; two of the four days this schedule ran on node 3866; and three of the four days this schedule ran on both node B4DB and 327C. All nodes were missing data or show 0% power from 7:00-8:00 a.m.

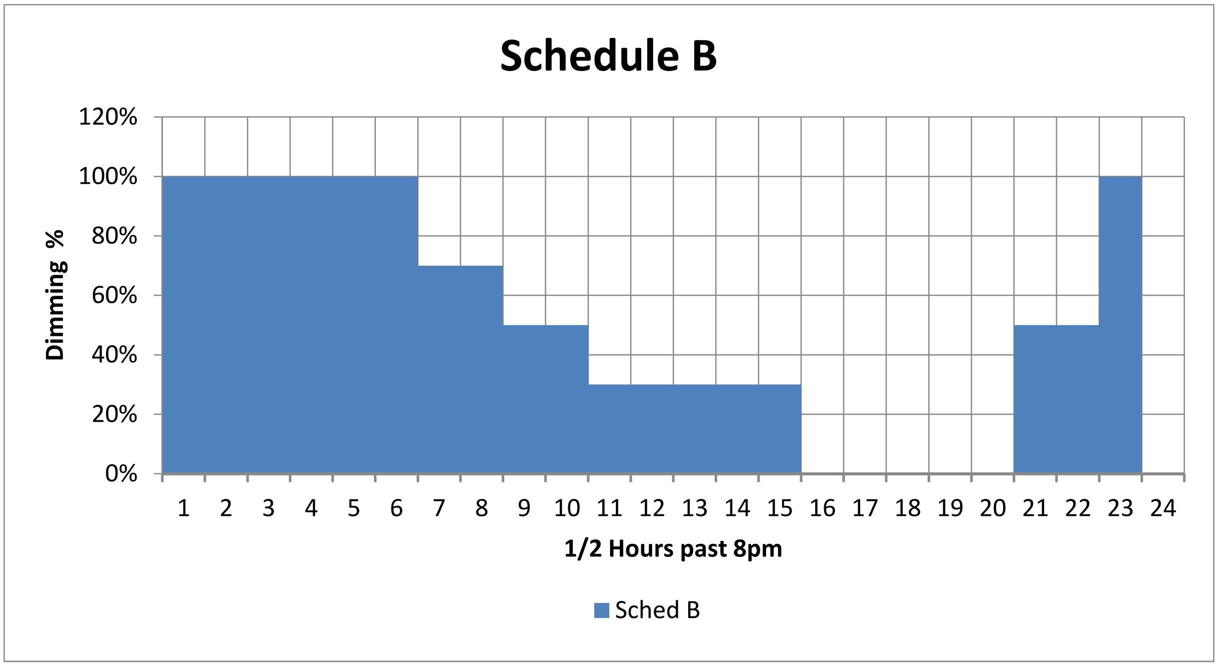
- **Vendor C Test**
  - Conditions – Nodes: 539B, DFEA, E2BF, D7CA.
    Luminaires: 11, 9, 2, 15.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).

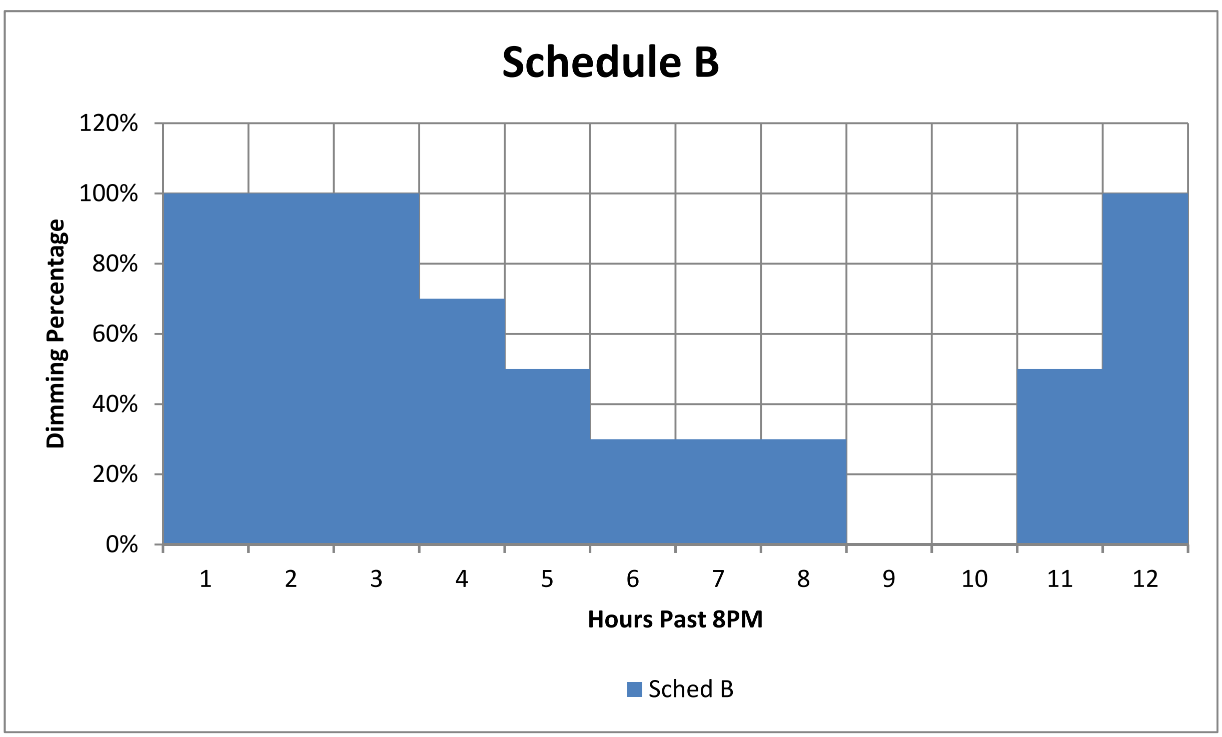
- Observations – Data always reported back 0% power from 7:00-8:00 a.m. for all nodes. A small non-zero data point was reported one time between 6:00-7:00 a.m. on nodes DFEA and D7CA (see charts at coordinates B3 and D4). 100% dimming power (i.e., full power) did not always stay at 100% and is noted to have happened one out of the four days this schedule ran on node E2BF and three out of four days on node D7CA.

- **Vendor D Test**
  - Conditions – Nodes: 2D14, 2DE8, 2DA9, 2D1F.
    Luminaires: 3, 10, 13, 4.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – Data always reported back 0% power from 6:00-8:00 a.m. for all nodes. 100% dimming power (i.e., full power) did not always stay at 100% and is noted to have happened on two of the four days this schedule ran on node 2D14, and one of four days on nodes 2DE8, 2DA9, and 2D1F.

Operating Schedule B

Graph 21





- **Vendor A Test**
  - Conditions – Nodes: 3850, 4028, 4030, 4068, 4094.
    Luminaires: 18, 7, 12, 17, 16.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs .
  - Observations – All tests reported data at least once from 2:00-5:00 a.m., except for node 4094 as seen in the chart at coordinate E5. The chart at coordinate E5 shows data as presented because of a faulty install that was later fixed. Data is missing at 6:00 a.m. on all four days that this schedule ran on nodes 3850, 4030, 4068, and 4094, while it was only missing on three of the four days this schedule ran on 4028. All nodes, except node 4094 in the chart at coordinate E5, are missing data from 4:00-4:30 a.m. All nodes are missing data at 8:00, 9:00, and 9:30 p.m.

- **Vendor B Test**
  - Conditions – Nodes: 43A7, 3866, B4DB, 327C.
    Luminaires: 5, 1, 14, 8.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – Data was not reported for node 43A7 on June 21-22 and 28-29, 2017. Data was consistently 0% power at 6:00-7:00 a.m., except for one instance on node 3866, which was not a correct value (see chart at coordinate B2). Dimming (i.e., full power) did not always stay at 100% power and is noted to have happened one of the two days this schedule ran on node 43A7; two of the four days on node 3866; all four days on node B4DB; and three of four days on node 327C. All nodes were missing or 0% power from 7:00-8:00 a.m. Non-zero data was reported between 5:00-6:00 a.m. when it should have reported 0% power on one of the four days this schedule ran on node 3866; one of four days on node B4DB; and two of four days on node 327C. All nodes went to 0% power an hour early instead of between 4:00-5:00 a.m.

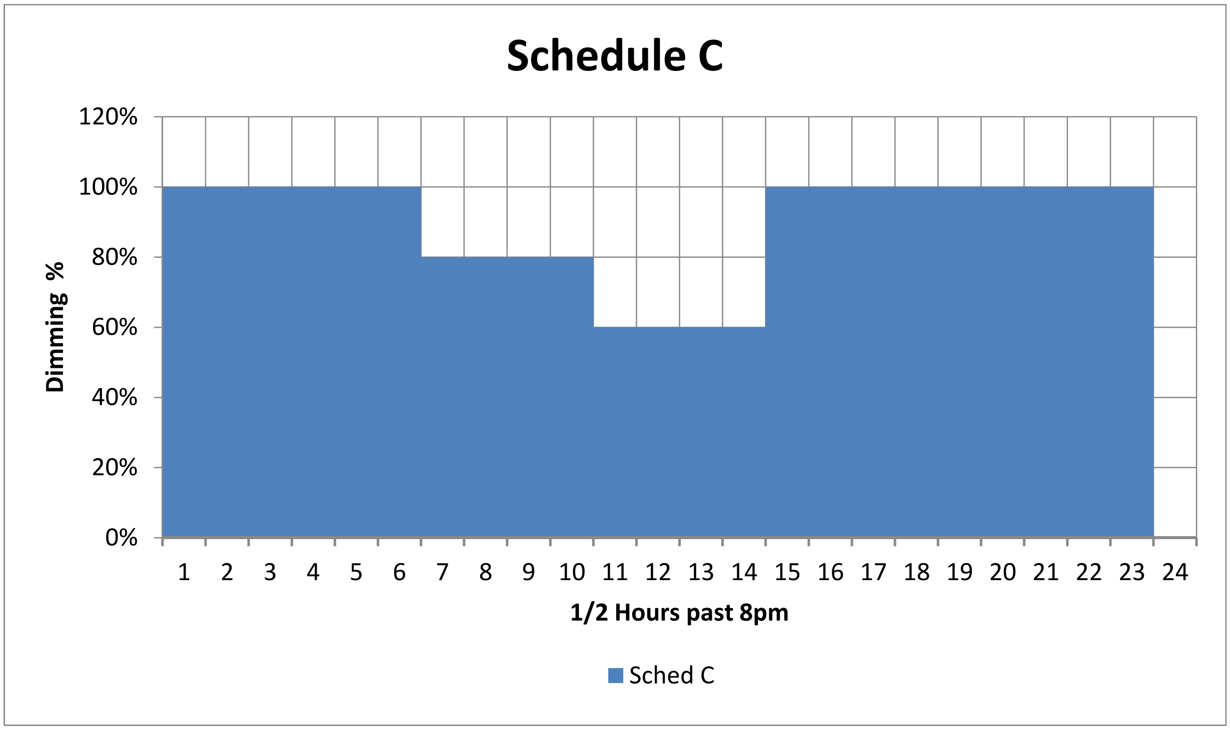
- **Vendor C Test**
  - Conditions – Nodes: 539B, DFEA, E2BF, D7CA.
    Luminaires: 11, 9 2, 15.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – Data was consistently 0% power at 6:00-7:00 a.m., except once on node E2BF(see chart at coordinate C1). Dimming (i.e., full power) did not always stay at 100% power and is noted to have happened two of the four days this schedule ran on node 539B and three of four days on nodes D7CA and 327C. All nodes were missing

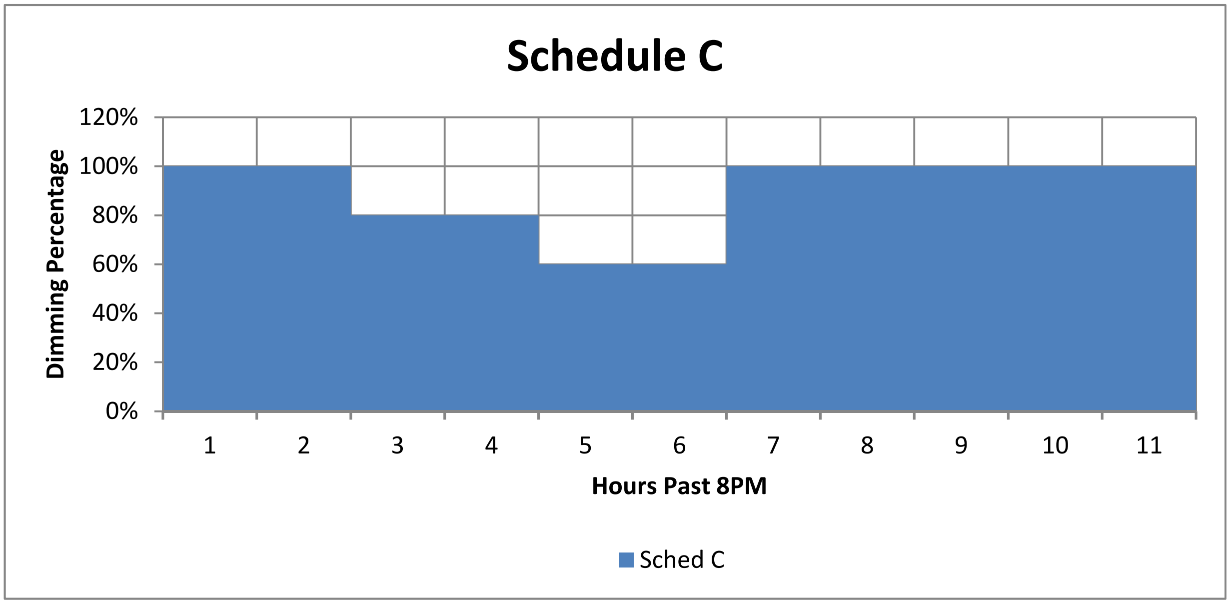
or 0% power from 7:00-8:00 a.m. Non-zero data was reported between 5:00-6:00 a.m. when it should have been 0% power once on node DFEA (see chart at coordinate B2). All nodes went to 0% power an hour early instead of between 4:00-5:00 a.m.

- **Vendor D Test**
  - Conditions – Nodes: 2D14, 2DE8, 2DA9, 2D1F.
    Luminaires: 3, 10, 13, 4.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – Data was consistently 0% power at 6:00-7:00 a.m. Dimming (i.e., full power) did not always stay at 100% power and is noted to have happened three of the four days this schedule ran on node 2D14 and two of the four days on nodes 2DE8, 2DA9, and 2D1F. All nodes were missing or 0% power from 7:00-8:00 a.m. Non-zero data was reported between 5:00-6:00 a.m. when it should have reported 0% power once on node 2D1F (see chart at coordinate D4). All nodes went to 0% power an hour early instead of between 4:00-5:00 a.m.

Operating Schedule C

Graph 22





- **Vendor A Tests**
  - Conditions – Nodes: 3850, 4028, 4030, 4068, 4094.
    Luminaires: 18, 7, 12, 17, 16.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – All nodes reported 0% power from 4:00-5:00 a.m. when they should have reported 100% power. No data reported at 6:00 a.m. for all nodes, except on two of the four days this schedule ran on node 3850 and one of the four days on node 4028 (see chart at coordinate B2). All nodes are missing data at 8:00, 9:00, and 9:30 p.m. All nodes did report data at 5:30 a.m. The data did not show a step down from 100% power on one of the four days this schedule ran on nodes 3850, 4030, 4068, and 4094.

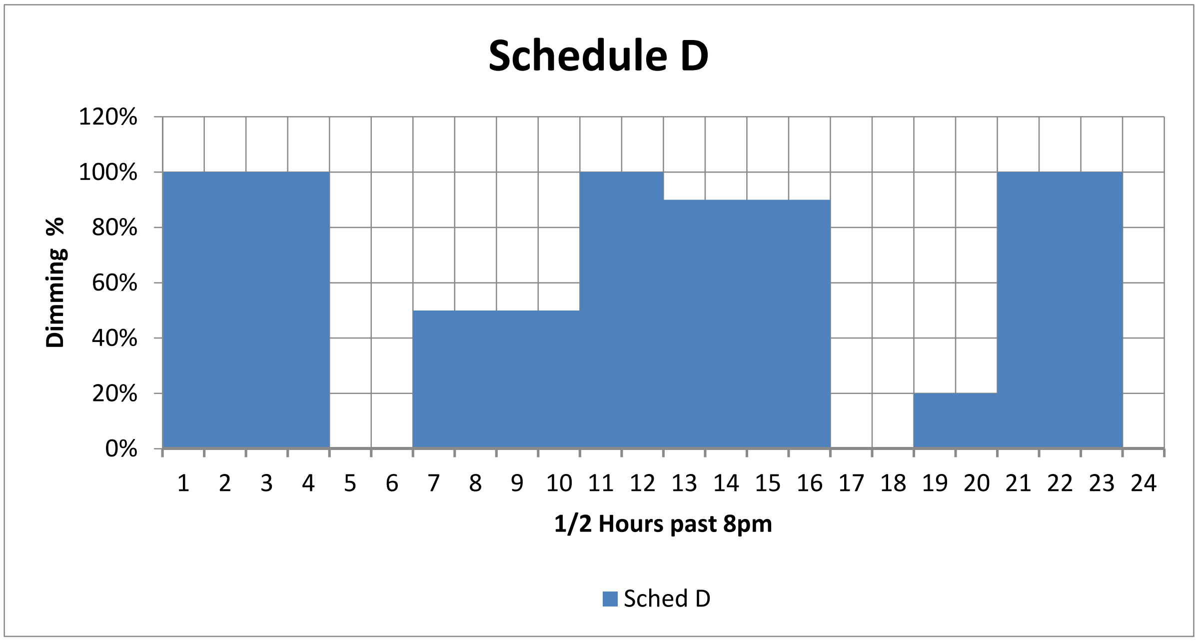
- **Vendor B Tests**
  - Conditions – Nodes: 43A7, 3866, B4DB, 327C.
    Luminaires: 5, 1, 14, 8.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – All nodes reported 0% power from 7:00-8:00 a.m. The data did not show a step down from 100% power on two of the four days this schedule ran on nodes 3866, B4DB, and 327C. Steps from 100% power and back to 100% power were all reported an hour late (if it was made at all) on all nodes. 100% power not maintained from 8:00-10:00 p.m. one of the three days this schedule ran on node 43A7; two of the four days on nodes 3866 and B4DB; and three of the four days on node 327C.

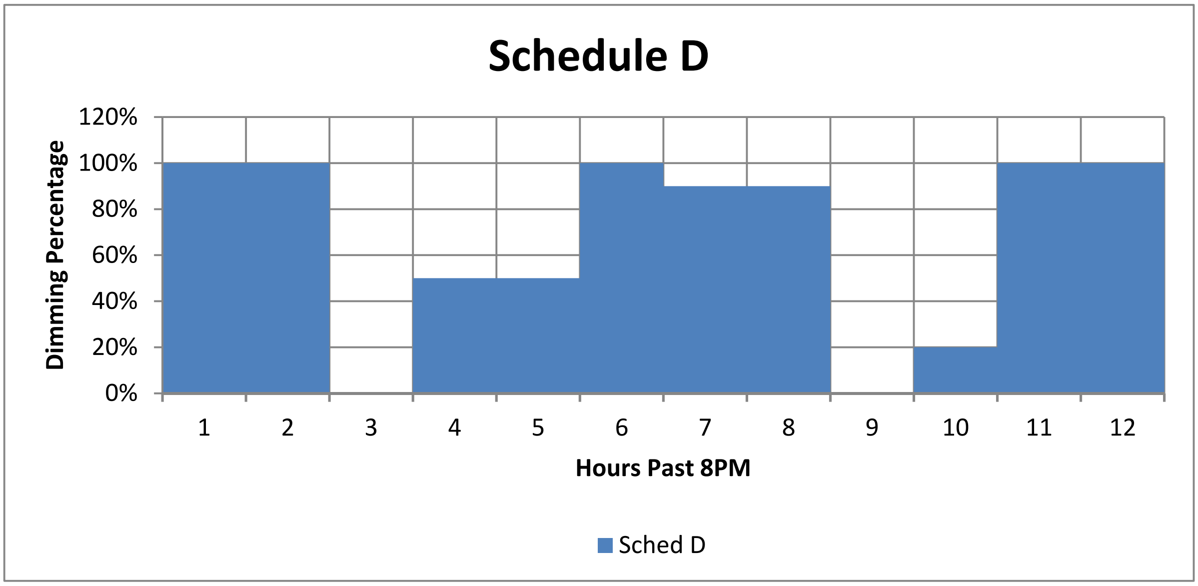
- **Vendor C Tests**
  - Conditions – Nodes: 539B, DFEA, E2BF, D7CA.
    Luminaires: 11, 9, 2, 15.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – All nodes reported 0% power from 7:00-8:00 a.m. The data did not show a step down from 100% power on three of the four days this schedule ran on nodes 539B, DFEA, E2BF, and D7CA. Steps from 100% power and back to 100% power were all reported an hour late (if made at all) on all nodes. 100% power not maintained from 8:00-10:00 p.m. on one of the four days this schedule ran on nodes E2BF and D7CA.

- **Vendor D Tests**
  - Conditions – Nodes: 2D14, 2DE8, 2DA9, 2D1F.
    Luminaires: 3, 10, 13, 4.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – All nodes reported 0% power from 7:00-8:00 a.m. The data did not show a step down from 100% power on one of the four days this schedule ran on nodes 2D14, 2DE8, 2DA9, and 2D1F. Steps from 100% power and back to 100% power were all reported an hour late (if made at all) on all nodes. 100% power not maintained from 8:00-10:00 p.m. on two of the four days this schedule ran on nodes 2D14, 2DE8, 2DA9, and 2D1F.

Operating Schedule D

Graph 23





- **Vendor A Test**
  - Conditions – Nodes: 3850, 4028, 4030, 4068, 4094.
    Luminaires: 18, 7, 12, 17, 16.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – All nodes are missing data at 6:00 a.m. All nodes are missing data at 5:00 a.m., except on two of the four days this schedule ran on node 4030 and one of the four days on nodes 4068 and 4094. Repeat data at midnight occurred on one of the four days this schedule ran on nodes 3850 and 4030; three of the four days on node 4028; and two of the four days on nodes 4068 and 4094. All nodes are missing data at 8:00 p.m. 0% power reported at 4:00-4:30 a.m. when they should have reported 100% power three of the four days this schedule ran on node 3850; two of the four days on nodes 4028 and 4068; and one of the four days on node 4094.

- **Vendor B Test**
  - Conditions – Nodes: 43A7, 3866, B4DB, 327C.
    Luminaires: 5, 1, 14, 8.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – All nodes were missing data or reported 0% power from 6:00-8:00 a.m. 100% power was not maintained from 8:00-10:00 p.m. on all three days this schedule ran on node 43A7; two of four days on node 3866; and three of four days on nodes B4DB and 327C. Instances of non-zero occurred twice on nodes 43A7 (see chart at coordinate A3) and 327C (see charts at coordinates D3 and D4), and once on node B4DB (see chart at coordinate C3).

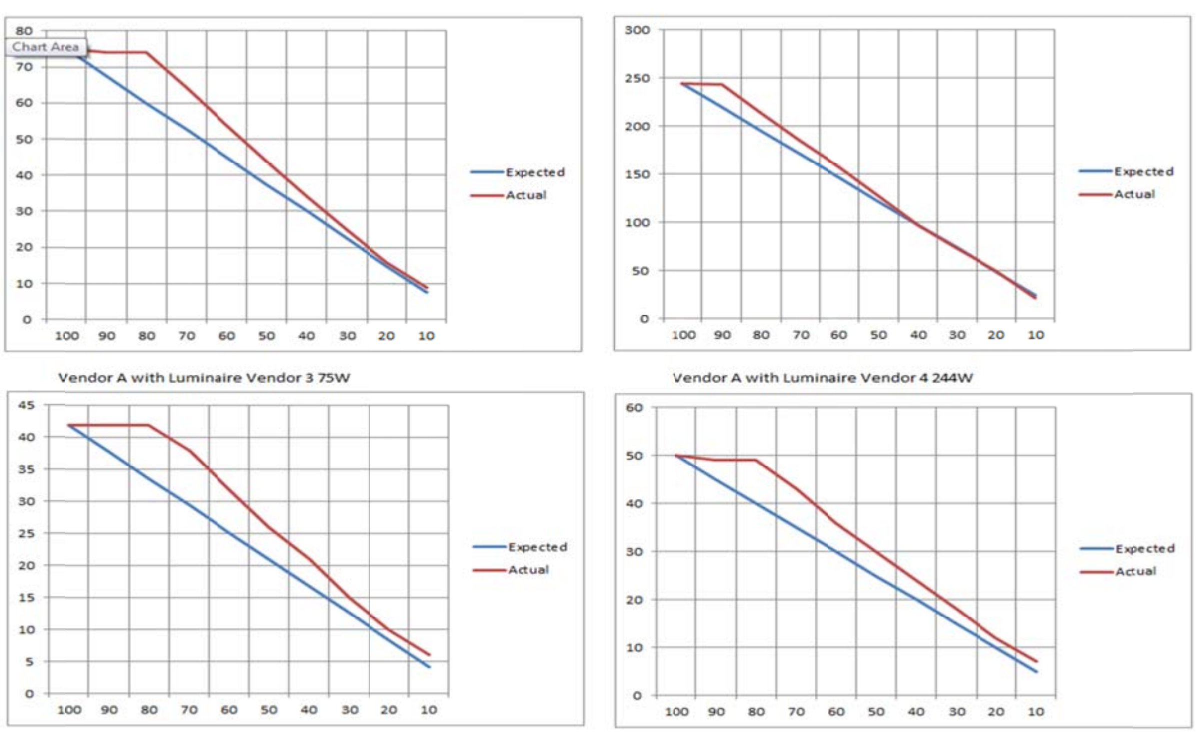
- **Vendor C Test**
  - Conditions – Nodes: 539B, DFEA, E2BF, D7CA.
    Luminaires: 11, 9, 2, 15.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – All nodes were missing data or reported 0% power from 6:00-8:00 a.m. 100% power was not maintained from 8:00-10:00 p.m. on two of the four days this schedule ran on node D7CA. Instances of non-zero occurred once on nodes DFEA (see chart at coordinate B2) and D7CA (see chart at coordinate D1).

- **Vendor D Test**
  - Conditions – Nodes: 2D14, 2DE8, 2DA9, 2D1F.
    Luminaires: 3, 10, 13, 4.
  - Results – See Attachment 11 (Meter Farm Schedule Graphs).
  - Observations – All nodes were missing data or reported 0% power from 6:00-8:00 a.m. 100% power was not maintained from 8:00-10:00 p.m. on two of the four days this schedule ran on nodes 2D14 and 2DE8, and one of the four days on nodes 2DA9 and 2D1F.

4.2.5.2.8. <u>LED Luminaire (0-10V Driver) Power Consumption – Dimming Rate Characterization</u>

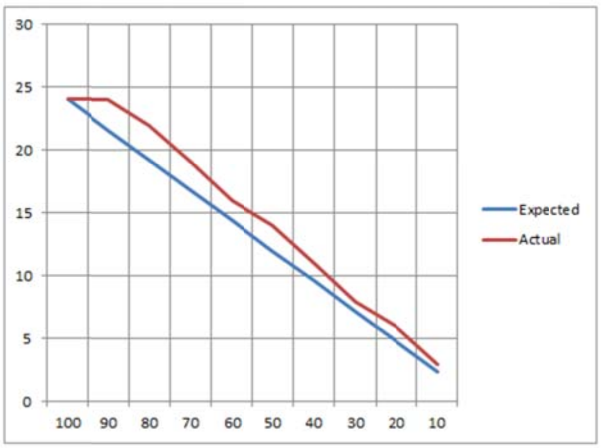
- Test 4.6.1 Characterizations – Different Nodes and Luminaires.
  - Conditions – Each of the charts below show the expected and actual power readings from the nodes. This data was read directly from the nodes and not through the head-end system. Only Vendors A, C, and D are detailed here. Vendor B results were identical to Vendor A.
  - Vendor A Results – In all four cases, the data shows that to varying degrees based on the luminaire, the relationship between the commanded dimming level and the actual power output of the node was not linear, especially above approximately 50%.

<u>Graph 24</u>

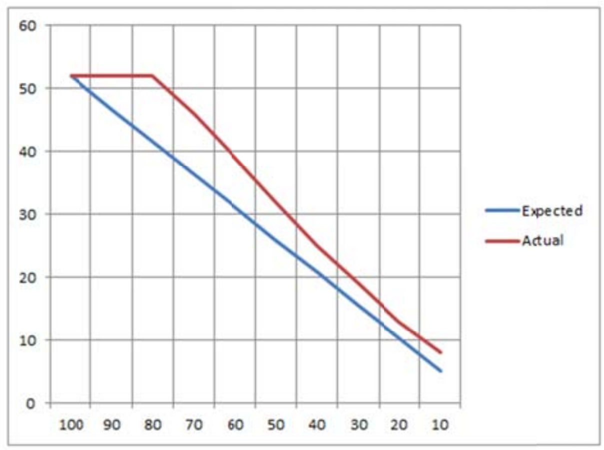


- Vendor C Results – Though quite close to the results for Vendor A, Vendor C's results appear to have less of an offset through the range. The Luminaire Vendor 3 luminaire seemed to have the least offset.

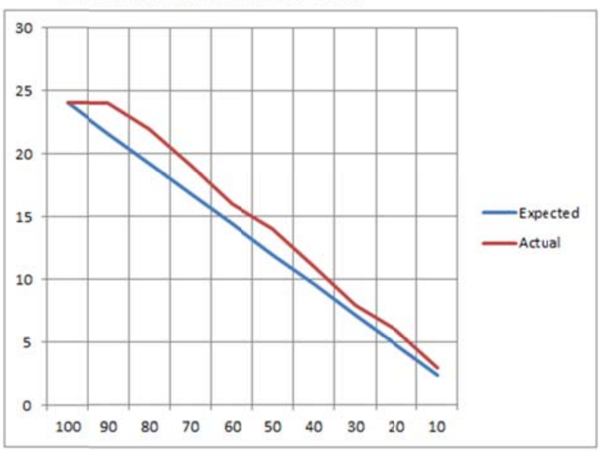
Graph 25



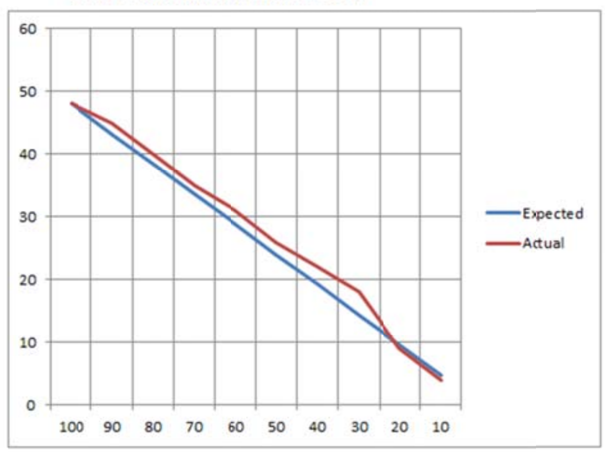
Vendor C with Luminaire Vendor 4 25W



Vendor C with Luminaire Vendor 1 52W



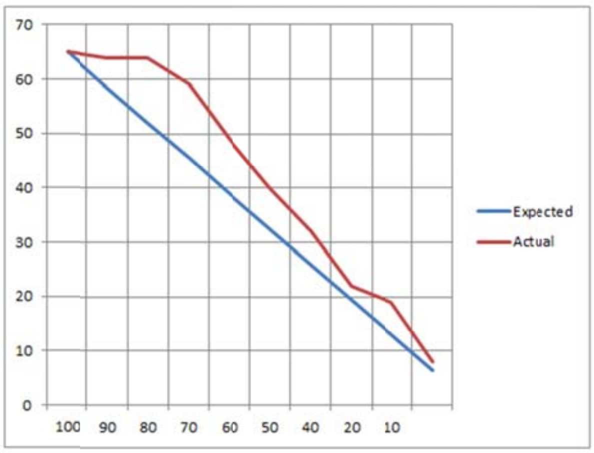
Vendor C with Luminaire Vendor 2 114W



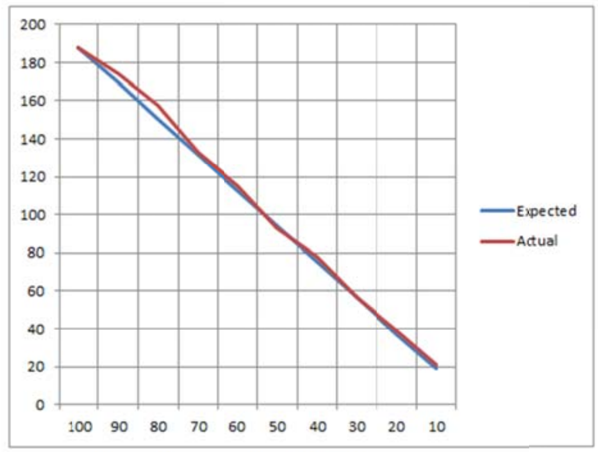
Vendor C with Luminaire Vendor 3 48W

- Vendor D Results – In this data, it appears that the Luminaire Vendors 1 and 2 luminaires have a greater offset through the range than Luminaire Vendors 3 or 4.

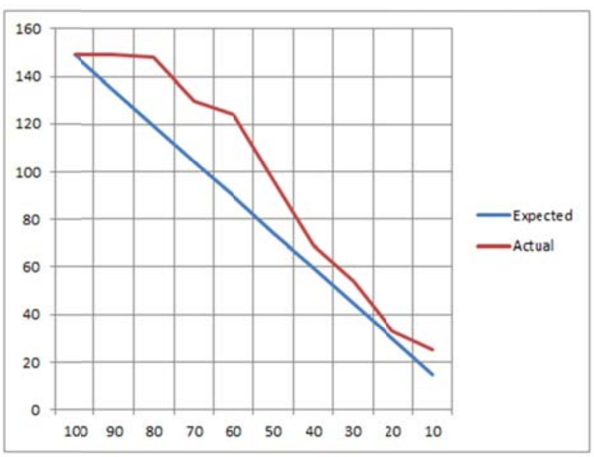
Graph 26



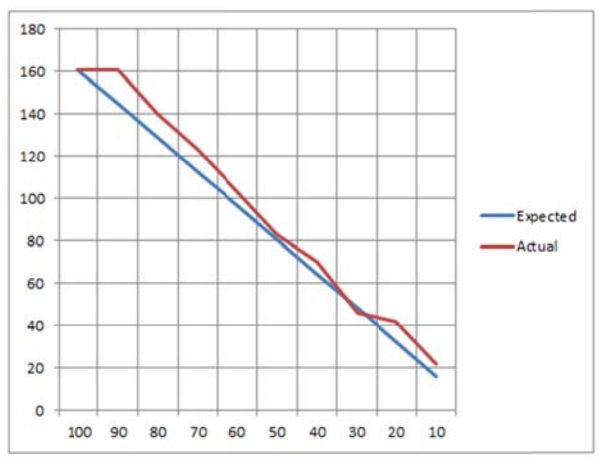
Vendor D with Luminaire Vendor 1 65W



Vendor D with Luminaire Vendor 3 188W



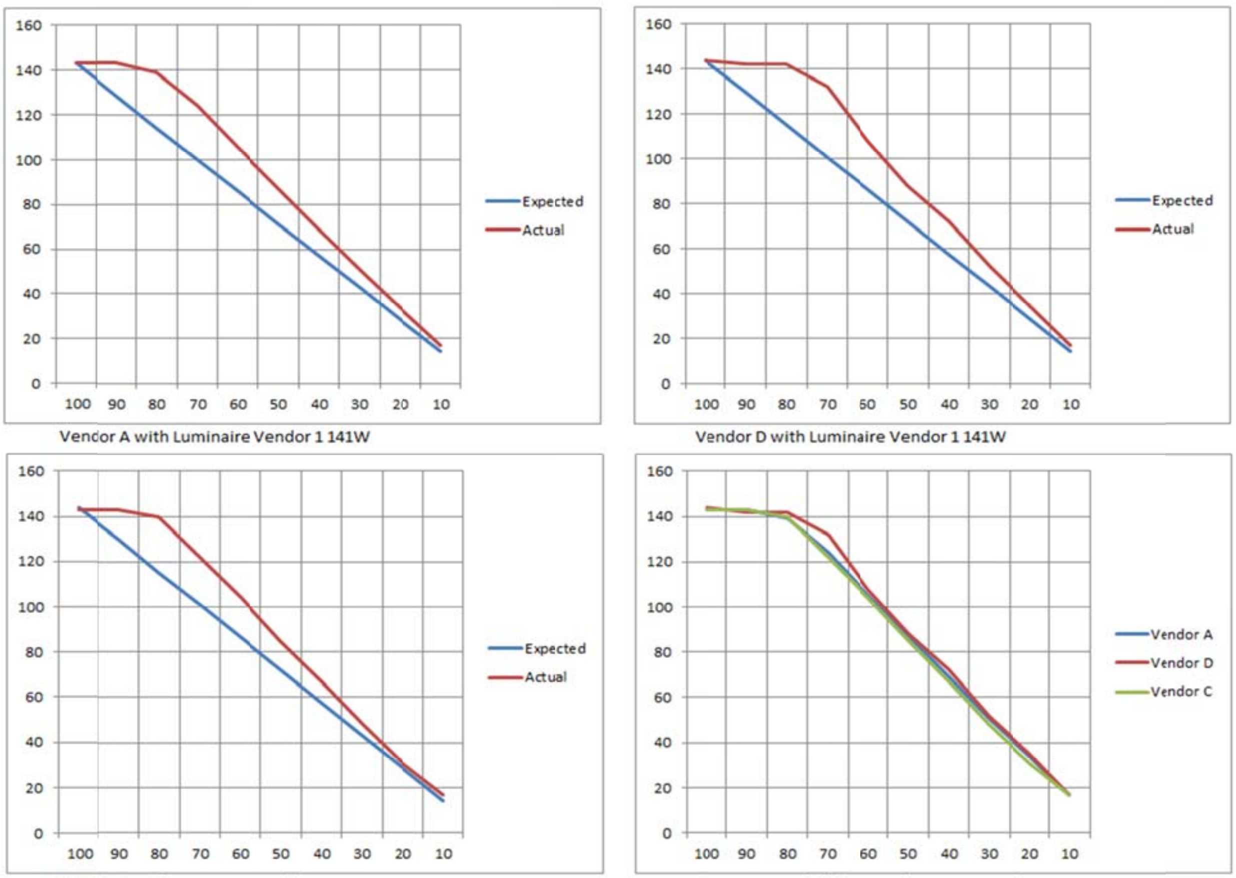
Vendor D with Luminaire Vendor 2 149W



Vendor D with Luminaire Vendor 4 161W

- Test 4.6.2 – Characterizations – Single luminaire
  - All Vendors had the same luminaire results. This data seems to show no significant difference in the offset from one vendor's node to another.

Graph 27



Vendor A with Luminaire Vendor 1 141W

Vendor D with Luminaire Vendor 1 141W

Vendor C with Luminaire Vendor 1 141W

Comparison of all three nodes to one another

4.2.6. Observations

- Service Provider 2 Database Software data – Pursuant to the original agreement with Service Provider 2, this information was to have been issued to TESCO on a weekly basis. However, TESCO only received one set of data for the entire term of the meter farm testing. This method proved far more difficult to work with than expected. The large volume of data that required review and processing in order to complete the meter test data analysis was far greater than anticipated, resulting in further project delays. In addition, missing data could not be corrected and tests that had missing data from the extensible markup language (XML) files could not be re-run after the test period had ended. These cumulative issues resulted in the inability of TESCO to complete a number of the Meter Farm tests that it had originally planned to perform.

- At the beginning of the Meter Farm testing, it was determined that a Luminaire Vendor 1 model did not have dimming capability and, therefore, could not be included in the varied operating schedule testing plan.

- The observed non-linear power consumption offsets at varied dimming levels, which were experienced by all tested LED luminaires, is an inherent characteristic of luminaires utilizing an analog (0-10V) signal to achieve dimming. Acknowledgement and concurrence of this condition was obtained by Michael Poplawski, Senior Engineer at Pacific Northwest National Laboratory. Mr. Poplawski provided further explanation related to recent test results on luminaires utilizing Digital Addressable Lighting Interface (DALI) dimming command protocol which yielded far more linear power consumption results at varied dimming levels.

- During the collection and analysis of the meter test data, TESCO observed an anomaly in the Vendor A and Vendor B nodes. There were numerous instances where the delta Watt-hour value (i.e., the difference between one hourly reading to the next) would spike up to 4,294,967,287. Additionally, the cumulative Watt-hour reading from the current hour was less than the previous hour.

- The communications integrity tests were inconclusive as there was no ability to receive real-time data during or immediately following the time of the testing. All test data was not received until well after the entire testing schedule had been completed and TESCO was unable to retest.

5. Pilot Program Testing and Results – Stage 1-Phase 2

The Stage 1-Phase 2 portion of the testing program evaluated the functional performance of the nodes in conjunction with an in-service communication network system utilizing multiple nodes experiencing real world environment conditions and operated using typical load and schedule characteristics.

5.2. Stage 1-Phase 2 Field Application Testing (RIDOT)

5.2.5. Test Plan

The field testing evaluated metering accuracy and reliability experienced during actual field operating conditions. To achieve this goal, the testing had to establish a baseline of energy consumption data relative to operating schedules.

The analysis compared the energy consumption recorded by the new network lighting control integrated circuit metering technology to actual energy consumption recorded by ANSI compliant automatic meter reading standard socket meters servicing those test sites. Additionally, in compliance with the pilot project requirements, National Grid performed an analysis comparing the energy consumption recorded by the new integrated circuit meter technology to the analytical results calculated using the PUC approved unmetered energy calculation model formulas. The consumption recorded by the standard revenue grade meters and the consumption determined by the unmetered energy calculation are both considered regulatory accepted energy reference baselines.

5.2.6. Logistics

RIDOT and National Gird jointly selected three existing "in-service" RIDOT field sites to conduct the field testing. RIDOT and National Grid based the locations on opportunities for varying operation/illumination applications and existing site/infrastructure conditions as outlined in the Pilot's requirements for Stage 1-Phase 2 of testing. Additionally, RIDOT and National Grid selected the sites based on RIDOT's requirement that the only electrical loads connected to these National Grid metered services be RIDOT street light luminaires, except for a small additional fixed load at one site. The three sites used a total of 172 street light luminaires at the following locations:

- 142 luminaires at a highway interchange cloverleaf (I-295 & RI-44);
- 22 luminaires at a highway straightaway (portion of RI-146); and
- 8 luminaires at a Park and Ride (Frenchtown Road, East Greenwich).

Detailed information, including the inventory of luminaires at each of the three sites, is detailed in Attachment 12 (RIDOT Selected Sites). During the field testing period, the Pilot used compatible communication network services being provided to RIDOT.

5.2.7. Test Equipment Deployment and Validation

The energy consumption data captured by the 172 RIDOT-owned nodes originally installed on street light luminaires at the designated sites were evaluated for the approximately 90-day period ending March 29, 2017. During this period, the nodes operated on a normal dusk-to-dawn schedule based on the standard photo-control ambient lumen sensing criteria prescribed by the RIDOT.

After testing the 172 luminaires, National Grid conducted additional "specialized" testing on 8 luminaires located at the RIDOT Park and Ride field test site in East Greenwich. Over an approximately 12 week period, National Grid tested nodes from three vendors on three different schedules. National Grid tested nodes from Vendors X, Y, and Z on dusk-to-dawn, dimming, and part-night schedules. RIDOT prescribed that the dusk-to-dawn schedule be based on photo cell sensing. National Grid and RIDOT selected the dimming and part night schedules used based on the "Part-Night" and "Dimming" operations in the S-05 Tariff. Metered energy consumption data was evaluated for these varied operating schedules for the approximately 80- day period ending August 16, 2017. A listing and description of the three operating schedules and the associated testing dates for each of the various manufacturers' nodes is provided in Attachment 13 (RIDOT-Frenchtown Road Park & Ride – Proposed Test Operating Schedule) and Attachment 14 (Frenchtown Road Park & Ride – Working Schedule).

6. Billing System Integration (Stage 2-Phase 1)

Stage 2-Phase 1 of the Pilot intended to identify the scope of work required to interface and integrate the node meter data information from the network service providers into National Grid's existing meter data management and billing Information Systems. National Grid initially worked to understand and recognize the business system impacts associated with the application of the new technology through the following focus: (i) identify the systems that would be impacted, (ii) identify the system requirements to integrate the data, (iii) determine necessary changes to the system architecture to facilitate the integration, and (iv) develop a high level design for the impacted systems. A document reflecting the complete scope of the Information Systems analysis, including identification of the tasks completed to date, is attached as Attachment 15 (Street Light Metering Pilot – IS Effort). The assessment proved much more complicated and time-consuming than originally estimated due to the scale of the total data management potential and the influence of the varied ownership conditions. As work progressed on the Information Systems analysis, the scope of the systems impacted has been larger and more diverse than expected, and the identification of the solutions to allow for the integration has been far more complicated than anticipated. The complexity of the analysis resulted in higher costs and an expanded schedule than originally proposed. Following the submission of a status report by National Grid on December 21, 2016 and a joint report of National Grid and the municipalities dated February 17, 2017, the PUC issued a directive on March 10, 2017 to suspend the Information System integration phase of the Pilot. Consequently, National Grid has postponed further work on this phase pending future direction by the PUC. Additional integration design remains to be completed to achieve the original cost and schedule estimate objectives.

7. Billing Analysis – Unmetered vs. Metered (Stage 2-Phase 2)

As mentioned in Section 4.2.5.2.7 (Variable Schedule Analysis (Both Service Provider Networks)), above, in the Meter Farm Testing section of this report, National Grid conducted a comparative metered billing analysis using data derived from the Stage 1- Phase 2 field testing. Data derived from the field testing was better suited for this analysis than Meter Farm data, as the field installations had the ability to compare each node to a qualified revenue-grade meter as well as the standard billing algorithm.

7.2. Unmetered Calculation Methodology

The unmetered energy consumption formula utilizes the total light source/luminaire system wattage and the hours of operation to calculate the expected kilowatt-hour (kWh) that each light will use. The basic principles of the formula to determine the kilowatt-hour is wattage multiplied by total burn hours, multiplied by the dimming power factor, multiplied by the number of lights, and divided by 1,000.

[KWh = WATTS x HOURS x DAYS x DIM FACTOR x LIGHTS / 1000]

The LED luminaire "system" wattage is obtained from the individual unit manufacturer's specifications. No adjustments were made to that value for other elements of the luminaire, such as any latent energy consumed by the nodes. The inventory list provided by RIDOT and the associated head-end software sets forth the number of lights for the calculation, as detailed in Attachment 12.

The S-05 Tariff, at Sheet 5, provided the operating hours, or "burn hours", to use, as set forth in Table 2, below. The monthly total hours were then divided by the number of days in the month to derive a daily average number of hours. That daily average number of hours was then multiplied by the actual number days in the measurement period, as provided in the S-05 Tariff.

Table 2

Monthly Operating Hours

January	442	July	267
February	367	August	301
March	363	September	338
April	309	October	392
May	280	November	418
June	251	December	447

The power at various dimming levels was estimated based on the data recorded by TESCO in its luminaire power characterization analysis, discussed above. TESCO's analysis charted the relationship between expected and actual power consumption at various dimming levels for a variety of LED luminaires. The TESCO values were taken from similar vendor nodes paired with the same manufacturer brand of luminaires, as used by RIDOT at its field test sites. Although the brand of luminaires at TESCO was the same, the model numbers differed from the RIDOT luminaires at the test sites. Therefore, because the energy consumed at various dimming levels is estimated, there is a marginal amount of error inherent in the calculations performed for test periods in which the dimming level percentage was not either 0% or 100%.

Recognition should be given to certain real-world circumstances that could impact the energy calculation. However, the occurrence rate of such conditions is unknown and, therefore, is not accounted for in the calculation. Examples of such types of conditions include, but are not limited to, lights not operating pursuant to the defined schedule, such as "day burners" and "outages"; undefined additional loads (i.e., convenience outlets and attachments); and stray (or elevated) voltage. Where possible, the Pilot attempted to account for all known additional loads within the energy consumption comparison analysis.

7.3. Metered Consumption Sources

The Pilot obtained metered energy consumption data from two sources for these comparisons. First, the existing National Grid standard revenue grade meters that currently exist and are used to bill energy at the RIDOT test sites served as one source. Meter read information for such standard meters could be pulled directly from the billed usage records in National Grid's Customer Service System (CSS). For comparison purposes, the meter readings occurred during the day while the lights were off.

National Grid Meter Information		
Rte. 295 North	Meter #	89-638-004
Rte. 295 South	Meter #	21-057-013
Route 146	Meter #	05-053-522
Park & Ride	Meter #	98-769-153

During the Park and Ride field testing period, additional meter reads were taken periodically by photographing the digital dial on the standard meter. A project timeline spreadsheet documented the readings to allow for the analysis of more granular comparisons than the normal monthly National Grid bill cycle reads provide.

Next, a summation of XML usage data exported from the Service Provider's system served as the second source. The Service Provider provided the extracted meter data for the requested time periods between January and March 2017 in standard XML format. The XML export included eight channels of hourly interval meter data per node, with various electrical measurements taken from the nodes plus event information, such as failures and status changes. Due to the voluminous nature of raw data included in the XML export files, the usage data is not included as an attachment in this report.

The data was extracted into Excel files and filtered to provide only the interval kilowatt-hour values. Those values were categorized according to the bill dates, or other reading dates, on National Grid standard meters for comparison.

During the course of this testing phase, the Service Provider informed National Grid that the meter read database had a limited retention time of approximately 90 days for the interval usage data, despite the calendar-daily consumption still available for viewing via reports on the head-end system software. National Grid verified that the daily consumption values observed online accurately matched the corresponding sum of interval periods.

7.4. Field Testing Observations

The general observations of node performance during the bench and meter farm testing phases identified the following issues: (i) the variability of meter accuracy between manufacturers; (ii) inconsistency of the small node populations to meet individual manufacturer's stated accuracy levels; and (iii) the individual vendor's node electrical tolerance sensitivities associated with load capacity, voltage fluctuation, frequency, and amperage thresholds. However, when properly specified, manufactured, and operated, the nodes' performance was reasonable in metering the energy consumption of the designated loads or street lights as compared with the existing unmetered analytical calculation.

The unmetered analytical ("burn-hour") calculation typically provided results similar to the measured node metered consumption. However, the unmetered calculation methodology cannot account for inoperative lights according to the established operating schedule. Despite that shortcoming, the unmetered calculation in the S-05 Tariff performed comparably with the node metered consumption and, in many cases, the unmetered calculation value was closer to the actual consumption measured on National Grid's standard revenue grade meters. As demonstrated in the graphs below, the usage values produced by the unmetered calculated method and the node meter method were generally within one or two kWh of each other per week at the Park and Ride test site, or a 2-3% variance.

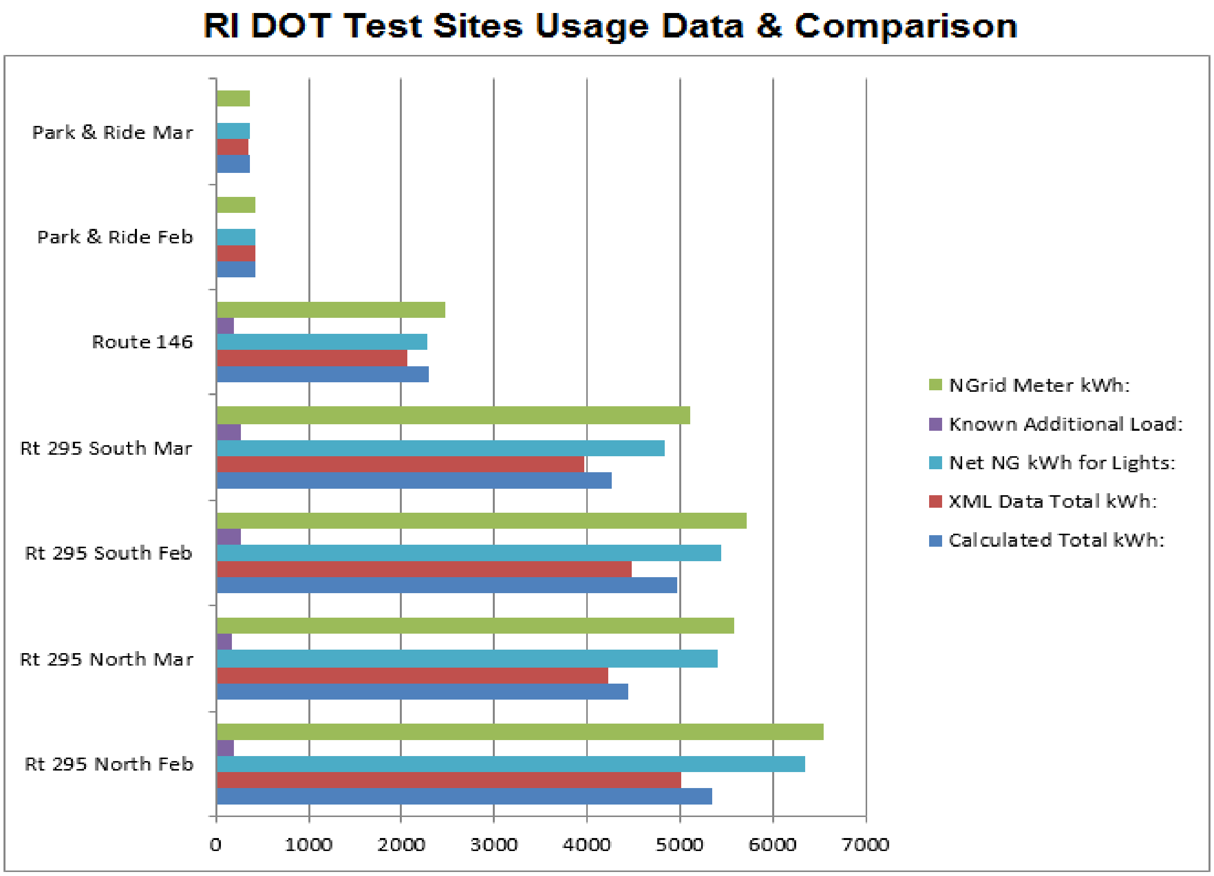
National Grid identified several anomalies within the exported XML meter read data from the nodes that suggest concerns with inconsistent data transmission when considering meter data integration with National Grid's billing systems. For example, the exported interval data received from the Service Provider did not include five nodes from the test equipment list. The nodes were found to be in various conditional states of commissioning or non-communication with the communication server. This condition was observed to exist for an extended time period. In specific cases, although a node would be inoperative, the light would be observed as operating during the time period when no energy usage data was being captured, causing inaccuracies in the aggregate usage totals.

In several instances, interval times were missing or not aligned with the stated schedule. Further complicating the data analysis, the subsequent interval data occasionally appeared to compensate for the missing data, and sometimes it did not. This random occurrence will make estimations and other data correction applications difficult to manage. Overall, the occurrence of the data anomalies will result in ancillary data clean-up functions if the meter data is planned to be used for billing.

As previously explained, National Grid also found instances where an inconsistent data value of 4,294,967.295 or just a few hundredths less appeared in the data range, which had to be flagged as a meter read exception and discarded. The problem with this value is that it represents the largest numeric value that 32 bits of data can retain, based on the conversion from watt-hours to kilowatt-hours: $(2^{32}-1)$ divided by 1,000. As National Grid flagged this occurrence as an exception, the data value did not pose a consumption calculation risk as part of the XML data. However, the occurrence of the inconsistent data does highlight an anomaly in the energy consumption metering data following an operation failure, as the data was applied as a roll-over of the metered usage. This circumstance introduced a very minimal (a few thousandths of a kilowatt-hour) decrease in the readings from one interval to the next after the node went offline and returned back online. These observations suggest that the nodes can “lose” some small meter reading periods and revert to a prior reading.

National Grid generally observed the existing National Grid standard revenue grade metered usage data to be noticeably higher than the calculated unmetered value or the exported XML usage values obtained by the nodes. Through various communication exchanges, the project became aware of a continuously operating 120W traffic camera located at the Route 295 South site and 500W cabinet heaters operating on thermostats at the three sites other than the Park and Ride site. Even with the additional loads considered, the aggregate metered usage suggests that there probably exists additional load at both Route 295 sites. Therefore, these sites were considered to provide no meaningful information about the performance of the nodes or the unmetered burn-hours calculation. This observation may be due to external circumstances existing at some of the test sites. However, because the Park and Ride standard meter’s connected load was exclusively for street lighting, the measured usage was closer to the node and unmetered calculated values. At the Park and Ride site, the other meter sources ranged between 91% and approximately 100% of the standard revenue grade metered usage.

Graph 28

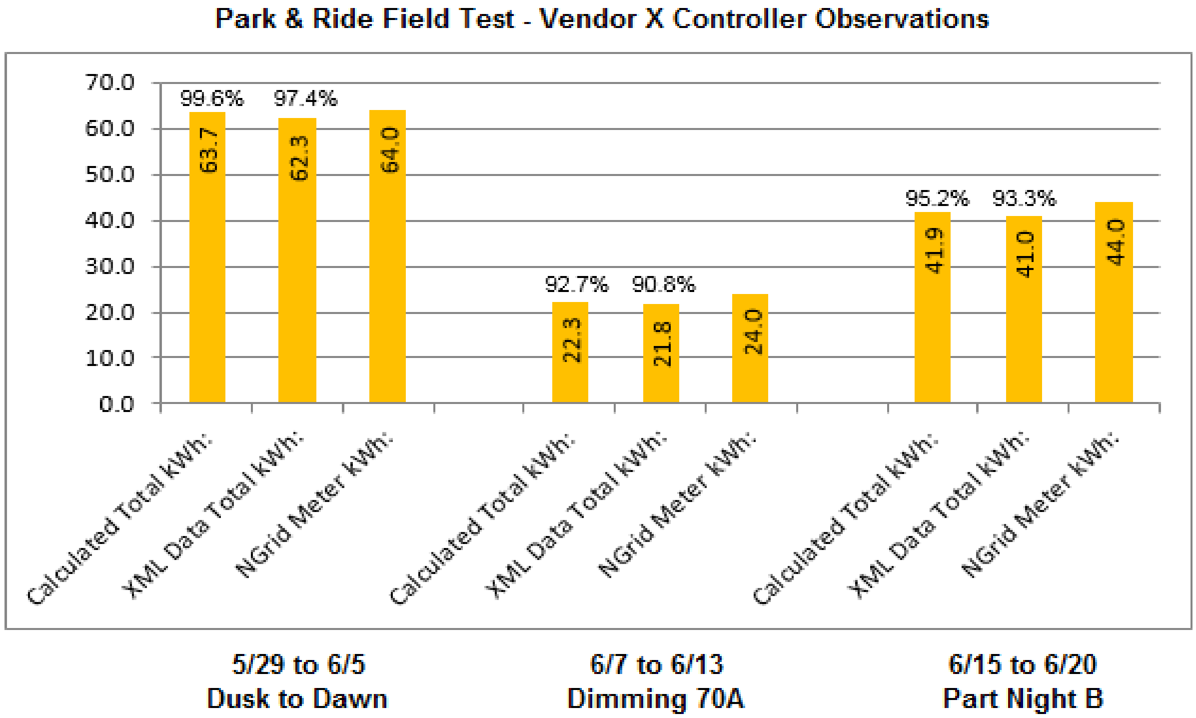


Raw Data:

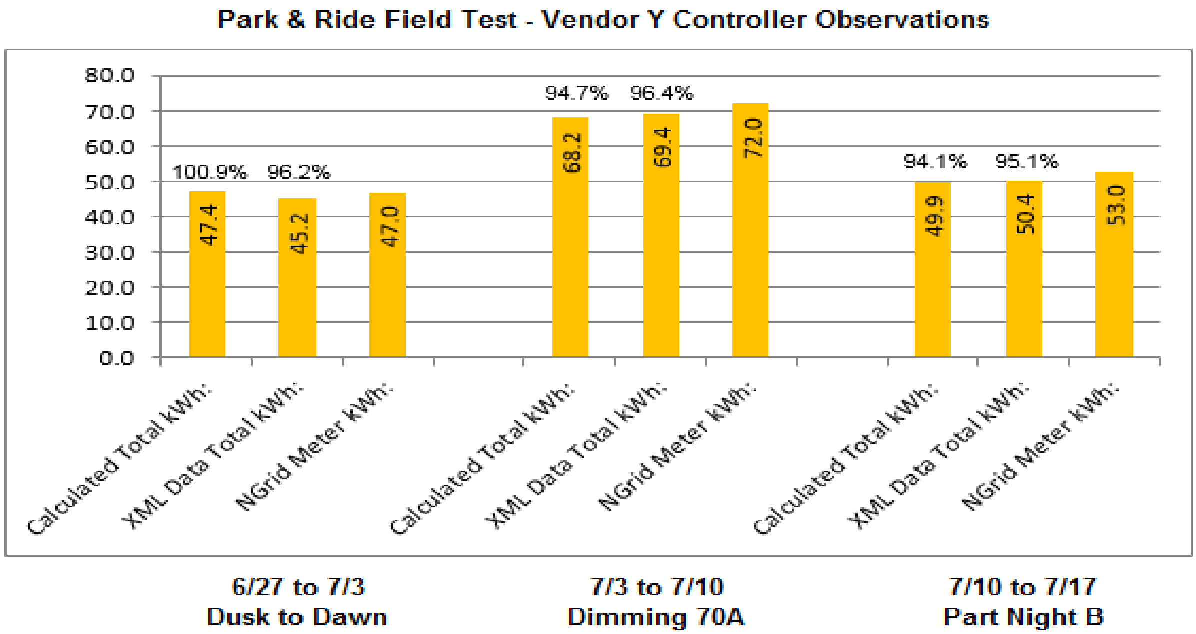
Meter #	Read Date	Location	Calculated Total kWh:	XML Data Total kWh:	NGrid Meter kWh:	Known Additional Load:	Net NG kWh for Lights:
89-638-004	2/27/2017	Rt 295 North Feb	5346.5	5013.107	6538	186	6352.0
89-638-004	3/28/2017	Rt 295 North Mar	4436.6	4230.298	5575	174	5401.0
21-057-013	2/27/2017	Rt 295 South Feb	4971.3	4484.125	5721	275	5445.7
21-057-013	3/29/2017	Rt 295 South Mar	4266.9	3967.849	5102	266	4835.6
05-053-522	3/13/2017	Route 146	2295.2	2059.241	2476	192	2284.0
98-769-153	2/27/2017	Park & Ride Feb	437.2	419.745	432	0	432.0
98-769-153	3/28/2017	Park & Ride Mar	362.8	354.767	367	0	367.0

Notes: The meter reading schedule for the Route 146 site occurred mid-month, resulting in only one full month of data being available. Supporting spreadsheet data is provided in Attachment 16 (RIDOT Test Sites (Burn Hours Calcs)).

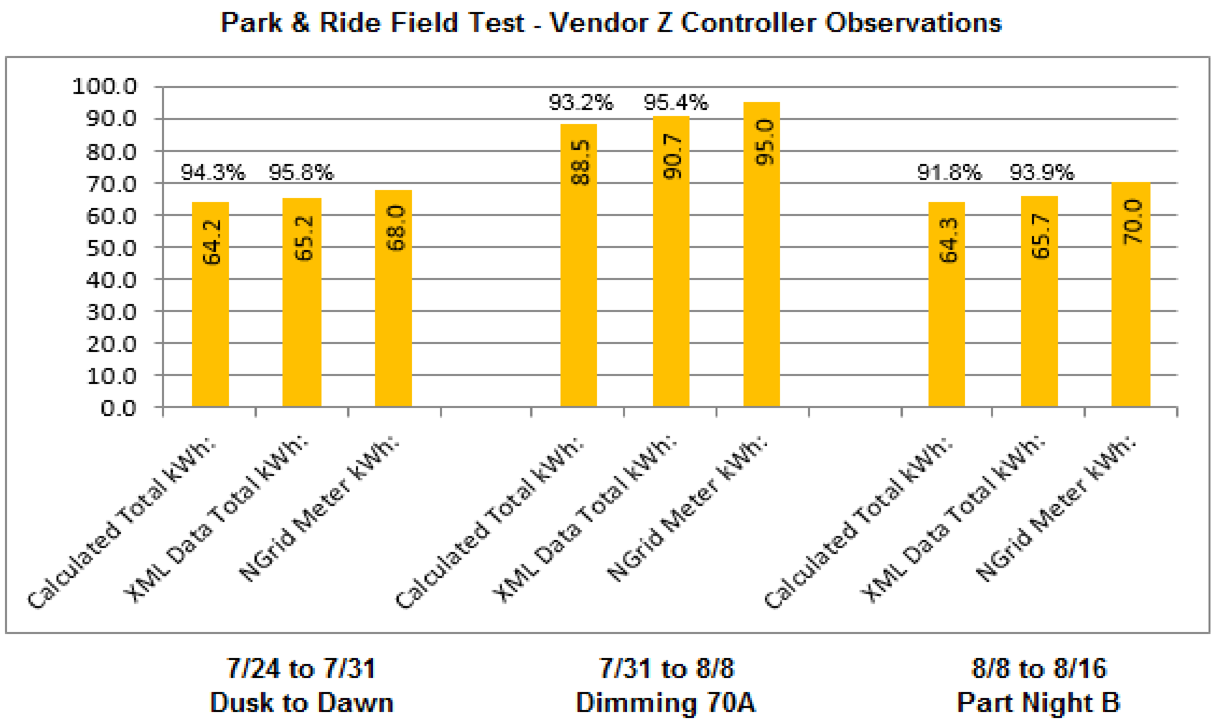
Graph 29



Graph 30



Graph 31



Note: Supporting spreadsheet data for Graphs 2-4 is provided in Attachment 17 (Park & Ride Site (Burn Hours Calcs).

8. National Grid Opinions and Recommendations

After completing the laboratory and field testing, National Grid has a number of concerns with using metered devices for street light billings. For example, the existence of other items at the test sites, such as the cabinet heaters, not only rendered the comparisons to National Grid's metered usage relatively meaningless, but also highlights a potential shortfall in using meter nodes for street light billing. In such a scenario, a second meter would be required to measure the consumption of heaters and other ancillary devices. This condition would require a dual metering solution, which would offset potential cost savings associated with the elimination of the standard revenue grade meter.

In consideration of the proprietary nature of the network applications and associated user software, National Grid observed that one of the network service provider's software platforms had some shortcomings. The data model application consisted of two separate platforms which had been only partially integrated. This condition resulted in two levels of data retention, with the shorter retention period purging the more detailed information. Moreover, the required detailed information for billing could not be accessible through the provider's client-facing software platform. The software would provide usage information only on calendar-day periods. This condition makes data assessment difficult when reviewing the usage based on the daily operating cycle of the light. A recommendation would be to fully integrate the two platforms to make the full detail available through the online user tool. Also, the common platform could fully define the data retention period for each level of detail. In this manner, the utility or other billing entity has a greater opportunity to validate usage data and increase confidence in the data's accuracy and availability.

Based on the observation that unmetered calculations performed comparably to the control device measurements, it appears that using the unmetered calculation method for billing remains a less expensive way to achieve similar results. In order to gain additional flexibility, National Grid's billing system can be expanded to accommodate a limited increase in the number of unmetered schedules to reflect a different series of operating hours and/or dimming levels. Additionally, this solution represents the lowest cost alternative as compared to developing Information System interfaces and the necessary data management to accommodate the node measurements. The use of the additional unmetered schedules poses a serious concern related to the affirmative application of the schedules by the operator and associated communication with the utility for accurate billing.

Utilizing the nodes for only monitoring the status of the lights and diagnostics of other electrical components via front-end reports and dashboards is a prudent application given the current state of the technology.

National Grid recommends further testing of the network lighting controls to address increased knowledge on power factor, total harmonic distortion, parasitic load, accuracy of power consumption of different dimming control protocols (i.e., digital addressable lighting interface, also known as “DALI”), and correlation of dimming control with actual illumination output. Thus, National Grid recommends continuing to complete the analysis of the Information System integration study related to achieving a cost and schedule for the data integration.

National Grid further recommends industry collaboration of node vendors, network service providers, utilities, end-users, and regulatory entities to address the following issues: industry standard testing protocols, definitive metrology performance requirements, data format and transmission quality standards, and software platform standards for data retrieval/export and retention.

Finally, National Grid recommends that regulatory compliance standards associated with street light metering, to establish a common industry baseline, be required for integrated circuit meter standardization.

9. Conclusions

9.1. Summary Of Data

9.1.1. Bench Testing

- Bench tests were completed on either (1) a set of 10 nodes per vendor (ANSI C12.20 testing) or (2) a set of 4 nodes per vendor (optional testing).
- According to ANSI C12.1, the meter type certification will be rejected if any of the example conditions represented in Diagram 6 occur:

Diagram 6

Table 2 – Table of Failures Based on the Number of Metering Devices Tested

# METERING DEVICES TESTED	FAILURES IN DIFFERENT TESTS INDIVIDUALLY: 0	1	2	3 or more
3	PASS	FAIL	FAIL	FAIL
4	PASS	FAIL	FAIL	FAIL
5	PASS	FAIL	FAIL	FAIL
6	PASS	PASS	FAIL	FAIL
7	PASS	PASS	FAIL	FAIL
8	PASS	PASS	FAIL	FAIL
9 or more	PASS	PASS	PASS	FAIL

Examples The following examples explain how to apply Table 2. Also, reference to "the series tests" in this paragraph means tests required to be performed in the series manner as specified in Section 4.1.6., and reference to "the parallel tests" means testing is not required to be perfomed in any particular sequence (either series or parallel).

Example 1: If 3 metering devices are selected for the series testing and one failure occurs in any test procedure, the meter type certification will be rejected and the entire eight series tests will be started over from the beginning.

Example 2: If 9 metering devices are selected for the series tests and the first, second, and third failures occur separately in three different tests or test procedures, the meter type certification will be rejected. These failures described here mean that a failure of the first metering device during one test procedure, a failure of a second metering device during another test procedure, and a failure of a third metering device during another test procedure different from the tests that the first two metering devices have failed previously. Once such failures occur, the entire eight series tests will be started over from the beginning.

However, if 3 metering devices are selected for a parallel test performed concurrently with the 9 metering devices selected for the series tests, the rejection criteria for the 3 metering devices tested in a parallel test shall not apply to the 9 metering devices tested in series, or vice versa. In addition, if a group of metering devices tested in a parallel test(s) fails according to the rejection criteria, only the particular failed test(s) needs to be repeated.

4.6.2.2.2 The failure of two or more metering devices during the same test or test procedure.

- In the 5 bench tests completed on a set of 10 samples from each node vendor, a failure occurred when any test conducted by a given vendor had 3 or more nodes fail to meet their stated specifications.
- In the bench tests performed on a set of four samples from each node vendor, a failure occurred when any test conducted by a given vendor had any nodes fail to meet their stated specifications.

- Based on the criteria listed above, Vendor A failed 13 tests; Vendor B failed 14 tests; Vendor C failed 12 tests; and Vendor D failed 10 tests.
- Overall, Vendor A nodes met their stated specifications in 35 of a total of 106 possible tests (33.0%); Vendor B nodes met their stated specifications in 32 of a total of 106 possible tests (30.2%); Vendor C nodes met their stated specifications in 46 of a total of 106 possible tests (43.4%); and Vendor D nodes met their stated specifications in 82 of a total of 106 possible tests (77.4%).

  - The majority of the failures occurred on tests using a load current of 10A or greater.

9.1.2. Meter Farm Testing

- The criteria for the Meter Farm testing did not comply with ANSI C12.1 criteria, while the bench testing did comply with ANSI C12.1.

- All of the Meter Farm testing charts were modified to align with the schedule charts with respect to time. The misalignment of the schedule with the meter reads is generally due to the coincidence of the desired test schedule changes being set to occur at the same time as the consumption read. This condition caused the reported Watt levels to correspond with the previous dimming value. As the reads could only be captured hourly, the data looked as though the dimming change was off by an hour. Closer analysis of this issue revealed the misalignment with the meter reads as the reason for the offset.

- Each meter farm schedule tested experienced multiple cases of missing and/or incorrect data reported back from the Service Provider 2 database program.

9.1.3. Field Testing

- As previously stated, the nodes did not measure usage within the industry established tolerance thresholds for revenue grade meters. However, when operated correctly, the nodes performed a reasonable job of energy consumption metering for street lights when compared with the existing unmetered burn-hours calculation. In fact, the unmetered burn-hours calculation typically had similar results to the node metered usage. Therefore, unless the node measurements are needed for other billing reasons (i.e., interval data for time-of-use billing), incurring the greater costs associated with developing the required interfaces may not be warranted. Considering that unmetered calculations performed comparably with the node consumption measurements, it appears that using the unmetered calculation method for billing is a less costly method to achieve similar results.

9.1.1. Billing Analysis – Unmetered vs. Metered

- The existence of the data anomalies within the XML exports poses a risk to the utility in using the data for billing purposes. Each instance of the questionable data would require a review, and probable data correction application to ensure that all network lighting control meter reads from the inventory listing are included. Moreover, it would require confirmation that all values are present for all time periods while lights operated pursuant to their schedule. As the data found that lights could be operational with the node offline, the confirmation would require validation based on an inventory and schedule report. The information required is similar to what would be needed for an unmetered burn-hours calculation if the node did not exist. Additionally, missing values would need to be evaluated for potential gaps in usage. This condition would require the qualification of missing intervals to be estimated or the determination of whether the subsequent readings captured the usage from the missing periods. Whereas the XML data exports demonstrated both outcomes, this level of review will be critical to ensure accurate billing with no double-counted or uncounted usage.

The general conclusion reached through the accuracy testing of this Pilot is that the network lighting controls did not meet the accuracy measurement tolerance criteria established by ANSI C12.20 for revenue grade meters. Prior to the adoption of nodes and supporting network infrastructure use for street light metering, appropriate ANSI industry accepted testing protocols must be available to qualify the specified revenue grade accuracy of the integrated circuit meters.

Attachment 1

RI Street Light Metering Pilot Project

IC Meter Testing

SCOPE

Overview:

National Grid is conducting a Pilot Study to evaluate new metering technology for its compatibility with street lighting applications. The study will evaluate the accuracy and capabilities of integrated circuit (IC) meter technology available for street lights. (Specifically control module nodes offered by CIMCON, Sunrise Technologies and SELC).

Laboratory Testing:

The laboratory testing of the IC meter devices will be in compliance with the latest industry standards. This testing will qualify various meter operating characteristics (e.g., accuracy, reliability, etc.) and validate the manufacturers' published performance results. Functional performance of the network-control system will also be evaluated with a focus on the interoperability with the Company's meter data management and billing systems.

Individual Device Testing:

The Company will employ an independent laboratory testing company to perform IC meter device testing in compliance with ANSI C12.20-2010 industry standards. These individual IC meter device tests will be performed on random samples of each of the three manufacturer's IC meter components. The Company also will comply with ANSI Z540 Standard Laboratory Practices regarding all testing instrumentation and will ensure that test results conform to National Institute of Standards and Technology (NIST) requirements.

Networked Device Testing:

The independent laboratory testing company will establish a functional "meter farm" environment to facilitate an end-to-end test program for the independent IC meters operating on unique communications networks. The Company will ensure that the systems under test will remain separate and unaffected by a compatible live system. The end-to-end test system will incorporate all components in a test environment to eliminate as many effects as possible that may impact field testing. In addition, the Company will perform testing prescribed by IEEE 519-1992 to assess the impact of the power inverter technologies used in these street light technologies.

Laboratory Role, Expectations & Deliverables:

The testing laboratory must be equipped and ready to meet the Project's laboratory testing schedule. That project schedule currently shows ten weeks of laboratory testing beginning the week of December 7, 2015 and ending the week of February 8, 2016.

RI Street Light Metering Pilot Project

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The laboratory must be capable of performing all of the laboratory testing work including development of the comprehensive test plan. It is important for the testing laboratory to understand that the National Grid project team's role is contributor; not developer or tester.

National Grid intends to work with its suppliers to provide the testing laboratory with the IC meter devices, as well as any equipment required to support the communications networks.

The final testing laboratory deliverables will include, but not be limited to:

- A complete report detailing the test plan (Individual Device Testing and Networked Device Testing). That report must clearly explain how the test plan exceeds existing standards.
- A complete and comprehensive report on the test results for the Individual Device Testing and Networked Device Testing.

End of Scope portion.

RI Street Light Metering Pilot Project

IC Meter Testing

REQUEST FOR INFORMATION

Based on the scope and testing outlined above, please reply to the following 10 questions, and provide examples and evidence supporting your responses:

VENDOR NAME:

TESCO- The Eastern Specialty Company

1. What is your Lab's experience in the general field of utility type electric revenue metering?
    a. Since 1904, TESCO has focused solely on metering. We manufacture meter field test equipment, meter shop equipment, meter qualification and certification equipment, meter accessory hardware, software for Meter Service Departments, and provide meter testing and meter laboratory services. Through our services, we have extensive experience in every aspect of electric utility metering. TESCO has been deeply involved in many AMI deployments, including vendor selection, qualification, certification and acceptance testing, business processes, deployment planning, and, of course, the software to support all these activities. We use our own software in our meter shop, and have processed millions of meters for numerous utilities. We understand metering, we understand AMI, and we understand how utilities operate and the challenges they face.
2. Why is this expertise in the general field an advantage to the specific field described in the scope?
    a. TESCO has been on the leading edge of new technology evaluation as this technology is being introduced into the metering field. The metering for the street light application is a new technology that is poised for mass deployment. The technical qualification and certification of this technology plays to the strength of the TESCO engineering and meter lab. TESCO has already been working on similar projects for other utilities.
3. What is your Lab's experience in the specific field related to the scope?
    a. TESCO has begun evaluating the application of street light meters into the electric utility meter infrastructure. This has involved working on the physical interface of the proposed meter to the light pole and the connection to the electric utility, the qualification of this metering technology and determining the new equipment and methods that can be used to test these meters in the field and the meter shop. TESCO has also developed and will be shortly installing the first meter farm for street light meters to assist in both the certification and acceptance testing of these meters and eventually in the life cycle management of this new technology.
4. Why does your Lab claim, if they do, to be better positioned than competitors, including utilities, in the specific field of testing Street Light metering?

RI Street Light Metering Pilot Project

IC Meter Testing

   a. TESCO has been involved in the start of the new generation of direct streetlight metering. As the only manufacturer of electric meter test equipment for the filed and shop who also has a meter lab and a meter shop TESCO has been contacted by both street light manufacturers and electric utilities to assist in the evaluation and eventual integration of this technology in our Utility infrastructure. TESCO has already started working with other utilities on equipment for testing CIMCON streetlight meters in conjunction with Phillips Lighting for both the meter lab and field. Tesco's meter shop facilities currently process nearly 1 million meters per year for utilities and meter manufacturers. Our scope of capabilities range from accuracy and functional testing to meter reprogramming and firmware updating. We have over 60 meter test stations in individual and multi-position test board arrangements and employ 15 people full time dedicated to this part of our business along with a staff of technicians trained on the calibration and repair of all of our equipment. We are ISO 9000 certified and are regularly audited by our registrar, our clients, independent third parties and government certification agencies. We have been working closely with CIRCOM and other utilities to adapt their technology in the field and even work with them in the development of the next gen version that will be used to meter loads greater than 50A. We are unaware of any other Utility or manufacturer who has this background or who would even be approached to do this type of work. TESCO has worked hard to put ourselves into a position where we are the most, if not only qualified vendor for this work.

5. Has your lab ever actually tested electronic integrated circuit type Metering Devices specifically described herein? (Specifically control module nodes offered by CIMCON, Sunrise Technologies and SELC).
   a. This is a premature question as this technology is still being evaluated and has not been implemented in anything other than pilot programs. TESCO has developed the equipment and protocols for certification and this same equipment and modified protocols is anticipated to eventually used to test the CIMCON, Sunrise, SELC and other vendors products once approved. TESCO has already designed our Multi-position ANSI meter test board to also accuracy test multiple electronic integrated circuit type Metering Devices meters.
   b. If so, please provide an overview and as much detail on that testing as possible.
      i. The testing of these boards is complicated only in the interface of these metering devices to the test boards. TESCO has designed this interface to be as universal as possible, but as there is no standard among the prospective suppliers and manufacturers of these devices there is no way to determine if this interface is the most efficient possible nor if this interface will be suitable for all devices introduced to the market place and considered by National Grid.

If new interfaces are required TESCO will either modify the existing interface or design a second interface to handle the new offering.

c. If so, how would your lab leverage that prior similar testing if you were selected for this testing engagement by National Grid?
   i. We have two methodologies by which to perform accuracy testing on these meters. One has already been implemented at a customer's site and the other is the multi-position board mentioned above. This multi-position board is simply an adaptation of our standard multi-position board, which has now been implemented at meter shops nationwide. This expertise and this equipment can be used to jump-start this project and provide data for National Grid while any other vendor would still be struggling to determine a plan of action.

6. Does your lab claim to be established, fully equipped and able to perform testing on electronic integrated circuit type Metering Devices specifically described herein?
   a. Yes. As mentioned in 4a. above, we are well equipped to perform all manner of meter testing as it is a dedicated part of our business.
   b. If yes, please explain why. To that end, for this specific IC device type, please provide a count of ANSI C136.41 Dimming Receptacles that are presently in place, wired, and ready for use in your lab. Currently, we have shipped out all of our in-house sockets to be part of a client's outdoor meter farm. Given the infancy of this technology we are not sure how long this initial design will be viable and wanted to make sure that when the next evaluation and testing project started we would start with sockets suitable for the devices being considered by our Utility customer. Even after shipping this meter farm for evaluation and certification testing, TESCO could have 8 positions on our multi-position boards available and a meter farm available for testing within two weeks of the start of a project.
   c. Why: See above and 4a.

7. If not able to start immediately, how much time and money would your lab require to prepare to be able to start the testing?
   a. Time: 2 weeks for initial testing and 16 weeks to set up a large scale test set-up that can be installed at National Grid once the evaluation project is complete.
   b. Cost less than ~~$5,000~~ to start testing and ~~$60,000 to $90,000~~ (USD) for a 15 position board that can be shipped and installed at the end of the project at National Grid in either Liverpool or Rhode Island.
   c. Would you expect the customer to provide this preparation funding, or self-absorb? TESCO can "self-absorb" the costs for the initial testing, but would work with National Grid on the specifications and budget for the board that we would eventually use and would be slated for installation at National Grid. This equipment would be paid for by National Grid and would become an asset of National Grid.

8. Please comment on vendor competition in the specific testing area described herein.

   a. As stated earlier we are unaware of any other Utility or vendor that has the infrastructure or experience in this niche. For another vendor to be able to quote this job, they would likely be quoting equipment, not services. They may quote a turnkey operation, but it would have to be something that they would have to develop an infrastructure for (including both equipment and staff) on short notice. We already have the equipment, an experienced staff, and a company dedicated to this type of service.

9. As stated herein, National Grid intends to test and analyze the following Metering Devices (electronic integrated circuit type Meter devices) from the (3) Manufacturers (CIMCON/Sunrise Technologies/SELC).
   a. Please fully disclose if your lab has ever performed work on behalf of the Manufacturer/Distributor (or similar vested party), for these devices including but not limited to: testing / analysis / data collection / performance analysis / reports or conclusions about the metering devices. Work performed for other Utilities or "end-user" roles does not require disclosure.
      i. No. All work has been contracted with "end users" although we have worked with these Manufacturers.
   b. If so, for whom, which device, and describe the relationship.
      i. We have only been contracted by end-users.
   c. Does that relationship create any potential conflict for your lab, or prevent you from performing labs services for National Grid?
      i. No. We have worked on several new technology projects over the past eight years (since AMI deployments began in the United States) where the various "end-users" not only accepted, but actively encouraged our work with other end-users and requested a free sharing of knowledge between them to accelerate the introduction of these new technologies.
10. Please comment below, referencing the "Laboratory Role, Expectations & Deliverables" section above.
   a. Explain why your lab is fully capable of fulfilling the role and meeting the expectations including the project's current laboratory testing schedule.
      i. Since our meter lab and our meter shop are separate entities from our production team, the "end of the year crunch" that affects our production team is less of a burden on the meter lab and the meter shop, thus the workload can be distributed more easily. We have an engineering staff that is fully prepared to develop the test plans and equipment required to do the job.
   b. Provide highlights, or some detail, on the contents of your lab's deliverables; those specified above as well as other deliverables that your lab will provide.
      i. The test plan (Individual Device Testing and Networked Device Testing) requirements will be reviewed by our engineering staff and a thorough plan derived. This report will clearly state the processes that will be followed,

equipment to be used, and the results that will be obtained from each stage of the process.

ii. The report on the test results for the Individual Device Testing and Networked Device Testing will be likewise conclusive. We will leverage our expertise in meter management and test software to analyze each aspect of the testing and present the findings in a logical and organized way.

End.

Attachment 2

ORIGINATING GROUP:	ORIGIN DATE:	REVISION DATE:	NO. OF SHEETS:
TESCO ENGINEERING	**19-Feb-2016**	**19-Sep-2016**	**9**

Test Specification
for

nationalgrid

Photocell Node Bench Testing
Project 8594
10/21/2016 - Rev 4A - Revised for Select Limited External Distribution

SHEET NO.	1	2	3	4	5	6	7	8	9	10												
REVISION	**-**	**-**	**-**	**3**	**-**	**4**	**1**	**3**	**3**	**3**												

APPROVED: Originator: John Williams	DATE: 19-Feb-16
APPROVED: Electrical:	DATE:
APPROVED: Project Mgr.: John Williams	DATE: 19-Feb-16

Revision 4A Note:

Two independent network platform providers were used to provide communications interfaces to the nodes.

Table of Contents

1 Purpose

Define all test equipment, procedures, and documentation specifications for the photocell node bench testing to be performed by Tesco for National Grid - RI.

2 Definitions, Acronyms and Abbreviations

Abbreviation	Definition
A	Amperes
AC	Alternating Current
ANSI	American National Standards Institute
DPT	Digital Power Technologies (Power supply mfg.)
MTB	Meter Test Board
PF	Power Factor
THD	Total Harmonic Distortion
V	Volt
VT	Voltage Transformer
Wh	Watt-hour

3 Test Equipment Specifications

3.1 Meter Test Board (MTB)

The Tesco MTB is a four socket unit capable of simultaneously testing 4 meters. It is ANSI C12.20 compliant and uses a NIST traceable 3 phase reference standard.

3.1.1 Main Components

3.1.1.1 Digital Power Supply - DPT 024 Series 3 phase source.

3.1.1.1.1 Frequency Accuracy - +/-0.02Hz

3.1.1.1.2 Voltage Set point accuracy - 0.5%

3.1.1.1.3 THD <0.5% Linear load

3.1.1.1.4 Phase Resolution - 0.01 degree

3.1.1.1.5 Current Accuracy - 0.5%

3.1.1.2 Reference standard - Radian RD-30-201

3.1.1.2.1 .04% accuracy class

3.1.1.2.2 Serial Number 301510

3.1.1.2.3 Calibration date: 04/20/15

3.1.1.2.4 Calibration certificate detailing results and NIST traceability available upon request. (Internal Tesco Link to Cal Cert)

3.1.1.3 Programmable Logic Controller – Automation Direct, Productivity 3000 series

3.1.1.3.1 Main unit controller that is responsible for setting up the power supply, monitoring voltages and currents, and counting reference standard energy pulses.

3.1.1.4 Socket adapter – by Tesco

3.1.1.4.1 This unit adapts a 7 pin standard photocell socket to a standard metering socket.

3.1.1.4.2 Design details available upon request.

3.1.1.5 Network Service Provider #1 – portable communication adapter between PC and nodes fitted with Network Service Provider #1's communication hardware.

3.1.1.6 Network Service Provider #2 – portable communication adapter between PC and nodes fitted with Network Service Provider #2's communication hardware.

4 Test Specifications

4.1 This section is meant to adhere as closely as possible to ANSI C12.20.

4.2 For the purposes of these tests, the node meter function will be treated as an ANSI socket meter form 1S.

4.3 Test Conditions

4.3.1 Temperature: 23°C, +/- 2°C

4.3.2 Rated voltage (120VAC): +/- 1%

4.3.3 Rated frequency (60Hz): +/- 1Hz

4.3.4 Test Amperes (1.5/10AAC): +/- 1%

4.3.5 Unity Power factor (0°): +/- 2°

4.3.6 Nodes will be temperature stabilized before testing

4.4 Prior to each test set performed, the nodes will be energized for a 5 minute warm-up period.

4.5 Tests to be performed

4.5.1 ANSI C12.20 – Test number 1: No Load

4.5.1.1 The node with only the voltage circuit energized shall not register one equivalent rotation in watthours (for nodes with a metering pulse) or 1 watthour in 10 minutes.

4.5.2 ANSI C12.20 – Test number 2: Starting load

4.5.2.1 The node shall operate continuously with a load current of .01A at its lowest rated voltage.

4.5.3 ANSI C12.20 – Test number 3: Load performance

4.5.3.1 Each node will be tested at 120V and 10A. The performance of each node will be documented under this condition. Comparison will be made in each case to the stated accuracy specification (0.5% or 2.0%).

4.5.3.2 Each node will be tested at 120V and 1.0A. The performance of each node will be documented under this condition. Comparison will be made in each case to the stated accuracy specification (0.5% or 2.0%).

4.5.4 ANSI C12.20 – Test number 4: Effect of variation of power factor for single element meters.

4.5.4.1 Each node will be tested at 120V and 10A, with 0.5 lagging power factor. The performance of each node will be documented under this condition. Comparison will be made in each case to the stated accuracy specification (0.5% or 2.0%).

4.6 Optional tests that can be performed (time permitting)

4.6.1 ANSI C12.20 – Test number 5: Effect of variation of voltage

4.6.1.1 Each node will be tested at 120V and 10A. The performance of each node will be documented under this condition. This will be given as the reference accuracy.

4.6.1.2 Each node will be tested at 108V and 10A. The performance of each node will be documented under this condition. Comparison will be made in each case to the reference accuracy listed in 4.6.1.1.

4.6.1.3 Each node will be tested at 132V and 10A. The performance of each node will be documented under this condition. Comparison will be made in each case to the reference accuracy listed in 4.6.1.1.

4.6.1.4 Each node will be tested at 120V and 1.0A. The performance of each node will be documented under this condition. This will be given as the reference accuracy.

4.6.1.5 Each node will be tested at 108V and 1.0A. The performance of each node will be documented under this condition. Comparison will be made in each case to the reference accuracy listed in 4.6.1.4.

4.6.1.6 Each node will be tested at 132V and 1.0A. The performance of each node will be documented under this condition. Comparison will be made in each case to the reference accuracy listed in 4.6.1.4.

4.6.2 ANSI C12.20 – Test number 6: Effect of variation of frequency (note that all previous testing is done at 60Hz)

4.6.2.1 Each node will be tested at 120V, 10A and 60Hz. The performance of each node will be documented under this condition. This will be given as the reference accuracy.

4.6.2.2 Each node will be tested at 120V, 10A and 58.8Hz. The performance of each node will be documented under this condition. Comparison will be made in each case to the reference accuracy listed in 4.6.2.1.

4.6.2.3 Each node will be tested at 120V, 10A and 61.2Hz. The performance of each node will be documented under this condition. Comparison will be made in each case to the reference accuracy listed in 4.6.2.1.

4.6.2.4 Each node will be tested at 120V, 1.0A and 60Hz. The performance of each node will be documented under this condition. This will be given as the reference accuracy.

4.6.2.5 Each node will be tested at 120V, 1.0A and 58.8Hz. The performance of each node will be documented under this condition. Comparison will be made in each case to the reference accuracy listed in 4.6.2.4.

4.6.2.6 Each node will be tested at 120V, 1.0A and 61.2Hz. The performance of each node will be documented under this condition. Comparison will be made in each case to the reference accuracy listed in 4.6.2.4.

4.6.3 In addition to the ANSI specified tests, perform multiple accuracy tests per node type at +/-15% and +/-20% voltage variations.

4.6.4 In addition to the ANSI specified tests, perform multiple accuracy tests per node type at 0.5A and 15A.

4.7 Testing method

4.7.1 Network Service Provider #1 Communication method

4.7.1.1 This method will be used on all nodes for all tests listed in sections 4.5 and 4.6.

4.7.1.2 Each test will be performed on the Tesco MTB, four nodes at a time.

4.7.1.3 Each node will be energized with potential only.

4.7.1.4 Each node will be registered through Network Service Provider #1's network using their portable communications adaptor.

4.7.1.5 An initial Wh query will be done on each node and recorded in the data collection spreadsheet.

4.7.1.6 The testing parameters will then be set in the MTB. The MTB will be set to run a Demand test, with the interval set to a value which should register at least 1,000Wh on both the nodes and the reference standard (i.e. for 120V, 1.00 PF, 10A test, the time interval will be set to (1,000*60)/(120*10) = 50 minutes).

4.7.1.7 At the end of the interval, the number of Wh from the reference standard will be recorded, along with the ending Wh readings from each of the four nodes.

4.7.1.8 The percent accuracy will then be given by the ratio of Node Wh/Reference Standard Wh.

4.7.2 Meter Pulse method

4.7.2.1 This method will only be used on nodes that have a metering IR pulse output on all the tests listed in sections 4.5 and 4.6, and will be done in addition to the method described in section 4.7.1

4.7.2.2 Each test will be performed on the Tesco MTB, four nodes at a time.

4.7.2.3 Each node will be energized with potential and load current so that the metering pulse will be activated.

4.7.2.4 Each node's metering pulse pickup assembly (part of the MTB) will be aligned with the metering pulse output.

4.7.2.5 The testing parameters will then be set in the MTB. The MTB will be set to run a Full Load, Light Load, or Power Factor test, depending on the requirements of the test.

4.7.2.6 At the end of the test, the registration value will be read directly from the MTB.

4.7.3 Network Service Provider #2 Communication method

4.7.3.1 This method will be used on all nodes fitted with the Network Service Provider #2's communication hardware for all tests listed in sections 4.5 and 4.6.

4.7.3.2 Each test will be performed on the Tesco MTB, four nodes at a time.

4.7.3.3 Each node will be energized with potential only.

4.7.3.4 Each node will be registered through Network Service Provider #2's network using their communication software.

4.7.3.5 An initial Wh query will be done on each node and recorded in the data collection spreadsheet.

4.7.3.6 The testing parameters will then be set in the MTB. The MTB will be set to run a Demand test, with the interval set to a value which should register at least 1,000Wh on both the nodes and the reference standard (i.e. for 120V, 1.00 PF, 10A test, the time interval will be set to (1,000*60)/(120*10) = 50 minutes).

4.7.3.7 At the end of the interval, the number of Wh from the reference standard will be recorded, along with the ending Wh readings from each of the four nodes.

4.7.3.8 The percent accuracy will then be given by the ratio of Node Wh/Reference Standard Wh.

5 Documentation

5.1 The results of each of the aforementioned tests will be documented in a fashion that will first sort the information based on the test performed.

5.2 Each test result will be further sorted by node manufacturer.

5.3 Each test result will be listed and if multiple tests were performed based on the same criteria, due to a test procedural fault, or due to a repair required to the testing equipment; those tests will be listed together, with a notation as to the reasons why the additional test was required.

5.4 Each test result will (at a minimum) list the following information:

5.4.1 Test name and description (as listed in sections 4.5 and 4.6 above)

5.4.2 Test conditions (as listed in section 4 above)

5.4.3 Manufacturer name

5.4.4 Node serial number or other identifying information.

5.4.5 Expected test result or acceptable result.

5.4.6 Actual result

5.4.7 Units

5.4.8 Notes – this will be a section that will be used in the case where the tester observes a notable condition that existed prior to, during, or after the test was performed.

5.5 Each section will be followed by an additional notes section that will be used to summarize the findings and will be kept to observable facts.

5.6 Finally, the report will contain a summary of all testing performed, observed information not included in the otherwise presented data, and a clearly indicated section for opinions and recommendations.

6 Reference Documents

6.1 ANSI C12.20 Specification – see Link to ANSI webstore

7 Revision Record

Revision Record

REV	ECN:	REVISION DESCRIPTION:	APPR:	REL:
-	N/A	Draft	JFW	2/17/16
1	N/A	Added section 6 – reference documents Added section 4.6.3 – additional voltage variations	JFW	3/3/16
2	N/A	Revised section 3.1; added (MTB) reference Revised section 3.1.1.2.4; changed displayed text for internal hyperlink Revised section 3.1.1.5; was FTU Revised section 4.3.4; was 15AAC Added section 4.6.4	JFW	3/4/16
3	N/A	Added section 3.1.1.6 Added section 4.7.3	JFW	3/10/16
4	N/A	Revised section 4.6.2; Test 6 was Test 5	JFW	9/19/16
4A		Revised for Select Limited External Distribution – by E. Bonetti	EPB	10/21/16

Attachment 3

MTB Calibration Report

2/18/2015 04:00 PM

Calibration Date: 2/18/2015

Calibration Standard: RD 31 301504

Internal Standard: RD 30 301425

Calibration Performed By: John F. Williams

Socket: 11

Current	WATT-HR % REG PF=1.00		WATT-HR % REG PF=0.50	
	120/208	277/480	120/208	277/480
0.25	0.003%	0.000%		
2.50	0.001%	0.001%	0.011%	0.012%
3.00	0.000%	0.001%		
5.00	0.001%	0.001%		
30.00	0.001%	0.002%	0.011%	0.012%
50.00	0.002%	0.002%	0.012%	0.012%

Socket: 13

Current	WATT-HR % REG PF=1.00		WATT-HR % REG PF=0.50	
	120/208	277/480	120/208	277/480
0.25	0.003%	0.002%		
2.50	0.002%	0.001%	0.012%	0.012%
3.00	0.002%	0.001%		
5.00	0.001%	0.000%		
30.00	0.001%	0.001%	0.011%	0.012%
50.00	0.003%	0.001%	0.011%	0.011%

Socket: 12

Current	WATT-HR % REG PF=1.00		WATT-HR % REG PF=0.50	
	120/208	277/480	120/208	277/480
0.25	0.002%	0.001%		
2.50	0.003%	0.001%	0.013%	0.014%
3.00	0.002%	0.000%		
5.00	0.002%	-0.001%		
30.00	0.001%	0.000%	0.015%	0.013%
50.00	0.001%	0.001%	0.014%	0.015%

Socket: 14

Current	WATT-HR % REG PF=1.00		WATT-HR % REG PF=0.50	
	120/208	277/480	120/208	277/480
0.25	0.001%	0.001%		
2.50	0.001%	-0.001%	0.003%	0.002%
3.00	0.001%	0.000%		
5.00	0.001%	0.000%		
30.00	0.001%	0.000%	0.001%	0.002%
50.00	0.002%	0.001%	0.002%	0.003%

Calibration Validated By: ____________________ Date: ____________

MTB Calibration Report

4/21/2015 04:00 PM

Calibration Date: 4/21/2015

Calibration Standard: RD-30-201 301563

Internal Standard: RD-30-201 301510

Calibration Performed By: John F. Williams

Socket: 11

Current	120/208		120/240		277/480	
	PF=1.00	PF=0.50	PF=1.00	PF=0.50	PF=1.00	PF=0.50
0.25	0.003%		0.003%		0.000%	
2.50	0.001%	0.011%	0.001%	0.011%	0.001%	0.012%
3.00	0.000%		0.000%		0.001%	
5.00	0.001%		0.001%		0.001%	
30.00	0.001%	0.011%	0.001%	0.011%	0.002%	0.012%
50.00	0.002%	0.012%	0.002%	0.012%	0.002%	0.012%
Average	0.001%	0.011%	0.001%	0.011%	0.001%	0.012%
Max	0.003%	0.012%	0.003%	0.012%	0.002%	0.012%
Min	0.000%	0.011%	0.000%	0.011%	0.000%	0.012%

Socket: 13

Current	120/208		120/240		277/480	
	PF=1.00	PF=0.50	PF=1.00	PF=0.50	PF=1.00	PF=0.50
0.25	0.003%		0.003%		0.000%	
2.50	0.001%	0.011%	0.001%	0.011%	0.001%	0.012%
3.00	0.000%		0.000%		0.001%	
5.00	0.001%		0.001%		0.001%	
30.00	0.001%	0.011%	0.001%	0.011%	0.002%	0.012%
50.00	0.002%	0.012%	0.002%	0.012%	0.002%	0.012%
Average	0.001%	0.011%	0.001%	0.011%	0.001%	0.012%
Max	0.003%	0.012%	0.003%	0.012%	0.002%	0.012%
Min	0.000%	0.011%	0.000%	0.011%	0.000%	0.012%

Socket: 12

Current	120/208		120/240		277/480	
	PF=1.00	PF=0.50	PF=1.00	PF=0.50	PF=1.00	PF=0.50
0.25	0.003%		0.003%		0.000%	
2.50	0.001%	0.011%	0.001%	0.011%	0.001%	0.012%
3.00	0.000%		0.000%		0.001%	
5.00	0.001%		0.001%		0.001%	
30.00	0.001%	0.011%	0.001%	0.011%	0.002%	0.012%
50.00	0.002%	0.012%	0.002%	0.012%	0.002%	0.012%
Average	0.001%	0.011%	0.001%	0.011%	0.001%	0.012%
Max	0.003%	0.012%	0.003%	0.012%	0.002%	0.012%
Min	0.000%	0.011%	0.000%	0.011%	0.000%	0.012%

Socket: 14

Current	120/208		120/240		277/480	
	PF=1.00	PF=0.50	PF=1.00	PF=0.50	PF=1.00	PF=0.50
0.25	0.003%		0.003%		0.000%	
2.50	0.001%	0.011%	0.001%	0.011%	0.001%	0.012%
3.00	0.000%		0.000%		0.001%	
5.00	0.001%		0.001%		0.001%	
30.00	0.001%	0.011%	0.001%	0.011%	0.002%	0.012%
50.00	0.002%	0.012%	0.002%	0.012%	0.002%	0.012%
Average	0.001%	0.011%	0.001%	0.011%	0.001%	0.012%
Max	0.003%	0.012%	0.003%	0.012%	0.002%	0.012%
Min	0.000%	0.011%	0.000%	0.011%	0.000%	0.012%

Calibration Validated By: John F. Williams

Date: 4/21/2015

Attachment 4

MTB Calibration Report

Calibration Date: 4/20/2016 Board Number: 8121-1 Mode: Watthour

Calibration Standard: RD-30-201 301563 Internal Standard: RD-30-201 301509

Calibration Performed By: John F. Williams

Socket: 11 Calibration Date: 4/20/2016

Current	120/208		277/480	
	PF=1.00	PF=0.50	PF=1.00	PF=0.50
0.25	0.000%		0.000%	
2.50	0.004%	0.005%	0.000%	0.007%
3.00	0.000%		-0.001%	
5.00	0.000%		0.000%	
30.00	-0.001%	0.004%	-0.001%	0.006%
50.00	-0.001%	0.005%	0.000%	0.007%
Average	0.000%	0.005%	0.000%	0.007%
Max	0.004%	0.005%	0.000%	0.007%
Min	-0.001%	0.004%	-0.001%	0.006%

Socket: 12 Calibration Date: 4/20/2016

Current	120/208		277/480	
	PF=1.00	PF=0.50	PF=1.00	PF=0.50
0.25	0.000%		0.000%	
2.50	0.004%	0.005%	0.000%	0.007%
3.00	-0.003%		0.000%	
5.00	0.002%		0.001%	
30.00	-0.001%	0.006%	-0.001%	0.006%
50.00	-0.001%	0.006%	0.000%	0.008%
Average	0.000%	0.006%	0.000%	0.007%
Max	0.004%	0.006%	0.001%	0.008%
Min	-0.003%	0.005%	-0.001%	0.006%

Socket: 13 Calibration Date: 4/20/2016

Current	120/208		277/480	
	PF=1.00	PF=0.50	PF=1.00	PF=0.50
0.25	0.000%		0.005%	
2.50	0.000%	0.005%	0.002%	0.010%
3.00	0.003%		0.001%	
5.00	0.002%		0.001%	
30.00	-0.001%	0.006%	0.000%	0.006%
50.00	0.000%	0.006%	0.001%	0.008%
Average	0.001%	0.006%	0.002%	0.008%
Max	0.003%	0.006%	0.005%	0.010%
Min	-0.001%	0.005%	0.000%	0.006%

Socket: 14 Calibration Date: 4/20/2016

Current	120/208		277/480	
	PF=1.00	PF=0.50	PF=1.00	PF=0.50
0.25	0.005%		0.005%	
2.50	0.004%	-0.005%	0.002%	0.003%
3.00	0.003%		0.001%	
5.00	-0.002%		0.000%	
30.00	-0.001%	-0.002%	-0.001%	-0.002%
50.00	-0.002%	-0.002%	0.000%	-0.001%
Average	0.001%	-0.003%	0.001%	0.000%
Max	0.005%	-0.002%	0.005%	0.003%
Min	-0.002%	-0.005%	-0.001%	-0.002%

Calibration Validated By: John F. Williams Date: 4/20/2016

Attachment 5

Radian Research, Inc. | 3852 Fortune Drive, Lafayette, Indiana 47905 | Ph: 765-449-5500 Fax: 765-448-4614 | www.radianresearch.com

Certificate of Calibration

Manufacturer: **Radian Research, Inc.**
Instrument Model: **RD-30-201 Dytronic Portable Standard**
Serial Number: 301563
Firmware Revision: 07.34.04
Error Specification: .04% worst case

Quality Management System
ISO 9001Certified

Customer Name:
Address:

P.O.Number:
CE Number:
RMA / Certificate Number:
Calibration Date: 1-Jul-15
Based on the recommended calibration interval, the next calibration is due on: 30-Jun-16

Environmental Conditions
Temperature: 23ºC +/- 2ºC
Humidity: between 30% and 60%

Physical Condition: Undamaged
Radian Research's As-Found Test Results showed this Instrument to be:
[X] New [ ] In Tolerance [ ] Out of Tolerance [ ] Inoperative [ ] Limited Calibration
For Out of Tolerance conditions, As-Found Data Reports are furnished.

Radian Research Inc. certifies the instrument listed above meets or exceeds all published specifications and was calibrated in compliance with ANSI/NCSL Z540-1 using applicable Radian Research procedures which meet the requirements of ISO 9001:2008.
This instrument was calibrated by a Radian Research RS-933 Syntron Automated Calibration System which is traceable to the National Institute of Standards and Technology (NIST) and / or other National Metrology Institute (NMI). The RS-933 Calibration System is traceable within the limitations of NIST's services, by accuracies derived from accepted values of natural physicalconstants, or accepted ratio type calibration techniques. The RS-933 Calibration System is cross checked and calibrated on a schedule which is adjusted to maintain required accuracies and traceability.

Procedure used for Calibration: 9912987
Software used for Calibration: Radian Source Control Program Rel.04.30.19 Test Release Mar 31, 2011
RS-933 serial number: 703201, 703198, 703199

Applicable Traceability & Report Numbers for References used by Radian's Metrology Lab:

Watt-hour, VA-hour, VAR-hour, Q-hour, Amp-hour, Volt-hour, Volt-Squared hour, AC Volt
Master Reference Bank consisting of (3) RD-22-RTS
Serial Numbers: 200717, 200718, 200719, Calibration Due Date: 01-Dec-2015
Traceable to (3) RD-22-RTS SN's 202098, 202099, 202100 calibrated by NIST

Time Base (Frequency)
Arbiter Systems Model 1083B Satellite-Controlled Frequency Standard s/n B1057. GPS controlled system with an uncertainty of 0.000002ppm. No calibration required.

DC Volts
Fluke Model 732B DC Volt Standard s/n 7703004 with an uncertainty of ± .1ppm.
Fluke Certificate Number 12D5460. Calibration Due Date: 25-Oct-2015.

Resistance
Guildline Standard Resistor Model 9330/10K s/n 62623, 62624 with an Expanded Uncertainty of ± .320pp
Test Certificate GCS15215, GCS15216. Calibration Due Dates: 25-Oct-2015.

Other
Hewlett Packard 8 Digit Multi-Meter Model 3458A s/n 2823A02816. Agilent Technologies
Test Certificate Number 63336: Calibration Due Date 28-Oct-2015.

Metrology Laboratory Technician Signature

This report shall not be reproduced, except in full, without prior written approval of the Calibration Facility

LAB 223

DOC ID: 9903209.B

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. **Watt-hour 60 Hz** **Phase A**

Date........................... **1-Jul-15**

Serial Number.......... **301563**

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards Tranceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.25	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
0.3	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
0.5	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
1.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
2.0	0.000	0.001	0.000	0.001	0.000	0.000	0.001	0.001
2.5	0.000	0.001	0.000	0.001	0.000	0.000	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
4.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
5.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
7.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
10.0	0.000	0.001	0.000	0.001	0.000	0.000	0.001	0.001
15.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
20.0	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
40.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
45.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
50.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
60.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
80.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
100.0	0.001	0.001	0.001	0.000	0.000	-0.001	0.000	0.000
120.0	0.001	0.001	0.001	0.001	0.000	-0.001	0.000	-0.001
Average	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.000**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	-0.001
Maximum	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Overall	**Unity**	**60°Lag**
Average	0.000	0.001
Minimum	0.000	-0.001
Maximum	0.001	0.001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. Watt-hour 60 Hz **Phase B**

Date........................ 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards Tranceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.25	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.3	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
0.5	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
1.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
2.0	0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001
2.5	0.000	0.001	0.000	0.001	0.000	0.001	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.000	0.001	0.000	0.001	0.000	0.001	0.001	0.001
5.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
7.0	0.000	0.001	0.000	0.002	0.000	0.001	0.001	0.001
10.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
15.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
20.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
40.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
45.0	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.001
50.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001
60.0	0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001
80.0	0.000	0.001	0.000	0.001	0.000	0.000	0.001	0.001
100.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
120.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average	**0.000**	**0.001**	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001

Overall	**Unity**	**60°Lag**
Average	0.000	0.001
Minimum	0.000	0.000
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. Watt-hour 60 Hz **Phase C**

Date........................ 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards Tranceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.001	0.000	0.000	-0.001	0.001
0.25	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
0.3	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
0.5	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
1.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
2.0	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001
2.5	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
5.0	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001
7.0	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
10.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
15.0	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
20.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
40.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
45.0	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
50.0	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
60.0	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
80.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
100.0	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000
120.0	0.001	0.001	0.001	0.000	0.001	0.000	0.001	0.000
Average	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.000
Maximum	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001

Overall	**Unity**	**60°Lag**
Average	0.001	0.001
Minimum	-0.001	0.000
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. **Watt-hour 60 Hz** **Total**

Date......................... **1-Jul-15**

Serial Number.......... **301563**

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards Tranceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.25	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
0.3	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
0.5	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
1.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
2.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
2.5	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
4.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
5.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
7.0	0.000	0.001	0.001	0.001	0.000	0.001	0.000	0.001
10.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
15.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
20.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
40.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
45.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001
50.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.000
60.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.000
80.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
100.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
120.0	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Average	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.000**	**0.001**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Overall	**Unity**	**60°Lag**
Average	0.001	0.001
Minimum	0.000	0.000
Maximum	0.001	0.001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................... Watts 60 Hz Phase A

Date......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards Tranceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.25	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
0.3	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
2.0	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001
2.5	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
4.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
5.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
7.0	0.000	0.001	0.000	0.001	0.000	0.000	0.001	0.001
10.0	0.000	0.001	0.000	0.001	0.000	0.000	0.001	0.001
15.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
20.0	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.002	0.001	0.001	0.000	0.000	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
40.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
45.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
50.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.000
60.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
80.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
100.0	0.000	0.001	0.001	0.001	0.000	-0.001	0.000	0.000
120.0	0.000	0.001	0.001	0.001	0.000	-0.001	0.000	-0.001
Average	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.000**	**0.001**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	-0.001
Maximum	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001

Overall	**Unity**	**60°Lag**
Average	0.000	0.001
Minimum	0.000	-0.001
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function....................Watts **60 Hz** **Phase B**

Date........................ 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards Tranceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.25	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.3	0.000	0.001	0.000	0.001	0.000	0.000	0.001	0.001
0.5	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
1.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
2.0	0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001
2.5	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.000	0.001	0.000	0.001	0.000	0.001	0.001	0.001
5.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
7.0	0.000	0.001	0.001	0.002	0.000	0.001	0.001	0.002
10.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
15.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
20.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
40.0	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.001
45.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
50.0	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.001
60.0	0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001
80.0	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.001
100.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
120.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Average	**0.000**	**0.001**	**0.000**	**0.001**	**0.000**	**0.000**	**0.001**	**0.001**
Minimum	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Maximum	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002

Overall	Unity	60°Lag
Average	0.000	0.001
Minimum	0.000	0.000
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................... Watts 60 Hz Phase C

Date........................ 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards Tranceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	-0.001	0.000	0.000	0.001	0.000	0.000	-0.001	0.000
0.25	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
0.3	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
0.5	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
1.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
2.0	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
2.5	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
3.0	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
5.0	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001
7.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
10.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
15.0	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
20.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
40.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
45.0	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
50.0	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
60.0	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000
80.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
100.0	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000
120.0	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.000
Average	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.001**
Minimum	-0.001	0.000	0.000	0.000	0.000	0.000	-0.001	0.000
Maximum	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001

Overall	Unity	60°Lag
Average	0.001	0.001
Minimum	-0.001	0.000
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................... Watts 60 Hz Total

Date........................ 1-Jul-15

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards Tranceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
0.25	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
0.3	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
0.5	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
1.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
2.0	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001
2.5	0.000	0.001	0.000	0.001	0.000	0.001	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
4.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
5.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
7.0	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.001
10.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
15.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
20.0	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
40.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
45.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001
50.0	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.000
60.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
80.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
100.0	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000
120.0	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000
Average	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.000**	**0.001**	**0.001**
Minimum	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Maximum	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Overall	**Unity**	**60°Lag**
Average	0.000	0.001
Minimum	0.000	0.000
Maximum	0.001	0.001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. VAR-hour 60 Hz **Phase A**

Date.......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VAR-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for VAR-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 90°Lag	120 30°Lag	240 90°Lag	240 30°Lag	480 90°Lag	480 30°Lag	600 90°Lag	600 30°Lag
0.2	0.000	0.001	0.001	0.002	0.001	0.004	0.002	0.006
0.25	0.000	0.001	0.001	0.002	0.001	0.004	0.002	0.004
0.3	0.000	0.000	0.001	0.001	0.001	0.003	0.002	0.003
0.5	0.000	0.000	0.000	0.001	0.000	0.002	0.001	0.002
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
3.0	0.000	0.001	0.001	0.001	0.000	0.002	0.001	0.002
4.0	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
5.0	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.001
7.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10.0	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000
15.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
20.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
25.0	0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001
30.0	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.001
35.0	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
40.0	0.000	0.000	0.001	0.002	-0.001	0.000	0.000	0.000
45.0	0.000	0.000	0.000	0.001	-0.001	0.000	0.000	0.000
50.0	0.000	0.001	0.001	0.002	0.000	0.001	0.000	0.001
60.0	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000
80.0	0.000	0.000	0.001	0.003	-0.001	0.000	0.000	0.000
100.0	0.000	0.000	0.001	0.003	-0.001	0.000	0.000	0.000
120.0	0.000	0.001	0.001	0.004	-0.001	0.000	0.000	0.001
Average	**0.000**	**0.000**	**0.001**	**0.001**	**0.000**	**0.001**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000
Maximum	0.001	0.001	0.001	0.004	0.001	0.004	0.002	0.006

Overall	**90°Lag**	**30°Lag**
Average	0.000	0.001
Minimum	-0.001	0.000
Maximum	0.002	0.006

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. VAR-hour 60 Hz **Phase B**

Date.......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VAR-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for VAR-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 90°Lag	120 30°Lag	240 90°Lag	240 30°Lag	480 90°Lag	480 30°Lag	600 90°Lag	600 30°Lag
0.2	0.000	0.000	0.000	0.001	0.001	0.003	0.002	0.004
0.25	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.003
0.3	0.000	0.001	0.000	0.001	0.001	0.002	0.001	0.003
0.5	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002
1.0	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
2.0	0.000	0.000	0.001	0.000	0.001	0.001	0.001	0.001
2.5	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
3.0	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.002
4.0	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
7.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
10.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
15.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.0	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
25.0	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.002
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.000	0.001	0.001	0.001	0.000	0.001	0.000	0.001
40.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.000
45.0	0.000	0.001	0.001	0.001	0.000	0.001	0.000	0.001
50.0	0.000	0.001	0.001	0.002	0.000	0.001	0.000	0.001
60.0	0.001	0.001	0.001	0.002	0.000	0.001	0.000	0.001
80.0	0.000	0.001	0.001	0.002	0.000	0.001	0.000	0.001
100.0	0.000	0.002	0.001	0.003	0.000	0.001	0.000	0.001
120.0	0.001	0.002	0.001	0.003	0.000	0.001	0.000	0.001
Average	**0.000**	**0.001**	**0.000**	**0.001**	**0.000**	**0.001**	**0.001**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.001	0.002	0.001	0.003	0.001	0.003	0.002	0.004

Overall	90°Lag	30°Lag
Average	0.000	0.001
Minimum	0.000	0.000
Maximum	0.002	0.004

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. VAR-hour 60 Hz **Phase C**

Date......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VAR-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for VAR-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 90°Lag	120 30°Lag	240 90°Lag	240 30°Lag	480 90°Lag	480 30°Lag	600 90°Lag	600 30°Lag
0.2	-0.001	0.000	0.000	0.000	0.001	0.002	0.001	0.002
0.25	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.002
0.3	0.000	0.000	0.000	0.000	0.001	0.002	0.001	0.002
0.5	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.002
1.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
2.0	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
2.5	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
3.0	0.000	0.001	0.000	0.002	0.001	0.003	0.001	0.002
4.0	0.000	0.001	0.000	0.001	0.001	0.002	0.001	0.001
5.0	0.000	0.000	0.000	0.001	0.000	0.002	0.000	0.001
7.0	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
10.0	-0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.000
15.0	0.000	0.001	0.000	0.001	0.001	0.002	0.001	0.001
20.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
25.0	0.001	0.001	0.001	0.002	0.001	0.003	0.001	0.002
30.0	0.000	0.001	0.001	0.001	0.001	0.002	0.001	0.001
35.0	0.000	0.001	0.001	0.002	0.001	0.002	0.001	0.002
40.0	0.000	0.001	0.001	0.002	0.001	0.002	0.001	0.001
45.0	0.000	0.001	0.001	0.002	0.001	0.002	0.001	0.001
50.0	0.001	0.003	0.001	0.003	0.001	0.003	0.001	0.003
60.0	0.001	0.002	0.001	0.003	0.001	0.003	0.001	0.003
80.0	0.001	0.002	0.001	0.003	0.001	0.002	0.001	0.002
100.0	0.001	0.003	0.001	0.004	0.001	0.003	0.001	0.002
120.0	0.001	0.003	0.002	0.005	0.001	0.003	0.001	0.002
Average	**0.000**	**0.001**	**0.000**	**0.002**	**0.001**	**0.002**	**0.001**	**0.002**
Minimum	-0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Maximum	0.001	0.003	0.002	0.005	0.001	0.003	0.001	0.003

Overall	**90°Lag**	**30°Lag**
Average	0.001	0.002
Minimum	-0.001	0.000
Maximum	0.002	0.005

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function................... VAR-hour 60 Hz Total

Date......................... 1-Jul-15

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VAR-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for VAR-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 90°Lag	120 30°Lag	240 90°Lag	240 30°Lag	480 90°Lag	480 30°Lag	600 90°Lag	600 30°Lag
0.2	0.000	0.000	0.000	0.001	0.001	0.003	0.002	0.004
0.25	0.000	0.000	0.000	0.001	0.001	0.003	0.001	0.003
0.3	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.003
0.5	0.000	0.000	0.000	0.001	0.000	0.002	0.001	0.002
1.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
2.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
2.5	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
3.0	0.000	0.001	0.001	0.001	0.001	0.002	0.001	0.002
4.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
7.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
10.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
15.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
20.0	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
25.0	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.002
30.0	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001
40.0	0.000	0.001	0.001	0.001	0.000	0.001	0.000	0.001
45.0	0.000	0.001	0.001	0.002	0.000	0.001	0.000	0.001
50.0	0.000	0.001	0.001	0.002	0.000	0.002	0.000	0.002
60.0	0.000	0.001	0.001	0.002	0.000	0.001	0.000	0.001
80.0	0.000	0.001	0.001	0.003	0.000	0.001	0.000	0.001
100.0	0.000	0.002	0.001	0.003	0.000	0.001	0.000	0.001
120.0	0.000	0.002	0.001	0.004	0.000	0.002	0.000	0.001
Average	**0.000**	**0.001**	**0.000**	**0.001**	**0.000**	**0.001**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.001	0.002	0.001	0.004	0.001	0.003	0.002	0.004

Overall	90°Lag	30°Lag
Average	0.000	0.001
Minimum	0.000	0.000
Maximum	0.002	0.004

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. VAR 60 Hz Phase A

Date.......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VAR calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for VAR-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 90°Lag	120 30°Lag	240 90°Lag	240 30°Lag	480 90°Lag	480 30°Lag	600 90°Lag	600 30°Lag
0.2	0.000	0.001	0.001	0.002	0.001	0.005	0.002	0.005
0.25	0.000	0.001	0.001	0.002	0.001	0.004	0.002	0.005
0.3	0.000	0.001	0.000	0.001	0.001	0.003	0.002	0.003
0.5	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.003
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
3.0	0.000	0.001	0.001	0.001	0.000	0.002	0.001	0.002
4.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
5.0	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.001
7.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10.0	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000
15.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
20.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
25.0	0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001
30.0	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.001
35.0	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
40.0	0.000	0.001	0.001	0.002	-0.001	0.000	0.000	0.000
45.0	0.000	0.000	0.000	0.001	-0.001	0.000	0.000	0.000
50.0	0.000	0.001	0.001	0.002	0.000	0.001	0.000	0.001
60.0	0.000	0.001	0.001	0.002	0.000	0.001	0.000	0.000
80.0	0.000	0.000	0.001	0.003	0.000	0.000	0.000	0.000
100.0	0.000	0.000	0.001	0.003	-0.001	0.000	0.000	0.001
120.0	0.000	0.001	0.001	0.004	-0.001	0.000	0.000	0.001
Average	**0.000**	**0.000**	**0.001**	**0.001**	**0.000**	**0.001**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000
Maximum	0.001	0.001	0.001	0.004	0.001	0.005	0.002	0.005

Overall	90°Lag	30°Lag
Average	0.000	0.001
Minimum	-0.001	0.000
Maximum	0.002	0.005

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. VAR 60 Hz Phase B

Date........................ 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VAR calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for VAR-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 90°Lag	120 30°Lag	240 90°Lag	240 30°Lag	480 90°Lag	480 30°Lag	600 90°Lag	600 30°Lag
0.2	0.000	0.001	0.000	0.001	0.001	0.003	0.001	0.004
0.25	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.003
0.3	0.000	0.001	0.000	0.001	0.001	0.002	0.002	0.003
0.5	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002
1.0	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
2.0	0.000	0.001	0.001	0.000	0.001	0.000	0.001	0.001
2.5	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002
4.0	0.000	-0.001	0.000	0.000	0.000	0.001	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
7.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
10.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
15.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002
35.0	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001
40.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
45.0	0.000	0.000	0.001	0.002	0.000	0.001	0.000	0.001
50.0	0.000	0.001	0.001	0.002	0.000	0.001	0.000	0.001
60.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
80.0	0.000	0.001	0.001	0.002	0.000	0.002	0.000	0.001
100.0	0.000	0.002	0.001	0.003	0.000	0.001	0.000	0.001
120.0	0.001	0.002	0.001	0.003	0.000	0.002	0.000	0.001
Average	**0.000**	**0.001**	**0.000**	**0.001**	**0.000**	**0.001**	**0.001**	**0.001**
Minimum	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.001	0.002	0.001	0.003	0.001	0.003	0.002	0.004

Overall	**90°Lag**	**30°Lag**
Average	0.000	0.001
Minimum	0.000	-0.001
Maximum	0.002	0.004

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. VAR 60 Hz Phase C

Date.......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VAR calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for VAR-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 90°Lag	120 30°Lag	240 90°Lag	240 30°Lag	480 90°Lag	480 30°Lag	600 90°Lag	600 30°Lag
0.2	-0.001	-0.001	0.000	0.000	0.000	0.001	0.001	0.002
0.25	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.002
0.3	0.000	-0.001	0.000	0.001	0.001	0.002	0.001	0.002
0.5	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.002
1.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
2.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
2.5	0.000	0.000	0.000	0.001	0.000	0.002	0.001	0.001
3.0	0.000	0.002	0.000	0.002	0.001	0.003	0.001	0.002
4.0	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.001
5.0	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
7.0	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
10.0	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000
15.0	0.000	0.001	0.000	0.001	0.001	0.002	0.000	0.001
20.0	0.000	0.001	0.000	0.001	0.001	0.002	0.001	0.001
25.0	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.002
30.0	0.000	0.001	0.001	0.002	0.001	0.002	0.001	0.001
35.0	0.001	0.000	0.001	0.002	0.001	0.002	0.001	0.002
40.0	0.000	0.001	0.001	0.002	0.001	0.001	0.000	0.001
45.0	0.000	0.001	0.001	0.002	0.001	0.002	0.001	0.001
50.0	0.001	0.003	0.001	0.004	0.001	0.004	0.001	0.003
60.0	0.001	0.002	0.001	0.003	0.001	0.002	0.001	0.003
80.0	0.001	0.002	0.001	0.003	0.001	0.002	0.001	0.002
100.0	0.001	0.003	0.001	0.004	0.001	0.003	0.001	0.002
120.0	0.001	0.003	0.002	0.005	0.001	0.003	0.001	0.003
Average	**0.000**	**0.001**	**0.001**	**0.002**	**0.001**	**0.002**	**0.001**	**0.002**
Minimum	-0.001	-0.001	0.000	0.000	0.000	0.001	0.000	0.000
Maximum	0.001	0.003	0.002	0.005	0.001	0.004	0.001	0.003

Overall	**90°Lag**	**30°Lag**
Average	0.001	0.002
Minimum	-0.001	-0.001
Maximum	0.002	0.005

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. VAR 60 Hz Total

Date........................ 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VAR calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for VAR-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 90°Lag	120 30°Lag	240 90°Lag	240 30°Lag	480 90°Lag	480 30°Lag	600 90°Lag	600 30°Lag
0.2	0.000	0.000	0.000	0.001	0.001	0.003	0.001	0.004
0.25	0.000	0.001	0.001	0.001	0.001	0.003	0.002	0.004
0.3	0.000	0.001	0.000	0.001	0.001	0.002	0.001	0.003
0.5	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.002
1.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
2.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
2.5	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
3.0	0.000	0.001	0.001	0.001	0.001	0.002	0.001	0.002
4.0	0.000	0.001	0.000	0.000	0.000	0.001	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
7.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
20.0	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
25.0	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.002
30.0	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001
40.0	0.000	0.001	0.001	0.002	0.000	0.001	0.000	0.001
45.0	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.001
50.0	0.000	0.002	0.001	0.002	0.000	0.002	0.001	0.002
60.0	0.000	0.001	0.001	0.002	0.000	0.002	0.000	0.001
80.0	0.000	0.001	0.001	0.002	0.000	0.001	0.000	0.001
100.0	0.000	0.002	0.001	0.003	0.000	0.001	0.000	0.001
120.0	0.000	0.002	0.001	0.004	0.000	0.002	0.000	0.002
Average	**0.000**	**0.001**	**0.001**	**0.001**	**0.000**	**0.001**	**0.001**	**0.002**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.001	0.002	0.001	0.004	0.001	0.003	0.002	0.004

Overall	**90°Lag**	**30°Lag**
Average	0.000	0.001
Minimum	0.000	0.000
Maximum	0.002	0.004

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function...........VA-hour RMS 60 Hz Phase A

Date.......................... 1-Jul-15

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VA-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other national Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.002
0.25	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.002
0.3	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.002
0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
2.5	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
4.0	0.001	0.000	0.001	0.001	0.000	0.000	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
40.0	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
45.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
50.0	0.001	0.000	0.001	0.001	0.000	0.000	0.001	0.000
60.0	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000
80.0	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000
100.0	0.000	0.000	0.000	0.001	0.000	-0.001	0.000	0.000
120.0	0.001	0.000	0.001	0.002	0.000	-0.001	0.000	0.000
Average	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.000
Maximum	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002

Overall	**Unity**	**60°Lag**
Average	0.000	0.000
Minimum	0.000	-0.001
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function..........VA-hour RMS 60 Hz **Phase B**

Date......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VA-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other national Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.000	-0.001	0.001	0.000	0.001
0.25	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
0.3	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
2.5	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
3.0	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.0	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
40.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
45.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
50.0	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.001
60.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
80.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
100.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
120.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Average	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000
Maximum	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Overall	**Unity**	**60°Lag**
Average	0.000	0.000
Minimum	-0.001	0.000
Maximum	0.001	0.001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function...........VA-hour RMS 60 Hz Phase C

Date........................ 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VA-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other national Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	-0.001	0.000	0.000	0.000	0.000	0.001	-0.001	0.001
0.25	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001
0.3	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001
0.5	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001
1.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
2.0	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001
2.5	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
5.0	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001
7.0	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.001	0.000	0.001	0.001	0.001	0.001	0.000	0.001
20.0	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
40.0	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001
45.0	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001
50.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
60.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
80.0	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
100.0	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.001
120.0	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
Average	**0.001**	**0.000**	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.001**
Minimum	-0.001	0.000	0.000	0.000	0.000	0.000	-0.001	0.000
Maximum	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001

Overall	**Unity**	**60°Lag**
Average	0.001	0.001
Minimum	-0.001	0.000
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function...........VA-hour RMS 60 Hz Total

Date........................ 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VA-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other national Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
0.25	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.002
0.3	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
0.5	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2.0	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.001
2.5	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.0	0.000	0.000	0.001	0.001	0.001	0.000	0.001	0.001
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
40.0	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
45.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
50.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
60.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
80.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.000
100.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
120.0	0.001	0.001	0.001	0.002	0.000	0.000	0.000	0.000
Average	**0.000**	**0.000**	**0.001**	**0.001**	**0.000**	**0.000**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002

Overall	**Unity**	**60°Lag**
Average	0.000	0.001
Minimum	0.000	0.000
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function................ VA RMS 60 Hz Phase A

Date......................... 1-Jul-15

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VA calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other national Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.002
0.25	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.002
0.3	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.002
0.5	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.0	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.001
2.5	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
4.0	0.001	0.000	0.001	0.001	0.000	0.000	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.0	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000
25.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
40.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
45.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
50.0	0.001	0.000	0.001	0.001	0.000	0.000	0.001	0.000
60.0	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000
80.0	0.001	0.000	0.001	0.001	0.000	0.000	0.001	0.000
100.0	0.000	0.000	0.001	0.001	0.000	-0.001	0.000	0.000
120.0	0.000	0.000	0.001	0.002	0.000	-0.001	0.000	0.000
Average	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.000
Maximum	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002

Overall	Unity	60°Lag
Average	0.000	0.000
Minimum	0.000	-0.001
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function................ VA RMS 60 Hz Phase B

Date.......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VA calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other national Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
0.25	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
0.3	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.001
0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
2.5	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.001
3.0	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.0	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
40.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
45.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
50.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
60.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
80.0	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000
100.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
120.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Average	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Overall	**Unity**	**60°Lag**
Average	0.000	0.000
Minimum	0.000	0.000
Maximum	0.001	0.001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function................ VA RMS 60 Hz Phase C

Date......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VA calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other national Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	-0.001	0.000	0.000	0.000	0.000	0.001	-0.001	0.001
0.25	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001
0.3	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001
0.5	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001
1.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
2.0	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001
2.5	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.001	0.000	0.001	0.001	0.001	0.001	0.000	0.001
5.0	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001
7.0	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.001	0.000	0.001	0.001	0.001	0.001	0.000	0.001
20.0	0.001	0.000	0.001	0.001	0.001	0.001	0.000	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
40.0	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
45.0	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001
50.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
60.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
80.0	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
100.0	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.001
120.0	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.001
Average	**0.001**	**0.000**	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.001**
Minimum	-0.001	0.000	0.000	0.000	0.000	0.000	-0.001	0.000
Maximum	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001

Overall	**Unity**	**60°Lag**
Average	0.001	0.001
Minimum	-0.001	0.000
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function................ VA RMS 60 Hz Total

Date......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VA calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other national Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
0.25	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.002
0.3	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
0.5	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2.0	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.001
2.5	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.0	0.001	0.000	0.000	0.001	0.001	0.001	0.001	0.001
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.0	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
40.0	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
45.0	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
50.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
60.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
80.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
100.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
120.0	0.001	0.001	0.001	0.002	0.000	0.000	0.000	0.000
Average	**0.000**	**0.000**	**0.001**	**0.001**	**0.000**	**0.001**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002

Overall	**Unity**	**60°Lag**
Average	0.000	0.001
Minimum	0.000	0.000
Maximum	0.001	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................... Q-hour 60 Hz Phase A

Date.......................... 1-Jul-15

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 Q-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for Q-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 60°Lag	120 Unity	240 60°Lag	240 Unity	480 60°Lag	480 Unity	600 60°Lag	600 Unity
0.2	0.001	0.000	0.002	0.001	0.004	0.001	0.005	0.002
0.25	0.001	0.000	0.002	0.001	0.002	0.001	0.003	0.002
0.3	0.000	0.000	0.001	0.001	0.002	0.001	0.003	0.002
0.5	0.000	0.000	0.001	0.000	0.001	0.001	0.002	0.001
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
2.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
2.5	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
4.0	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000
20.0	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
25.0	0.001	0.001	0.002	0.001	0.001	0.000	0.001	0.001
30.0	0.001	0.001	0.002	0.001	0.000	0.000	0.001	0.001
35.0	0.001	0.001	0.002	0.001	0.000	0.000	0.001	0.001
40.0	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
45.0	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000
50.0	0.001	0.000	0.003	0.001	0.001	0.000	0.001	0.000
60.0	0.001	0.000	0.002	0.001	0.000	0.000	0.000	0.000
80.0	0.001	0.000	0.003	0.001	0.000	0.000	0.000	0.000
100.0	0.001	0.000	0.003	0.001	0.000	-0.001	0.000	0.000
120.0	0.001	0.000	0.004	0.002	0.001	-0.001	0.001	0.000
Average	**0.000**	**0.000**	**0.001**	**0.001**	**0.001**	**0.000**	**0.001**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.000
Maximum	0.001	0.001	0.004	0.002	0.004	0.001	0.005	0.002

	60°Lag	Unity
Average	0.001	0.000
Minimum	0.000	-0.001
Maximum	0.005	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................... Q-hour 60 Hz Phase B

Date........................ 1-Jul-15

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 Q-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for Q-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 60°Lag	120 Unity	240 60°Lag	240 Unity	480 60°Lag	480 Unity	600 60°Lag	600 Unity
0.2	0.000	0.000	0.001	0.000	0.002	0.001	0.003	0.001
0.25	0.000	0.000	0.001	0.000	0.002	0.001	0.003	0.001
0.3	0.001	0.000	0.001	0.001	0.002	0.001	0.002	0.001
0.5	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
2.0	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.001
2.5	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.001
3.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7.0	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001
10.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25.0	0.002	0.001	0.002	0.001	0.002	0.001	0.001	0.001
30.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
35.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
40.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
45.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.000
50.0	0.001	0.001	0.002	0.001	0.001	0.000	0.001	0.001
60.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
80.0	0.001	0.001	0.002	0.001	0.001	0.000	0.001	0.000
100.0	0.002	0.001	0.002	0.001	0.001	0.000	0.001	0.000
120.0	0.002	0.001	0.003	0.001	0.001	0.000	0.001	0.000
Average	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.001**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.002	0.001	0.003	0.001	0.002	0.001	0.003	0.001

	60°Lag	Unity
Average	0.001	0.001
Minimum	0.000	0.000
Maximum	0.003	0.001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................... Q-hour 60 Hz Phase C

Date.......................... 1-Jul-15

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 Q-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for Q-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 60°Lag	120 Unity	240 60°Lag	240 Unity	480 60°Lag	480 Unity	600 60°Lag	600 Unity
0.2	-0.001	0.000	0.000	0.000	0.002	0.001	0.001	0.001
0.25	0.000	0.000	0.001	0.001	0.002	0.001	0.002	0.001
0.3	0.000	0.000	0.000	0.001	0.002	0.001	0.001	0.001
0.5	0.000	0.000	0.001	0.001	0.002	0.001	0.001	0.001
1.0	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000
2.0	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
2.5	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
3.0	0.002	0.001	0.002	0.001	0.003	0.001	0.002	0.001
4.0	0.001	0.000	0.001	0.001	0.002	0.001	0.001	0.001
5.0	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.000
7.0	0.001	0.000	0.001	0.001	0.002	0.001	0.001	0.001
10.0	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.000
15.0	0.001	0.000	0.001	0.001	0.002	0.001	0.001	0.001
20.0	0.001	0.000	0.001	0.001	0.002	0.001	0.001	0.001
25.0	0.002	0.001	0.002	0.001	0.003	0.001	0.002	0.001
30.0	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.001
35.0	0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.001
40.0	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.001
45.0	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.001
50.0	0.003	0.001	0.004	0.001	0.004	0.001	0.003	0.001
60.0	0.002	0.001	0.003	0.001	0.003	0.001	0.002	0.001
80.0	0.002	0.001	0.003	0.002	0.002	0.001	0.002	0.001
100.0	0.003	0.001	0.004	0.002	0.003	0.001	0.002	0.001
120.0	0.004	0.001	0.005	0.002	0.003	0.001	0.003	0.001
Average	**0.001**	**0.000**	**0.002**	**0.001**	**0.002**	**0.001**	**0.001**	**0.001**
Minimum	-0.001	0.000	0.000	0.000	0.001	0.001	0.001	0.000
Maximum	0.004	0.001	0.005	0.002	0.004	0.001	0.003	0.001

	60°Lag	Unity
Average	0.002	0.001
Minimum	-0.001	0.000
Maximum	0.005	0.002

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function................ Volts RMS 60 Hz Phase A

Date.......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 Voltage Axis is calibrated to a bank of three RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.0008%. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds per point with a 5 second stabilization time in between points. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage	V RMS	Vh RMS	V2h RMS
60	0.000		
80	0.000		
100	0.000		
120	0.000		
140	0.000		
160	0.000		
180	0.000		
200	0.000		
220	0.000		
240	0.000		
260	0.000		
280	0.000		
300	-0.001		
320	-0.001		
340	-0.001		
360	-0.001		
380	-0.001		
400	0.000		
420	0.000		
440	0.000		
460	0.000		
480	0.000		
500	0.000		
520	0.000		
540	0.000		
560	0.000		
580	0.000		
600	0.000		
Average	**0.000**		
Minimum	-0.001		
Maximum	0.000		

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function................. Volts RMS 60 Hz Phase B

Date......................... 1-Jul-15

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 Voltage Axis is calibrated to a bank of three RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.0008%. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds per point with a 5 second stabilization time in between points. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage	V RMS	Vh RMS	V2h RMS
60	0.000		
80	0.001		
100	0.001		
120	0.000		
140	0.001		
160	0.000		
180	0.000		
200	0.001		
220	0.000		
240	0.000		
260	0.000		
280	0.000		
300	0.000		
320	0.000		
340	0.000		
360	0.000		
380	0.000		
400	0.000		
420	0.000		
440	0.000		
460	0.000		
480	0.000		
500	0.000		
520	0.000		
540	0.000		
560	0.000		
580	0.000		
600	0.000		
Average	**0.000**		
Minimum	0.000		
Maximum	0.001		

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function................ Volts RMS 60 Hz Phase C

Date........................ 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 Voltage Axis is calibrated to a bank of three RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.0008%. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds per point with a 5 second stabilization time in between points. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage	V RMS	Vh RMS	V2h RMS
60	0.000		
80	0.002		
100	0.001		
120	0.000		
140	0.001		
160	0.001		
180	0.000		
200	0.001		
220	0.000		
240	0.000		
260	0.000		
280	0.000		
300	0.002		
320	0.001		
340	0.001		
360	0.001		
380	0.000		
400	0.001		
420	0.001		
440	0.000		
460	0.000		
480	0.000		
500	0.000		
520	0.000		
540	0.000		
560	0.000		
580	0.000		
600	0.000		
Average	**0.000**		
Minimum	0.000		
Maximum	0.002		

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. Amps RMS 60 Hz **Phase A**

Date.......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 Current Axis calibration is derived directly from the ratio of the (3) Radian RD-22-RTS Dytronic Transfer Standards which are traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) for an uncertainty of .0028%. Calibration Temperature is 23° Centigrade. Test time is 5 seconds per point with a 5 second stabilization time inbetween points. Results are as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Amps	A RMS
0.2	0.000
0.25	0.000
0.3	0.000
0.5	0.000
1.0	0.000
2.0	0.000
2.5	0.000
3.0	0.001
4.0	0.000
5.0	0.000
7.0	0.000
10.0	0.000
15.0	0.000
20.0	0.000
25.0	0.001
30.0	0.000
35.0	0.000
40.0	0.000
45.0	0.000
50.0	0.000
60.0	0.000
80.0	0.000
100.0	0.000
120.0	0.000
Average	**0.000**
Minimum	0.000
Maximum	0.001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. Amps RMS 60 Hz **Phase B**

Date......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 Current Axis calibration is derived directly from the ratio of the (3) Radian RD-22-RTS Dytronic Transfer Standards which are traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) for an uncertainty of .0028%. Calibration Temperature is 23° Centigrade. Test time is 5 seconds per point with a 5 second stabilization time inbetween points. Results are as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Amps	A RMS
0.2	0.000
0.25	0.000
0.3	0.000
0.5	0.000
1.0	0.000
2.0	0.000
2.5	0.000
3.0	0.001
4.0	0.000
5.0	0.000
7.0	0.000
10.0	0.000
15.0	0.000
20.0	0.000
25.0	0.001
30.0	0.000
35.0	0.000
40.0	0.000
45.0	0.000
50.0	0.000
60.0	0.000
80.0	0.000
100.0	0.000
120.0	0.000
Average	**0.000**
Minimum	0.000
Maximum	0.001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. Amps RMS 60 Hz Phase C

Date........................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 Current Axis calibration is derived directly from the ratio of the (3) Radian RD-22-RTS Dytronic Transfer Standards which are traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) for an uncertainty of .0028%. Calibration Temperature is 23° Centigrade. Test time is 5 seconds per point with a 5 second stabilization time inbetween points. Results are as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Amps	A RMS
0.2	0.000
0.25	0.000
0.3	0.000
0.5	0.000
1.0	0.000
2.0	0.000
2.5	0.000
3.0	0.001
4.0	0.001
5.0	0.000
7.0	0.001
10.0	0.000
15.0	0.000
20.0	0.000
25.0	0.001
30.0	0.001
35.0	0.001
40.0	0.000
45.0	0.000
50.0	0.000
60.0	0.000
80.0	0.000
100.0	0.000
120.0	0.000
Average	**0.000**
Minimum	0.000
Maximum	0.001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Mode........................ Frequency Phase A

Date......................... 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 time base calibration (1/frequency) is derived directly from an Arbiter Systems Model 1083B GPS Satellite-Controlled Frequency Standard. Uncertainty of the GPS System is .00005 parts per milion, traceable to United States Naval Observatory (USNO). Calibration temperature is 23 degrees Centigrade. Test time is 2 seconds with a stabilization of 2 seconds in between points. All Results are listed as Percent Error. The RS933 has at least a 4 times greater accuracy than the Instrument under test.

Frequency

45	-0.0001
46	0.0001
47	0.0001
48	0.0000
49	0.0000
50	0.0000
51	0.0000
52	-0.0001
53	0.0000
54	0.0000
55	0.0000
56	0.0000
57	0.0000
58	0.0001
59	0.0000
60	0.0000
61	0.0001
62	0.0000
63	0.0000
64	0.0000
65	0.0000
Average	**0.0000**
Minimum	-0.0001
Maximum	0.0001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Mode......................... Frequency **Phase B**

Date........................... 1-Jul-15

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 time base calibration (1/frequency) is derived directly from an Arbiter Systems Model 1083B GPS Satellite-Controlled Frequency Standard. Uncertainty of the GPS System is .00005 parts per milion, traceable to United States Naval Observatory (USNO). Calibration temperature is 23 degrees Centigrade. Test time is 2 seconds with a stabilization of 2 seconds in between points. All Results are listed as Percent Error. The RS933 has at least a 4 times greater accuracy than the Instrument under test.

Frequency

45	0.0000
46	0.0000
47	0.0000
48	0.0001
49	0.0000
50	-0.0001
51	0.0000
52	-0.0001
53	-0.0001
54	0.0000
55	0.0000
56	0.0001
57	0.0000
58	0.0001
59	0.0000
60	0.0000
61	0.0001
62	0.0000
63	0.0000
64	0.0000
65	0.0000
Average	**0.0000**
Minimum	-0.0001
Maximum	0.0001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Mode......................... Frequency **Phase C**

Date........................ 1-Jul-15

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 time base calibration (1/frequency) is derived directly from an Arbiter Systems Model 1083B GPS Satellite-Controlled Frequency Standard. Uncertainty of the GPS System is .00005 parts per milion, traceable to United States Naval Observatory (USNO). Calibration temperature is 23 degrees Centigrade. Test time is 2 seconds with a stabilization of 2 seconds in between points. All Results are listed as Percent Error. The RS933 has at least a 4 times greater accuracy than the Instrument under test.

Frequency

45	-0.0001
46	0.0000
47	0.0000
48	0.0001
49	0.0000
50	0.0000
51	-0.0001
52	0.0000
53	0.0000
54	0.0001
55	0.0000
56	0.0000
57	0.0001
58	0.0000
59	0.0001
60	0.0000
61	0.0001
62	-0.0001
63	-0.0001
64	0.0000
65	0.0001
Average	**0.0000**
Minimum	-0.0001
Maximum	0.0001

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................... Phase 60 Hz

Date........................ 1-Jul-15 Phase A

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.003%. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Current

	120 1	120 5	120 15	120 30	120 50	240 1	240 5	240 15	240 30	240 50	480 1	480 5	480 15	480 30	480 50
Phase															
-179.9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-90	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
179.9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................... Phase 60 Hz

Date......................... 1-Jul-15 Phase B

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.003%. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Current

	120 1	120 5	120 15	120 30	120 50	240 1	240 5	240 15	240 30	240 50	480 1	480 5	480 15	480 30	480 50
Phase															
-179.9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-90	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
179.9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................... Phase 60 Hz

Date........................ 1-Jul-15 Phase C

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.003%. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Current

	120	120	120	120	120	240	240	240	240	240	480	480	480	480	480
	1	5	15	30	50	1	5	15	30	50	1	5	15	30	50
Phase															
-179.9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-90	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
179.9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. Watt-hour 60 Hz Total

Date.......................... 1-Jul-15 Pulse Output

Serial Number........... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 watt-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards Tranceable to the SI through the National Institute of Standards and Technology (NIST) and/or other National Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013
0.5	0.000	0.000	0.000	0.000	0.000	-0.010	0.000	0.000
1.0	0.000	0.000	0.000	0.000	-0.002	0.000	0.000	0.000
2.0	0.000	0.000	0.003	0.000	0.000	0.000	0.001	0.000
2.5	0.000	0.000	0.000	0.004	0.000	0.000	0.001	0.002
3.0	0.000	0.000	0.002	0.003	0.001	0.000	0.001	0.000
4.0	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.000
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
7.0	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
10.0	0.001	0.000	0.001	0.001	0.000	0.000	0.001	0.001
15.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
20.0	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
25.0	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001
30.0	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.001
35.0	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001
40.0	0.001	0.002	0.001	0.001	0.000	0.000	0.001	0.001
45.0	0.001	0.002	0.001	0.001	0.000	0.000	0.000	0.001
50.0	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.000
60.0	0.001	0.002	0.001	0.002	0.000	0.000	0.001	0.001
80.0	0.001	0.001	0.001	0.002	0.000	0.000	0.001	0.001
100.0	0.001	0.001	0.001	0.001	0.000	-0.001	0.000	0.000
120.0	0.001	0.001	0.001	0.001	0.000	-0.001	0.000	0.000
Average	**0.001**	**0.001**	**0.001**	**0.001**	**0.000**	**0.000**	**0.001**	**0.001**
Minimum	0.000	0.000	0.000	0.000	-0.002	-0.010	0.000	0.000
Maximum	0.002	0.002	0.003	0.004	0.001	0.001	0.001	0.013

Overall	Unity	60°Lag
Average	0.001	0.001
Minimum	-0.002	-0.010
Maximum	0.003	0.013

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Calibration Report

RD-30-201 Dytronic Portable Standard

Function.................. VAR-hour 60 Hz **Total**

Date........................ 1-Jul-15 **Pulse Output**

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VAR-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or oth National Metrology Institute (NMI) with the use of an ultra low distortion synthesis and digital delay. Uncertainty is 0.005% for VAR-hour. Calibration temperature is 23 degrees Centigrade. Test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 90°Lag	120 30°Lag	240 90°Lag	240 30°Lag	480 90°Lag	480 30°Lag	600 90°Lag	600 30°Lag
0.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000
0.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002
2.0	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
2.5	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.000
3.0	0.003	0.000	0.000	0.000	0.001	0.001	0.001	0.001
4.0	0.003	0.000	0.000	0.001	0.001	0.001	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
7.0	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
10.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001
15.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.0	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000
25.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
30.0	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001
35.0	0.000	0.001	0.001	0.001	0.000	0.001	0.000	0.001
40.0	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.001
45.0	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
50.0	0.000	0.001	0.001	0.001	0.000	0.001	0.000	0.001
60.0	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.001
80.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
100.0	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000
120.0	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001
Average	**0.000**	**0.001**	**0.000**	**0.001**	**0.000**	**0.000**	**0.001**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.003	0.001	0.001	0.002	0.001	0.001	0.008	0.002

Overall	**90°Lag**	**30°Lag**
Average	0.000	0.001
Minimum	0.000	0.000
Maximum	0.008	0.002

Radian Research, Inc. | 3852 Fortune Drive, Lafayette, Indiana 47905 | Ph: 765-449-5500 Fax: 765-448-4614 | www.radianresearch.com

Calibration Report

RD-30-201 Dytronic Portable Standard

Function..........VA-hour RMS 60 Hz **Total**

Date........................ 1-Jul-15 **Pulse Output**

Serial Number.......... 301563

The following data was collected by a Radian Research RS-933 Automated Calibration System. The RS-933 VA-hour calibration is derived directly from (3) Radian RD-22-RTS Dytronic Transfer Standards traceable to the SI through the National Institute of Standards and Technology (NIST) and/or other national Metrology Institute (NMI) to an uncertainty of 0.002% @ unity and 0.003% @ 60 degrees lagging Power Factor. Calibration temperature is 23 degrees Centigrade. The test time is 5 seconds and the stabilization time in between points is 5 seconds. For lagging power factors the current lags the voltage. Results are listed as Percent Error. The RS-933 has at least a 4 times greater accuracy than the instrument under test.

Voltage & Phase Angle

Amps	120 Unity	120 60°Lag	240 Unity	240 60°Lag	480 Unity	480 60°Lag	600 Unity	600 60°Lag
0.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.25	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000
0.3	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.000
0.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
2.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.5	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
3.0	0.000	0.000	0.002	0.002	0.002	0.002	0.001	0.001
4.0	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
5.0	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
7.0	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
10.0	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.000
15.0	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
20.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
25.0	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001
30.0	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001
35.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
40.0	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001
45.0	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
50.0	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
60.0	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
80.0	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
100.0	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.000
120.0	0.000	0.001	0.000	0.002	0.001	0.001	0.000	0.001
Average	**0.000**	**0.001**	**0.000**	**0.001**	**0.001**	**0.002**	**0.000**	**0.001**
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	0.001	0.001	0.002	0.002	0.002	0.010	0.001	0.002

Overall	**Unity**	**60°Lag**
Average	0.000	0.001
Minimum	0.000	0.000
Maximum	0.002	0.010

Attachment 6

ORIGINATING GROUP:	ORIGIN DATE:	REVISION DATE:	NO. OF SHEETS:
TESCO ENGINEERING	**20-Apr-2016**	**17-Oct-2017**	**9**

Test Specification
for

nationalgrid

Photocell Node Meter Farm Testing
Project 8594

11/11/17 – Rev 7A – Revised for Select Limited External Distribution

SHEET NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14						
REVISION	**-**	**-**	**3**	**3**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**						

APPROVED: Originator: John Williams	DATE: 20-Apr-16
APPROVED: Electrical:	DATE:
APPROVED: Project Mgr.: John Williams	DATE: 20-Apr-16

Revision 7A Note:

Two independent network platform providers were used to provide communication interfaces to the nodes.

Table of Contents

1 Purpose

Define all test equipment, procedures, and documentation specifications for the photocell node meter farm testing to be performed by Tesco for National Grid - RI.

2 Definitions, Acronyms and Abbreviations

Abbreviation	Definition
A	Amperes
AC	Alternating Current
ANSI	American National Standards Institute
DPT	Digital Power Technologies (Power supply mfg.)
MTB	Meter Test Board
PF	Power Factor
THD	Total Harmonic Distortion
V	Volt
VT	Voltage Transformer
Wh	Watt-hour
NIC	Network Interface Card

3 Test Equipment Specifications

3.1 Meter Farm Panels

Four meter farm panels will be built by Tesco for the purpose of testing end-to-end communications and meter node functionality. Operational and performance specifications of these panels are further described in the latest version of a TESCO Engineering document titled "Equipment Specification for National Grid Photo Cell Meter Test Equipment." Panel configuration drawings are provided in the latest version of a TESCO Engineering document titled "National Grid Panel." A Configuration drawing for a watertight enclosure for electrical connections to luminaires is provided in the latest version of a TESCO Engineering document titled "Wire Trough Assembly, Bottom Row."

3.1.1 18 sockets will be mounted on each of the four panels for a total of 72 socket positions.

3.1.2 Each socket will have 120VAC wired to it with an enclosed main disconnect switch that can be used to remove power to the panel.

3.1.3 Each panel will be separated into 3 rows of six sockets each.

3.1.4 The top row of sockets will have a resistive load wired to each socket which will result in a constant (approximately 1.0AAC) load on each node.

3.1.5 The middle row of sockets will have a custom designed light module wired to the node which will be used to test photocell relay on/off control and the dimmer control output (0-10VDC).

3.1.6 The bottom row of sockets will have a terminal block connection that can be used to connect various loads to the nodes, including actual luminaires, capacitive loads, or resistive loads. The dimming control output will also be wired out to the terminals.

3.2 External Components

3.2.1 Network Service Provider #2's Gateway – communication adapter between vendor's nodes and the Network Service Provider #2's host computer system.

3.2.2 Network Service Provider #1's DCU - communication adapter between vendor's nodes and the Network Service Provider #1's host computer system.

4 Test Specifications

4.1 General Notes

4.1.1 Nodes will be installed in the meter farm panels by vendor (TESCO), 18 at a time. For instance, board 1 Vendor D's nodes, 18 nodes; board 2 Vendor B's nodes, 18 nodes, board 3 Vendor C's nodes; board 4 Vendor A's nodes.

4.1.2 Each row of nodes will have a unique load connected to it so that the communications testing can exercise as many functions as possible

4.1.2.1 Row 1 – Resistive Load – Will be able to query the nodes at fixed intervals and check that the interval consumption is relatively equal.

4.1.2.2 Row 2 – Simulated Light module – Will be able to confirm manual on/off control as well as dimming responses.

4.1.2.3 Row 3 – Adaptable Load – Can be used to attach actual luminaires, capacitive, and inductive loads to check power factor response.

4.1.3 The main goal of the meter farm testing is to test the end-to-end communication from the nodes to the host computer systems through the Network Service Provider's networked systems. Another goal will be to provide data from this "simulated field environment" to facilitate an I.S. Interface Assessment by National Grid's analysts.

4.1.4 A total of 72 nodes; 18 of each Node/NIC configuration, will be tested during this phase.

4.1.5 Each node will be loaded into a socket on the meter farm panel.

4.1.6 Each node MAC address (Network Service Provider #2) or SLC ID (Network Service Provider #1) will be noted. The node's MAC address or SLC ID and row designation will be communicated to all parties participating in the testing, and will be included in the test documentation.

4.1.7 The panels will be powered up which, in turn, will power the connected loads.

4.1.8 Once powered, the communication testing will commence.

4.2 Testing method (Network Service Provider #1 & Nodes with Network Service Provider #1's NICs)

4.2.1 Setup

4.2.1.1 Must set gateway to read rate of one hour

4.2.1.2 Confirm that each node that is energized can be reached through the gateway

4.2.1.3 The command that will be used in this investigation is "Controls | SLC Actions | Read Data" from the Network Service Provider #1's menu to retrieve information, and various commands from the Network Services Provider #1s "SLC Actions" menu.

4.2.1.4 The read and write tests do not have to be done in series. Rather, the following describes the checks that will be performed, in no explicit order. Many of these checks can be done in combination and will be determined at the start of testing.

4.2.1.5 As the read and write tests are being done, there are a number of communications integrity checks that can be done. They are listed below as well.

4.2.2 Read Tests (Network Service Provider #1)

Note that all of the values read by the network system will be independently confirmed at the meter farm panels by Tesco technicians. Tesco will maintain a confirmation log.

4.2.2.1 Read Time – gives the current read time

4.2.2.2 Volts – gives the present voltage reading

4.2.2.3 Current

4.2.2.3.1 Confirm that on multiple reads from each node in row 1 (constant load), the Current remains relatively constant.

4.2.2.3.2 Confirm that on multiple reads from each node in row 3 (actual luminaire load), the Current changes.

The value of the current read by the node can be changed by changing the dimming value. See Write Tests.

4.2.2.4 kW (Power)

4.2.2.4.1 Confirm that on multiple reads from each node in row 1 (constant load), the power remains relatively constant.

4.2.2.4.2 Confirm that on multiple reads from each node in row 3 (actual luminaire load), the power changes. The value of the power read by the node can be changed by changing the dimming value (see Write Tests).

4.2.2.5 Cum_kWh (Energy)

Confirm that on multiple reads from each node in all of the rows, the energy increases at a rate determined by the power being delivered to the node.

4.2.2.6 Dimming Value

Confirm that on multiple reads from each node in all of the rows, the Dimming value follows the last value written to the node (see Write Tests).

4.2.3 Write Tests (Network Service Provider #1)

Note that all of the values written by the network system will be independently confirmed at the meter farm panels by Tesco technicians if these values represent physical changes. Tesco will maintain a confirmation log.

The attributes that can be written to are as follows.

4.2.3.1 Controls->SLC Action-> SLC On/Off

This attribute can take on the values 0 (off) or 1 (on)

4.2.3.2 Controls->Get/Set System Parameters->Set Dimming parameters value

This attribute can take on values from 0 (off) to 100 (maximum brightness).

4.2.4 Communication Integrity Tests

4.2.4.1 Dead Meter – No usage

This will require that the Tesco Meter Farm Technician either remove the node in question from the board, or simply power it off.

4.2.4.2 Zero Usage – Valid – no usage

This will require that the Tesco Meter Farm Technician ensure that there is no load applied to the node(s) under test between consecutive readings.

4.2.4.3 50% – Actual Data

This will require the Tesco Meter Farm Technician to take the node(s) offline for 50% of the readings (i.e. 1 hour out of a 2 hour period)

4.2.4.4 80% – Actual Data

This will require the Tesco Meter Farm Technician to take the node(s) offline for 20% of the readings (i.e. 1 hour out of a 5 hour period)

4.2.4.5 90% – Actual Data

This will require the Tesco Meter Farm Technician to take the node(s) offline for 10% of the readings (i.e. 1 hour out of a 10 hour period)

4.2.4.6 Simulated Gateway loss and recovery

The Tesco Meter Farm Technician will remove power from the gateway (Network Service Provider #1's Wireless DCU), then reapply power to it.

4.2.4.7 Read Rate Per Meter

Determine if "Read Rate per Meter" information is provided for the time period sent.

4.2.4.8 Total Meter Average Read Rate

Determine if "Total Meter Average Read Rate" information is provided for the time period sent.

4.3 Testing method (Network Service Provider #2 & Nodes with Network Service Provider #2's NICs)

4.3.1 Setup

4.3.1.1 Must set gateway to read rate of one hour

4.3.1.2 Confirm that each node that is energized can be reached through the gateway

4.3.1.3 The read and write tests do not have to be done in series. Rather, the following describes the checks that will be performed, in no explicit order. Many of these checks can be done in combination and will be determined at the start of testing.

4.3.1.4 As the read and write tests are being done, there are a number of communications integrity checks that can be done. They are listed below as well.

4.3.1.5 The read test will be managed by Network Service Provider #2 through regular updates from their system. The data will be collected by Network Service Provider #2 in an XML file and transmitted by e-mail to Tesco.

4.3.1.6 The write tests will be done directly through Network Service Provider #2's web interface per node or node group.

4.3.2 Read Tests (Network Service Provider #2)

Note that all of the values read by the network system will be independently confirmed at the meter farm panels by Tesco technicians. Tesco will maintain a confirmation log.

The attributes that can be read back from the nodes vary from vendor to vendor and fall into three categories.

4.3.2.1 Read Only – These attributes will not be changed using the available hardware. These points will be read on consecutive reads and confirmed to be accurate, based on the conditions. They include the following Attributes: Voltage and Frequency.

4.3.2.2 Controllable Feedback – These attributes can be manipulated by the hardware and consecutive readings can be made to change by a known amount, thus making it possible to check the accuracy of the data being returned in consecutive reads. These attributes are as follows:

4.3.2.2.1 Current (mA)

4.3.2.2.1.1 Confirm that on multiple reads from each node in row 1 (constant load), the Current remains relatively constant.

4.3.2.2.1.2 Confirm that on multiple reads from each node in row 2 (simulated dimmer load), the Current changes. The value of the current read by the node can be changed by changing the dimming value (see Write Tests).

4.3.2.2.2 Attribute 3 – Power (kW)

4.3.2.2.2.1 Confirm that on multiple reads from each node in row 1 (constant load), the power remains relatively constant.

4.3.2.2.2.2 Confirm that on multiple reads from each node in row 2 (simulated dimmer load), the power changes. The value of the power read by the node can be changed by changing the dimming value (see Write Tests).

4.3.2.2.3 Attribute 4 – Power Factor (100xpfs)

4.3.2.2.3.1 Confirm that on multiple reads from each node in rows 1 (constant load) and 2 (simulated dimmer load), the power remains relatively constant.

4.3.2.2.3.2 Confirm that on multiple reads from each node in row 3 (configurable load), the power factor changes. The value of the power factor read by the node can be changed by varying the type of load connected.

4.3.2.2.4 Attribute 6 – Energy (kWh)

Confirm that on multiple reads from each node in all of the rows, the energy increases at a rate determined by the power being delivered to the node.

4.3.2.2.5 Brightness Value (Lux)

Confirm that on multiple reads from each node in all of the rows, the Brightness value follows the last value written to the node (see Write Tests).

4.3.3 Write Tests (Network Service Provider #2)

Note that all of the values written by the network system will be independently confirmed at the meter farm panels by Tesco technicians if these values represent physical changes. Tesco will maintain a confirmation log.

The attributes that can be written to are as follows.

4.3.3.1 Brightness value

This attribute can take on values from 0 (off) to 100 (maximum brightness).

4.3.4 Communication Integrity Tests

4.3.4.1 Dead Meter – No usage

This will require that the Tesco Meter Farm Technician either remove the node in question from the board, or simply power it off.

4.3.4.2 Zero Usage – Valid – no usage

This will require that the Tesco Meter Farm Technician ensure that there is no load applied to the node(s) under test between consecutive readings.

4.3.4.3 50% – Actual Data

This will require the Tesco Meter Farm Technician to take the node(s) offline for 50% of the readings (i.e. 1 hour out of a 2 hour period)

4.3.4.4 80% – Actual Data

This will require the Tesco Meter Farm Technician to take the node(s) offline for 20% of the readings (i.e. 1 hour out of a 5 hour period)

4.3.4.5 90% – Actual Data

This will require the Tesco Meter Farm Technician to take the node(s) offline for 10% of the readings (i.e. 1 hour out of a 10 hour period)

4.3.4.6 Simulated Gateway loss and recovery

The Tesco Meter Farm Technician will remove power from the gateway (Network Service Provider #2's Access Point), then reapply power to it.

4.3.4.7 Read Rate Per Meter

Determine if "Read Rate per Meter" information is provided for the time period sent.

4.3.4.8 Total Meter Average Read Rate

Determine if “Total Meter Average Read Rate” information is provided for the time period sent.

4.4 Variable Schedule Analysis (Both networks)

This testing will be common to both communications types, as the method by which the Wh readings are gathered is irrelevant to the test results.

4.4.1 The nodes to be tested will be in the bottom row of their respective meter farm panels.

4.4.2 Each of the nodes under test will have luminaire connected to it.

4.4.3 The loads will be programmed to cycle on and off at given points in the day and will be allowed to run for a number of days. See Schedules listed in the next section.

4.4.4 This process will be repeated in such a way as to test each of the schedules selected on each of the luminaires available to each node panel. See NGRID Meter Farm Testing Data.xlsx, tab “Schedule Rotations”.

4.4.5 After all of the schedules are run, the data will be analyzed to determine whether all of the schedules were followed, and that all of the data for W and Wh was received properly. Any anomalies in the data will be reported.

4.5 Schedules to be used in the Comparative Billing Analysis testing

4.5.1 There will be four schedules run on each meter farm panel.

4.5.2 Each schedule will be run on each luminaire/node combination on that panel.

4.5.3 Run the nodes for at least one full week on a schedule.

4.5.4 The four schedules represent two dimming and two part night schedules. They are listed on NGRID Meter Farm Testing Data.xlsx, tab “Luminaire Schedules”

4.6 Characterizations of Luminaires and Nodes

4.6.1 A number of luminaires and node will be tested such that the dimming values will be adjusted in 10% increments from 10% to 100% and the wattage from each node will be read back to characterize the energy consumed at each dimming value.

4.6.2 A separate test will be performed using a single luminaire and nodes from 3 different vendors in order to characterize just the node response.

5 Documentation

5.1 The results of each of the aforementioned tests will be documented in a fashion that will first sort the information based on the test performed.

5.2 Each test result will be further sorted by node manufacturer and network service provider.

5.3 Each test result will be listed and if multiple tests were performed based on the same criteria, due to a test procedural fault, or due to a repair required to the testing equipment; those tests will be listed together, with a notation as to the reasons why the additional test was required.

5.4 Each test result will (at a minimum) list the following information:

5.4.1 Test name and description

5.4.2 Test conditions

5.4.3 Manufacturer name

5.4.4 Node serial number or other identifying information.

5.4.5 Expected test result or acceptable result.

5.4.6 Actual result

5.4.7 Notes – this will be a section that will be used in the case where the tester observes a notable condition that existed prior to, during, or after the test was performed.

5.5 Each section will be followed by an additional notes section that will be used to summarize the findings and will be kept to observable facts.

5.6 Finally, the report will contain a summary of all testing performed, observed information not included in the otherwise presented data, and a clearly indicated section for opinions and recommendations.

6 Revision Record

Revision Record

REV	REVISION DESCRIPTION:	APPR:	REL:
-	Draft	JFW	4/20/16
1	Revised per customer comments	JFW	5/3/16
2	Revised per customer comments	JFW	5/9/16
3	Corrected formatting	JFW	5/10/16
4	Added section 4.4 for comparative billing analysis	JFW	6/28/16
5	Deleted sections 4.3.1.3, 4.3.2.1, 4.3.2.3.7, 4.3.2.3.9-4.3.2.3.11, 4.3.3.3-4.3.3.5. Added sections 4.3.1.6 and 4.3.1.7	JFW	10/12/16
6	Revised section 4.1.4 to reduce total number of nodes to be tested based on time allottedRevised sections 4.2.2.4.2 and 4.2.2.5.2 to change row from 2 to 3 Revised section 4.3.2.2 to only show voltage and current as read elements for that test Deleted sections 4.2.2.2, 4.2.2.7, 4.3.2.3.5, 4.3.2.3.6, 4.3.2.3.7, 4.3.2.3.9, 4.3.2.3.10, 4.3.2.3.11, 4.3.3.1, 4.3.3.4, 4.3.3.5, and 4.4.3 and renumbered remaining sections Revised 4.3.1.6 to show that transmittal method is email Revised sections 4.3.2.3.1 through 4.3.2.3.4 to adjust parameter names to match data collected Revised section 4.4.2 to reflect that real luminaires will be used in the testing Revised section4.4.7 to remove socket meter Added sections 4.4.8, 4.5, and 4.6.2 for additional testing	JFW	6/9/17
7	Changed title to section 4.4 Deleted 4.4.4, 4.4.5, and 4.4.6, renumbered remaining sections in 4.4., and added section 4.5	JFW	10/18/17
7A	Revised for Selected Limited Distribution	EPB	11/11/17

Attachment 7

ORIGINATING GROUP:	ORIGIN DATE:	REVISION DATE:	NO. OF SHEETS:
TESCO ENGINEERING	**16-02-2016**	**04-03-2016**	**6**

Equipment Specification for National Grid Photo Cell Meter Test Equipment

SHEET NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
REVISION	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**--**	**-**									

APPROVED: Originator: Michael Guilfoyle	DATE: 2/16/16
APPROVED: Engineering Manager: John Williams	DATE: 2/16/16
APPROVED: Project Management: Bill Troutman	DATE: 2/16/16

Table of Contents

1 Purpose

Define the operational and performance specifications for the National Grid Meter Farm panel construction.

2 Definitions, Acronyms and Abbreviations

Abbreviation	Definition
A	Amperes
AC	Alternating Current
CT	Current Transformer
FAT	Factory Acceptance Test
FQTP	Final Qualification Test Plan
kVA	Kilovolt-Ampere
kVAR	Kilovolt-Ampere Reactive
kW	Kilowatt
kWh	Kilowatt-hour
MTB	Meter Test Board
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Agency
OSHA	Occupational Safety and Health Administration
QA	Quality Assurance
RMS	Root Mean Square calculation method
S (S_1)	Sensor
SAT	Site Acceptance Test
UL	Underwriters' Laboratories, Inc.
V	Volt
VA	Volt-Ampere
VAR	Volt-Ampere Reactive
VT	Voltage Transformer
Wh	Watt-hour

3 Scope

3.1 This document will cover all operational specifications for streetlight photocell controller/meter test panel design.

4 Operational Requirements and Panel Specifications

The construction and operation of the meter farm panels will be as follows:

4.1 BASIC PANEL CONFIGURATIONS and OPERATIONS (for all Meter Farm types)

4.1.1 Each panel will be powered separately.

4.1.2 Each panel will include a circuit breaker housed in a NEMA 3R enclosure. This circuit breaker will also serve as a local disconnect for the panel.

4.1.3 Each panel configuration will have all meter sockets and controls mounted to one side. Load resistors are mounted to the back side of panels.

4.1.4 Standard TESCO Meter Farm Panel Assemblies are designed to be mounted to a custom 4 inch steel tubing frame with farm panels on both sides.

4.1.5 The meter farm panels will be 4 foot high by 8 foot wide. The panels will be made of 5052 aluminum with clear anodize.

4.1.6 The panels will include two one-inch holes to be used for rigging the panel for mounting. Panel weight is estimated at 500 pounds.

4.1.7 The panels have ¼" clearance holes for mounting, with self-tapping screws, to horizontal structural steel strut channels. The strut is fastened to the custom frames.

4.1.8 Panels with components mounted on the back must be mounted on a frame with an adjoining panel without back side mounted components.

4.1.9 Panels with components mounted on the back include a top cover vent and side panels which will enclose and protect the components. These are mounted during installation of the panel. Covers and side plated are designed for use with Tesco custom mounting frame assemblies.

4.1.10 Panels with components mount on back side must be arranged so adjacent panel on frame does NOT have components mounted on the back side, or a blank panel is required.

5 Panel Details

5.1 TYPE ONE PANEL: NGRID Streetlight Photocell / Meter Test Panel.

5.1.1 Build Quantity: (4) panel assemblies, total socket test positons (72).

5.1.2 Size: 4ft high x 8ft wide x 1ft deep, 350 lbs.

5.1.3 Each panel will contain three test assemblies to perform three types of testing.

5.1.3.1 Load metering.

5.1.3.2 Photo cell control testing.

5.1.3.3 Streetlight luminaire testing.

5.1.4 Each test assembly will comprised of a NEMA 3R enclosure and contain six ANSI C136.41 7-pin photo control receptacles. There will 18 total sockets per panel. Socket will be spaced on 12.0 inch centers.

5.1.5 Test Socket Assembly Configurations:

5.1.5.1 Top row, load metering: the six sockets will be configured with a loading resistor and status indicator light for long term load testing of the meter. The resistive load will be comprised of a single 125 ohm, 250 watt power resistors. Load current is estimated at 0.96 amps. Each socket position will have a resistor load and LED lamp connected to the output line of the photocell

5.1.5.1.1 Loading resistors will be arranged so two panels can be mounted to Tesco custom frames without interference issues.

5.1.5.2 Middle row, photo cell control testing: the six sockets will be configured for testing photocell output control, 0-10V dimming controls, and communications. Each socket will be wired to a downward facing white LED light mounted to the front of the assembly. Each socket position will contain a LED driver with 0-10V dimming capability compatible with IEC 60929:2006 (0-10V ballast controls).

5.1.5.3 Bottom row, luminaire testing: The six sockets will be configured for Streetlight Luminaire testing. Each socket will be wired to the 120VAC supply. The neutral, the photocell output line, and the two 0-10V connections will be wired to binding post connectors on the front panel of the socket assembly for easy connection to test luminaires.

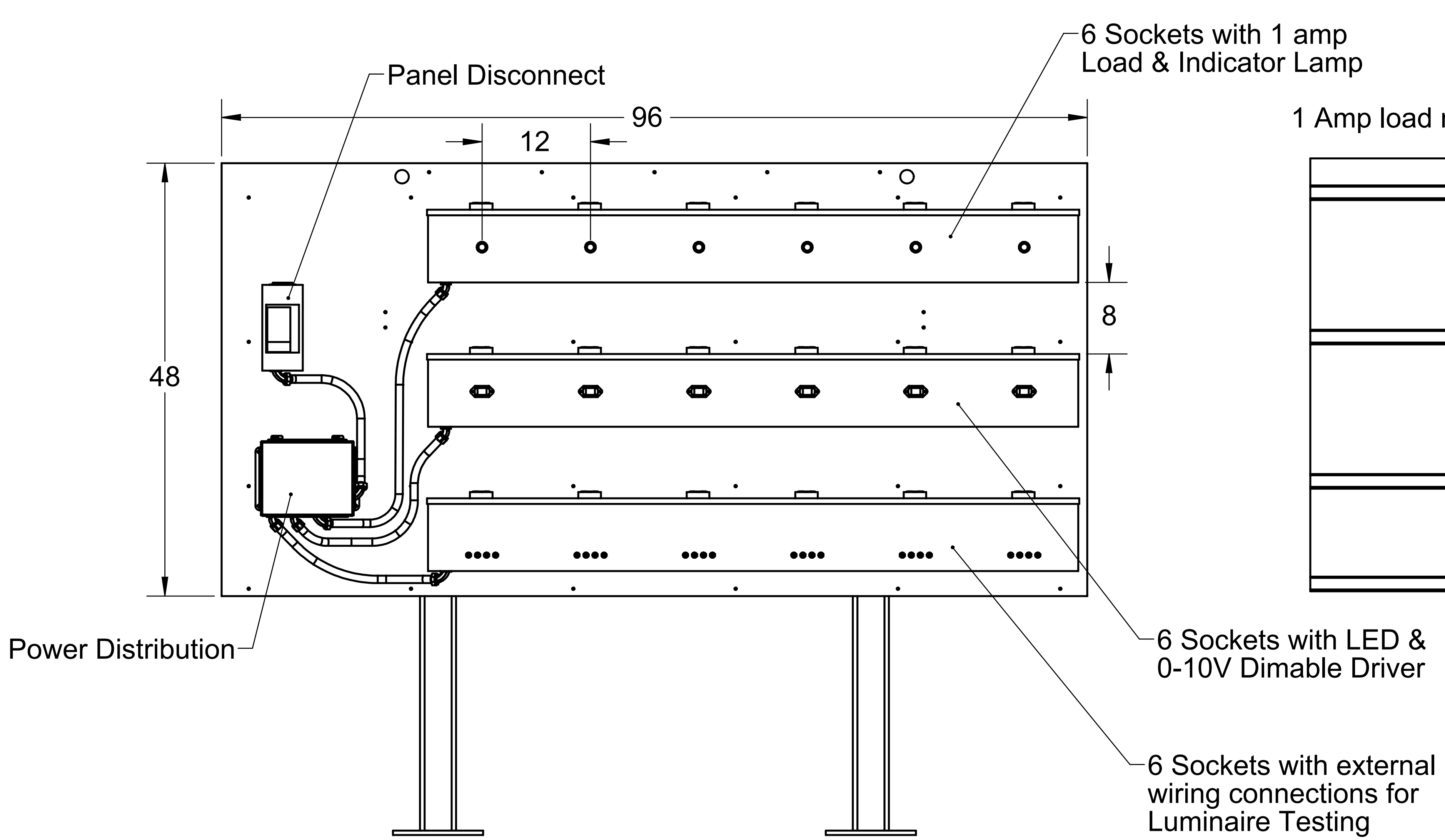
5.1.6 Power Requirements: 120VAC, 15 Amps, single phase

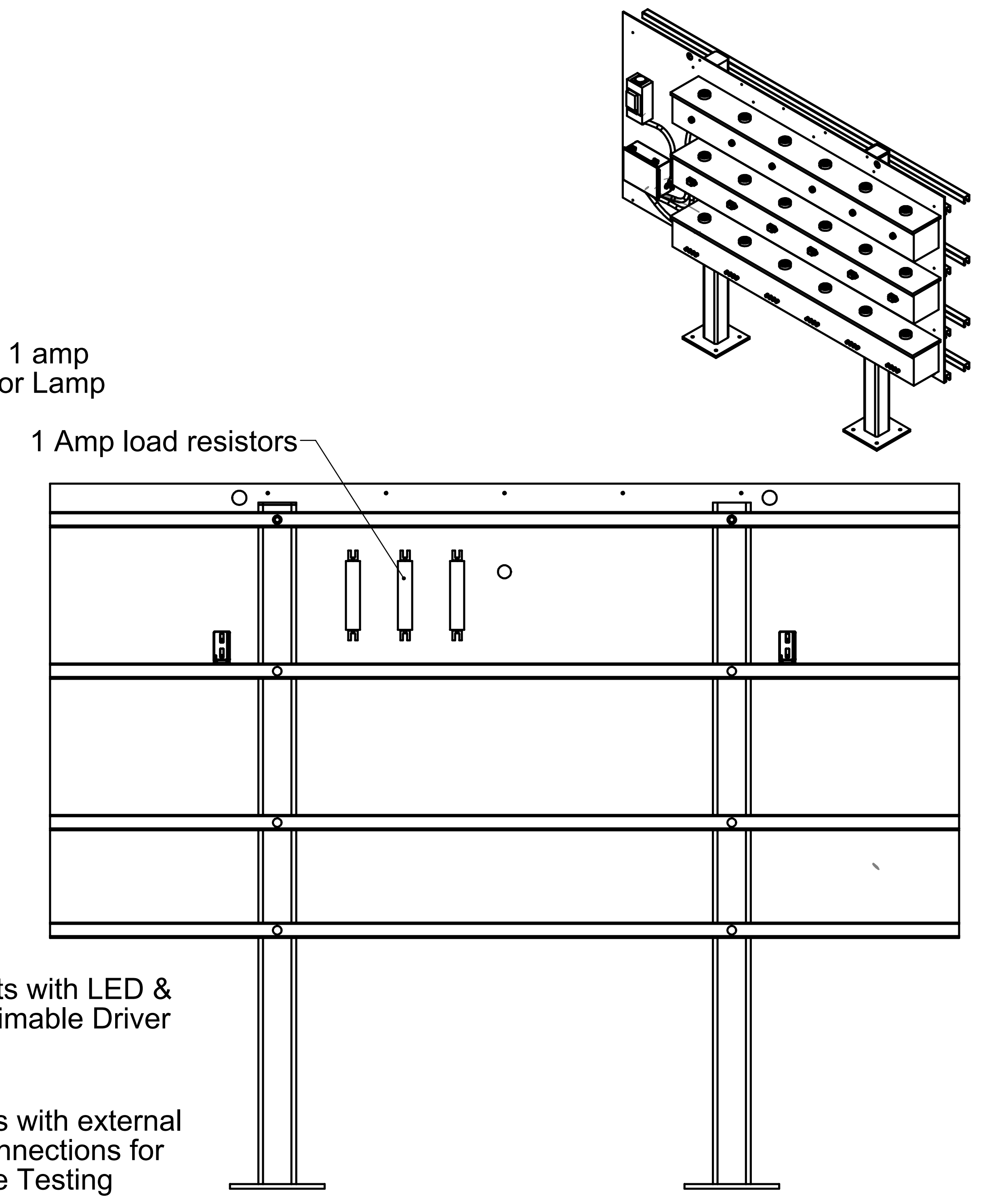
6 REVISION RECORD

REV	ECN:	REVISION DESCRIPTION:	APPR:	REL:
-	N/A	Initial Release	JFW	2/16/16
1	N/A	Modified Title	JFW	3/4/16

Attachment 8

REV	DESCRIPTION	DATE	APPR.
A	National Grid Panel	02/16/2016	





GEOMETRIC TOLERANCE UNLESS OTHERWISE SPECIFIED			
FORM		MACHINED	OTHER
▱ — ⌒ ⌓		.001"/1", TIR	1/16"/FT, TIR
∠ ⌿ // ⊥		.002"/1", TIR	1/8"/FT, TIR
◎	1/2 SUM OF DIAMETRAL TOLS., TIR		
SURFACE FINISH UNLESS SPECIFIED:	250 FOR FRACTIONAL DIM. 125 FOR 0.00 DIM. 63 FOR 0.000 DIM.		

DIMENSION TOLERANCE (UNLESS OTHERWISE SPECIFIED)	
FRACTION	± 1/32
0.00	± 0.015
0.000	± 0.005
0.0000	± 0.0005

CAD GENERATED DRAWING.
DO NOT MANUALLY UPDATE.
THE INFORMATION ON THIS DRAWING
IS CONFIDENTIAL.
UNAUTHORIZED USE IS PROHIBITED.

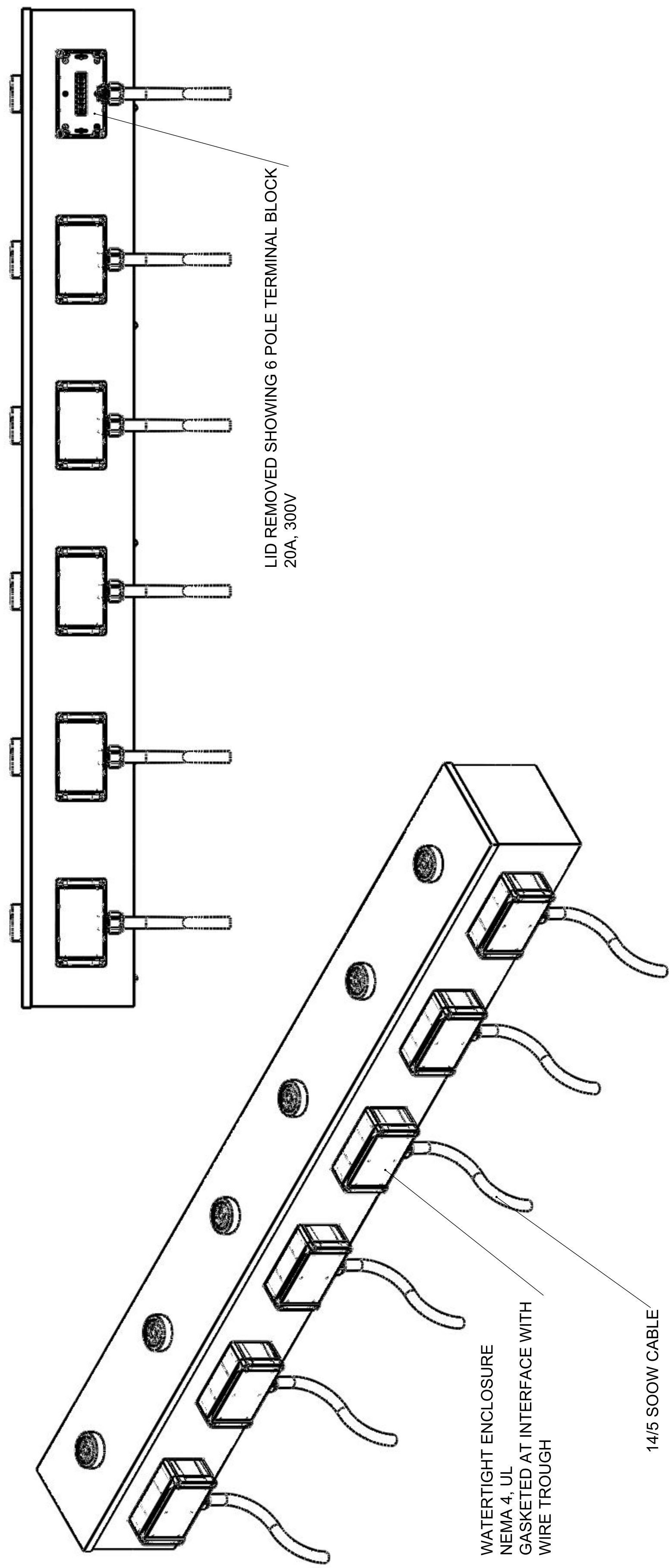
CUSTOMER: 8594	
DRAWN: XS	DATE: 2/16/2016
CHECKED: -	DATE: -
USED ON DWG NO: 8594-1000	

TESCO
an ADVENT DESIGN company
CANAL STREET & JEFFERSON AVE.
BRISTOL, PA 19007
800-762-8211

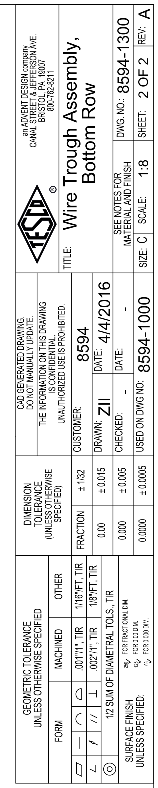
TITLE: National Grid Panel

SEE NOTES FOR MATERIAL AND FINISH		DWG. NO.: 8594-1000	
SIZE: B	SCALE: 1:16	SHEET: 1 OF 1	REV: A

Attachment 9



LID REMOVED SHOWING 6 POLE TERMINAL BLOCK
20A, 300V
WATERTIGHT ENCLOSURE
NEMA 4, UL
GASKETED AT INTERFACE WITH
WIRE TROUGH
14/5 SOOW CABLE



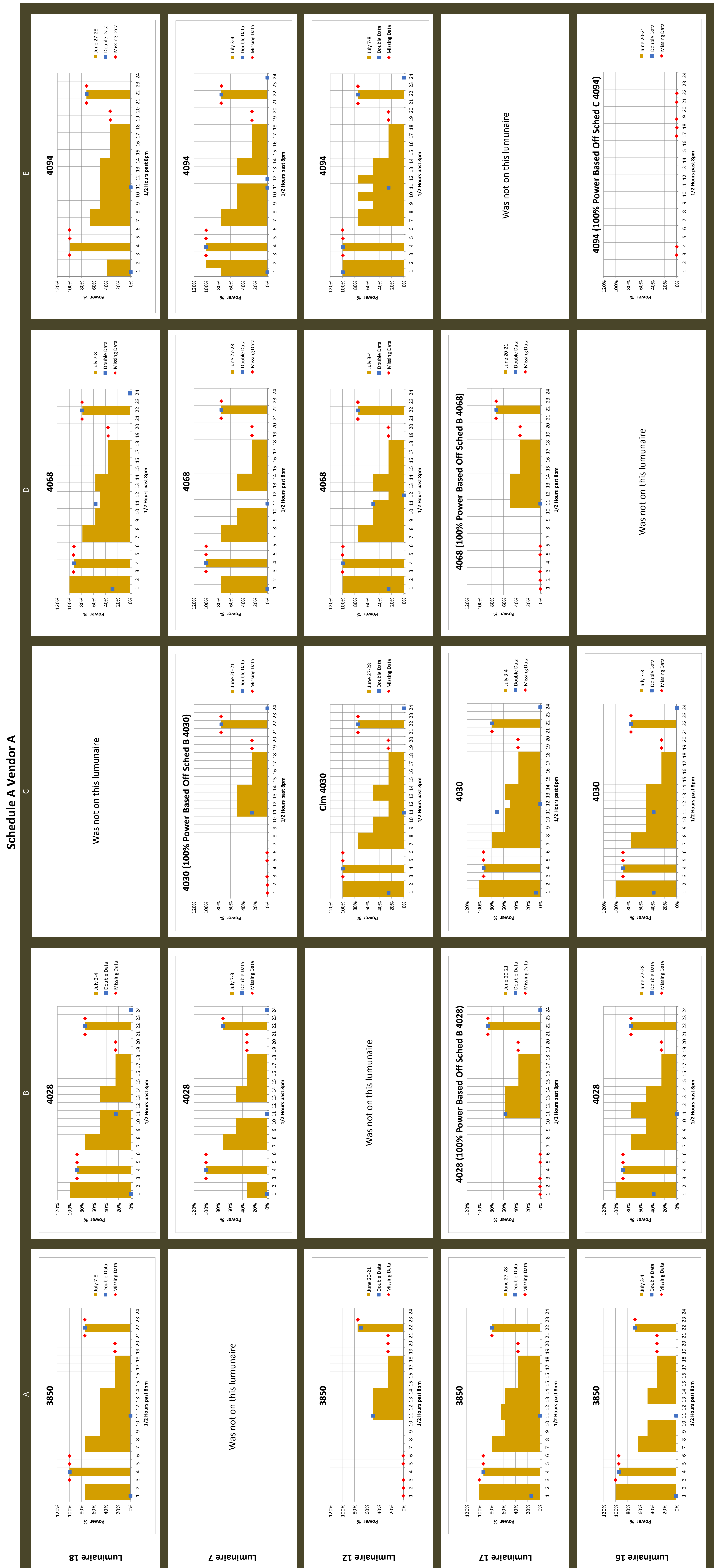
GEOMETRIC TOLERANCE UNLESS OTHERWISE SPECIFIED
FORM
MACHINED
OTHER
.001"/1", TIR
1/16"/FT, TIR
.002"/1", TIR
1/8"/FT, TIR
1/2 SUM OF DIAMETRAL TOLS., TIR
SURFACE FINISH UNLESS SPECIFIED:
DIMENSION TOLERANCE (UNLESS OTHERWISE SPECIFIED)
FRACTION ± 1/32
0.00 ± 0.015
0.000 ± 0.005
0.0000 ± 0.0005
CAD GENERATED DRAWING, DO NOT MANUALLY UPDATE.
THE INFORMATION ON THIS DRAWING IS CONFIDENTIAL. UNAUTHORIZED USE IS PROHIBITED.
CUSTOMER: 8594
DRAWN: ZII
DATE: 4/4/2016
CHECKED: -
DATE: -
USED ON DWG NO: 8594-1000
TESCO
an ADVENT DESIGN company
CANAL STREET & JEFFERSON AVE.
BRISTOL, PA 19007
800-762-8211
TITLE: Wire Trough Assembly, Bottom Row
SEE NOTES FOR MATERIAL AND FINISH
DWG. NO.: 8594-1300
REV: A
SIZE: C
SCALE: 1:8
SHEET: 2 OF 2

Attachment 10

Meter Farm Testing Data Final Report

Due to the large spreadsheet files contained within Attachment 10, please see the Excel version on CD-ROM

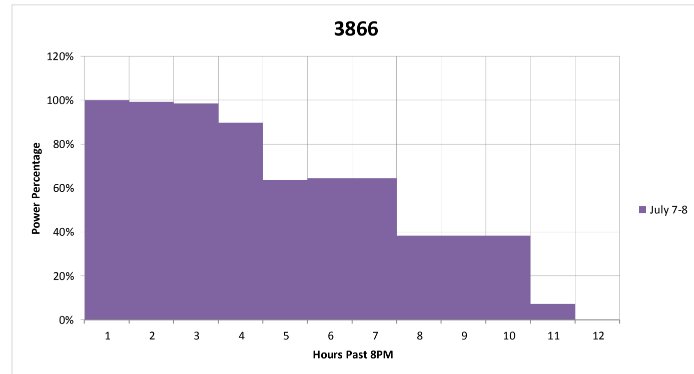
Attachment 11

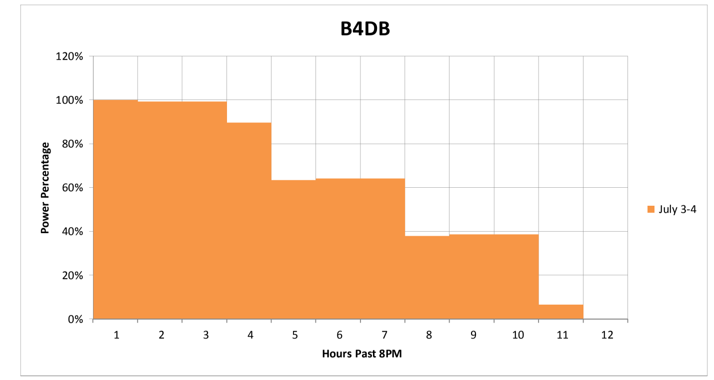

Schedule A Vendor A
A
B
C
D
E
Luminaire 18
Luminaire 7
Luminaire 12
Luminaire 17
Luminaire 16
3850
4028
4030
Cim 4030
4068
4094
4030 (100% Power Based Off Sched B 4030)
4028 (100% Power Based Off Sched B 4028)
4068 (100% Power Based Off Sched B 4068)
4094 (100% Power Based Off Sched C 4094)
Was not on this lumunaire
Power %
1/2 Hours past 8pm
June 20-21
June 27-28
July 3-4
July 7-8
Double Data
Missing Data

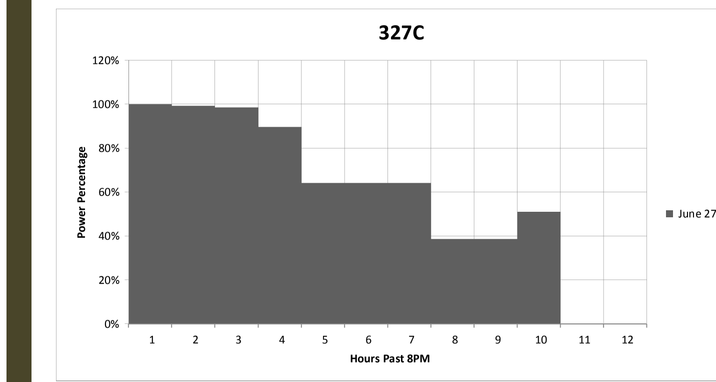
Schedule A Vendor B

Luminaire 5

Data Not Available

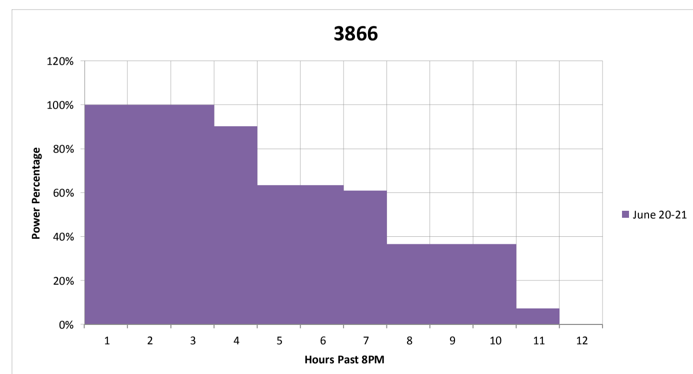


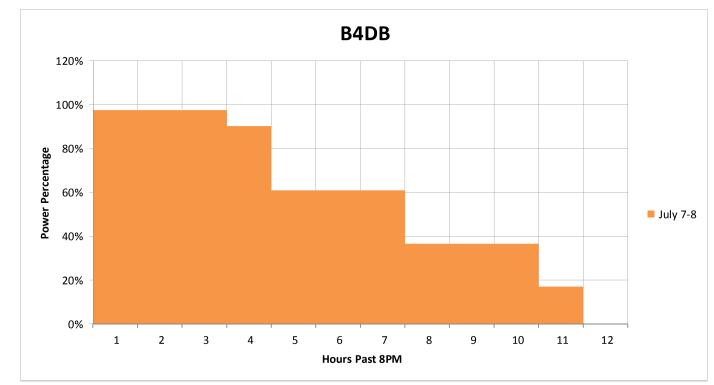


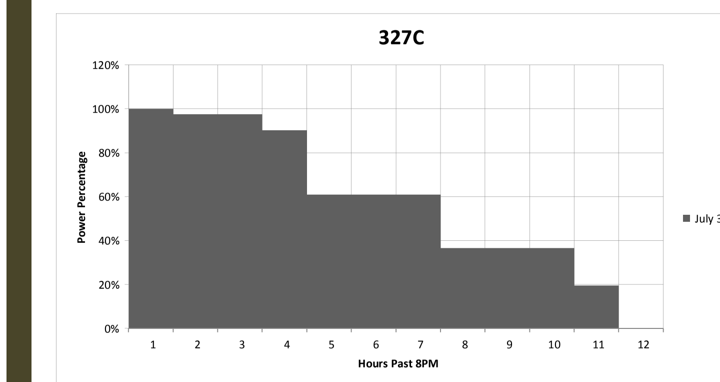


Luminaire 1

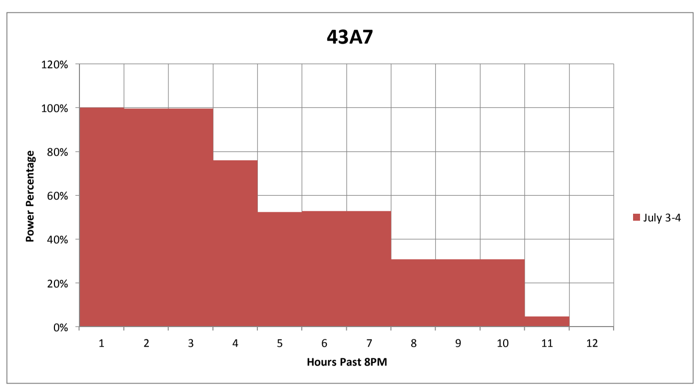
Data Not Available

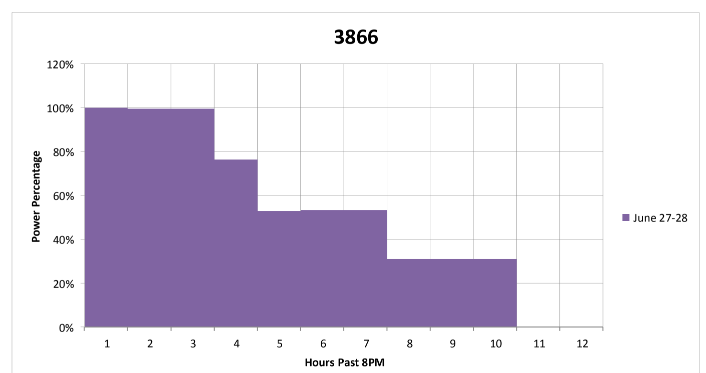


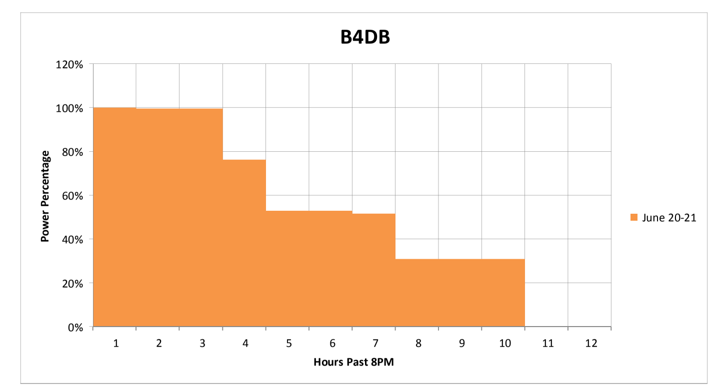


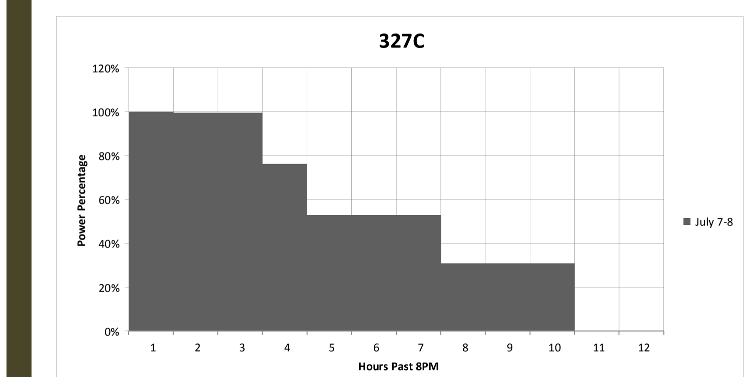


Luminaire 14

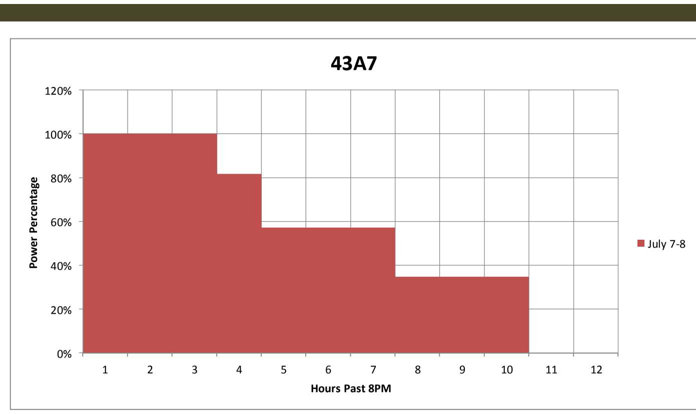


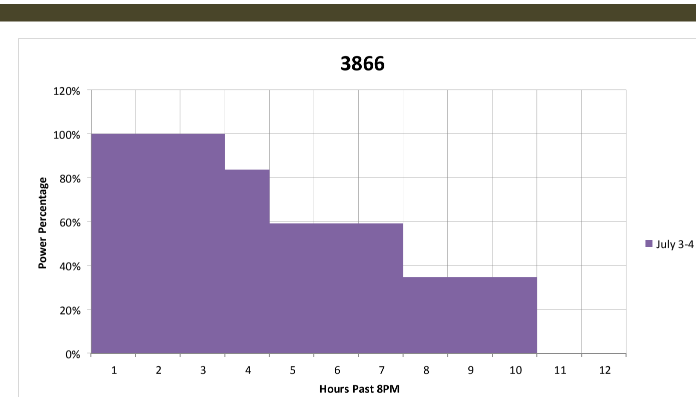


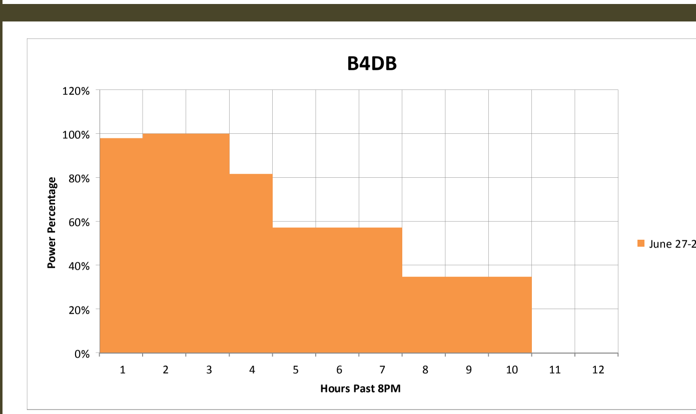


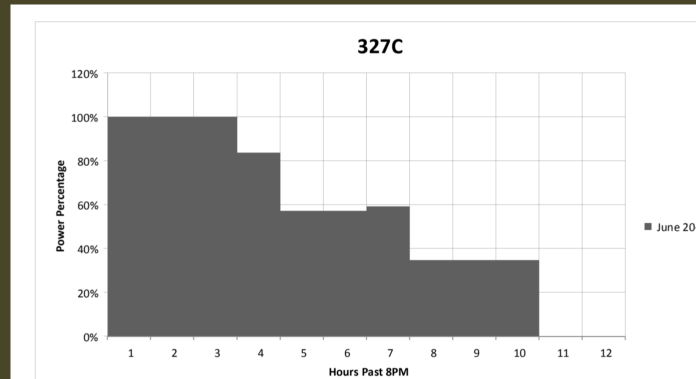


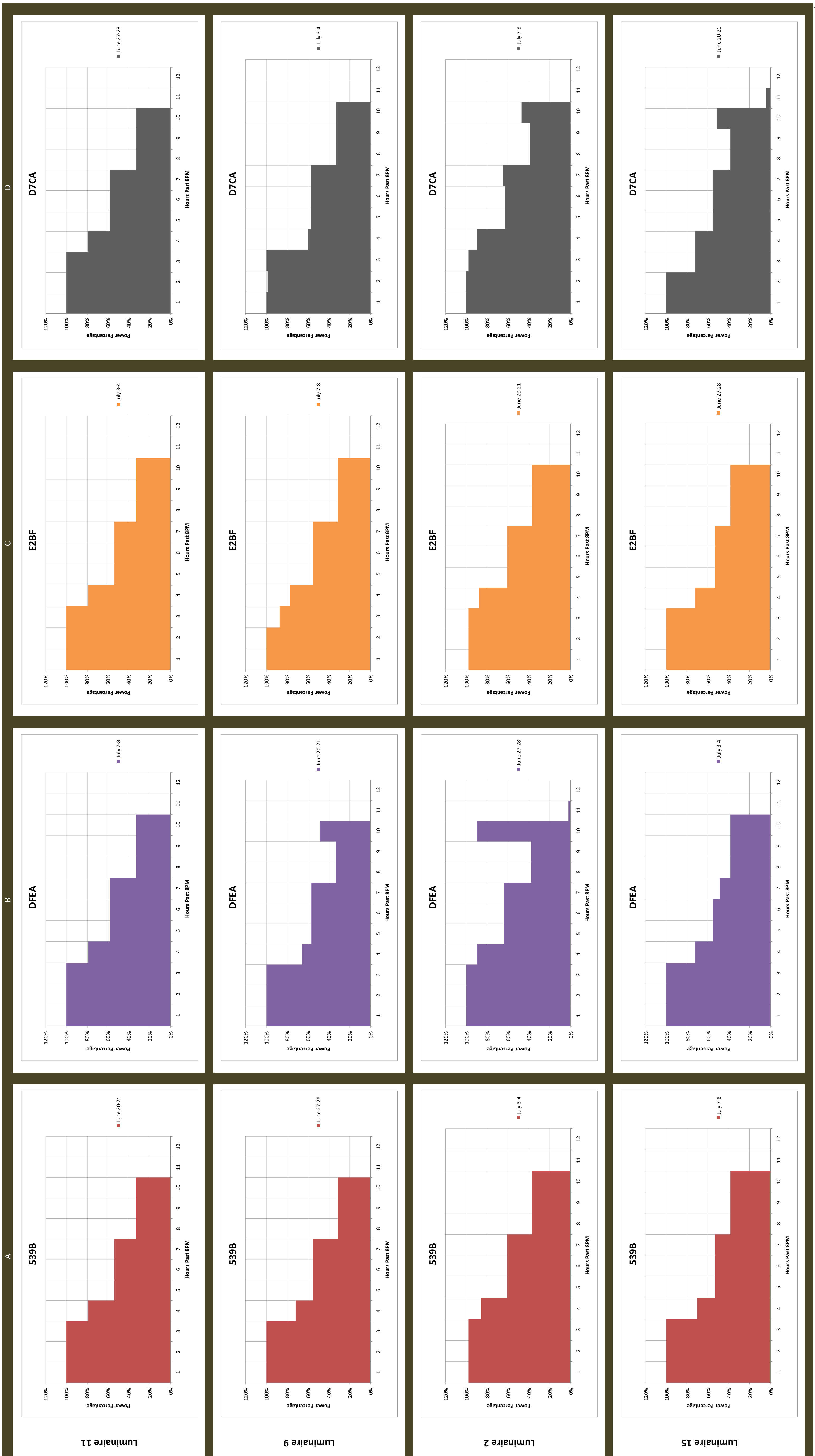
Luminaire 8







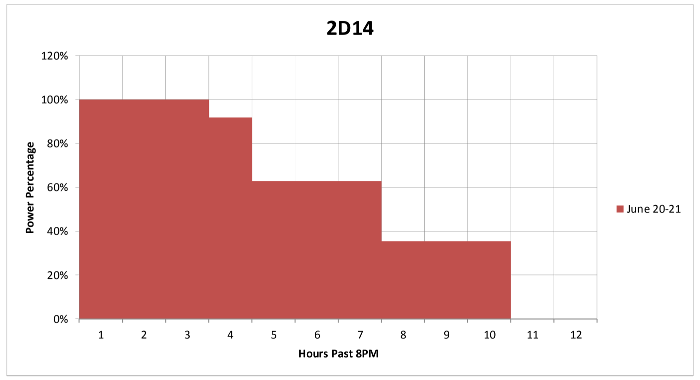


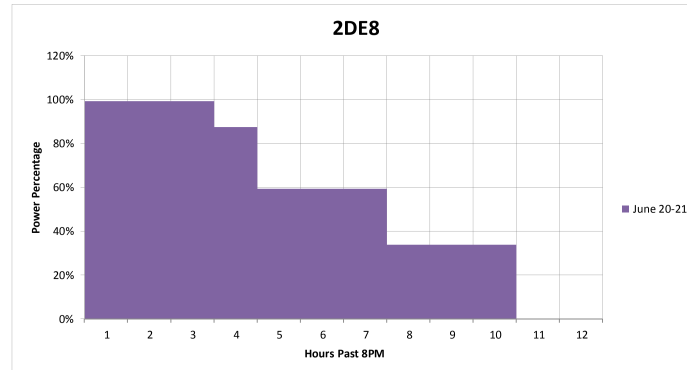

Schedule A Vendor C
A
B
C
D
1
2
3
4
Luminaire 11
Luminaire 9
Luminaire 2
Luminaire 15
539B
DFEA
E2BF
D7CA
Power Percentage
Hours Past 8PM
June 20-21
June 27-28
July 3-4
July 7-8

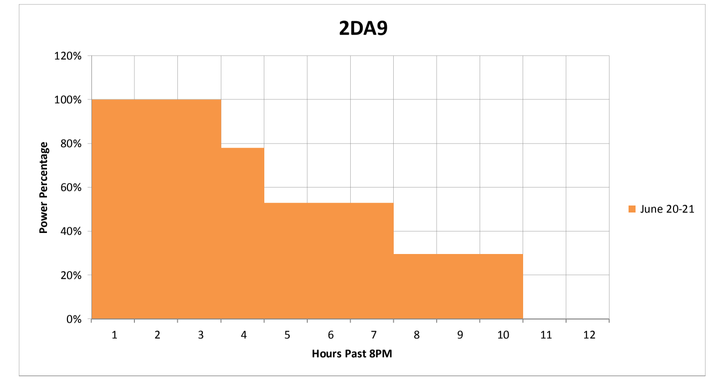
Schedule A Vendor D

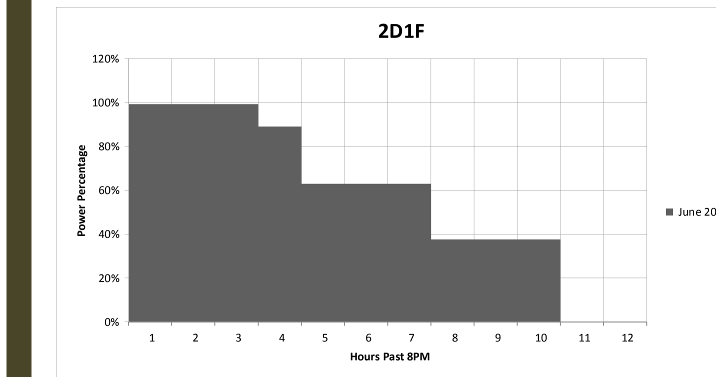
A | B | C | D

1 Luminaire 3

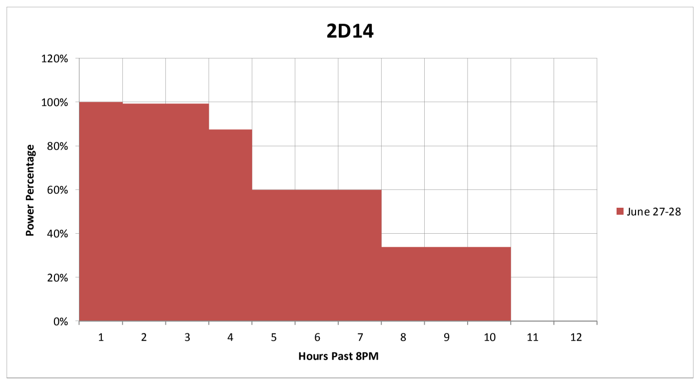


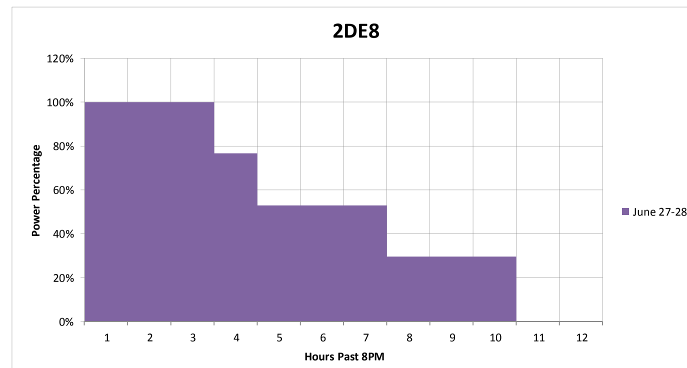


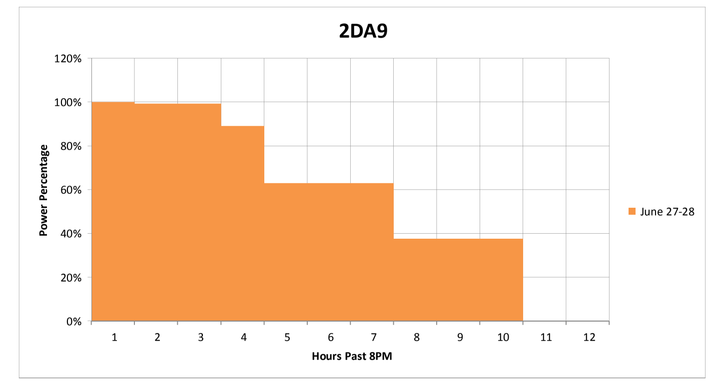


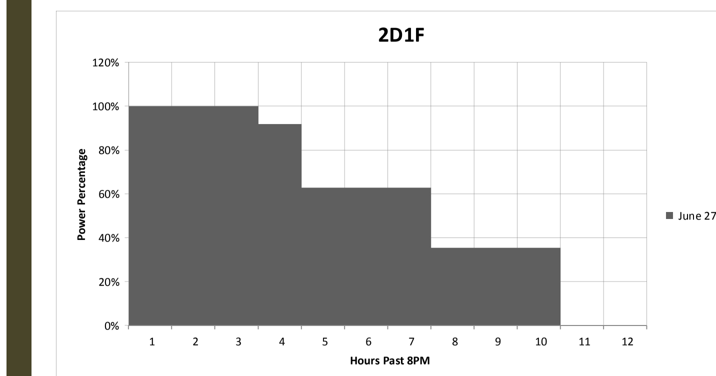


2 Luminaire 10

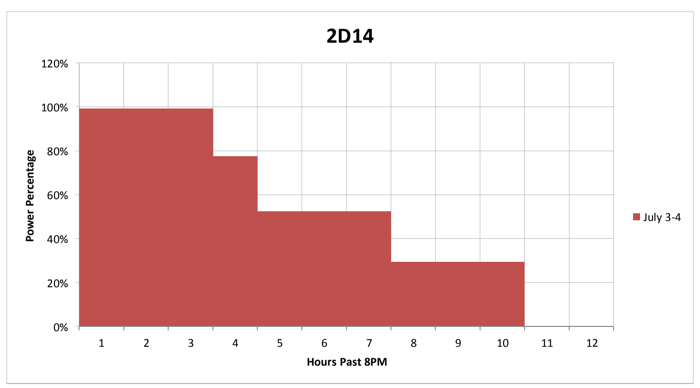


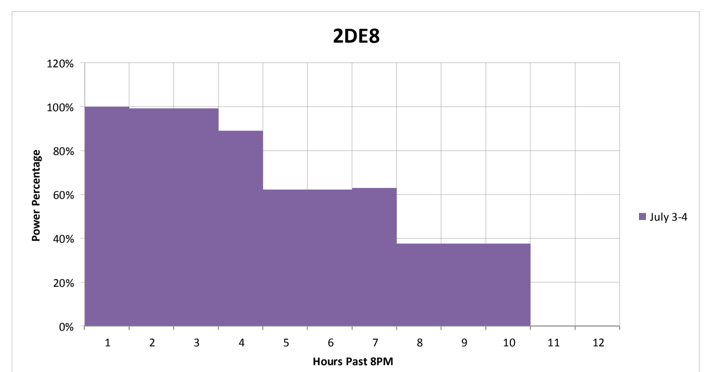


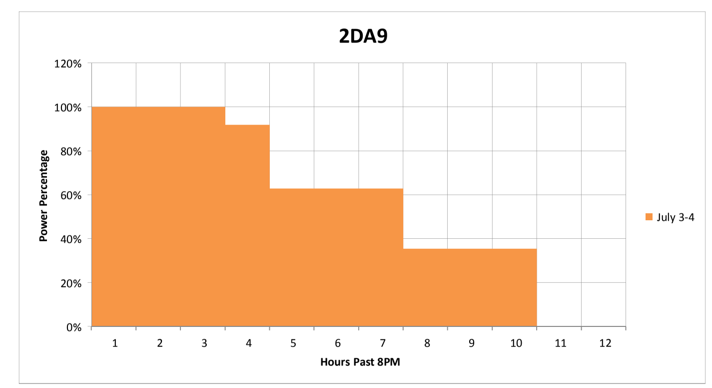


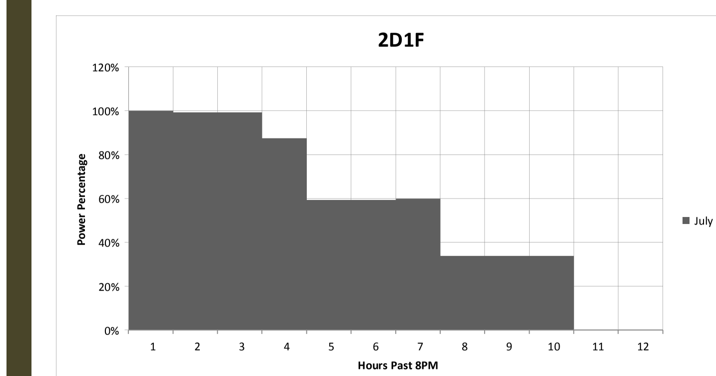


3 Luminaire 13

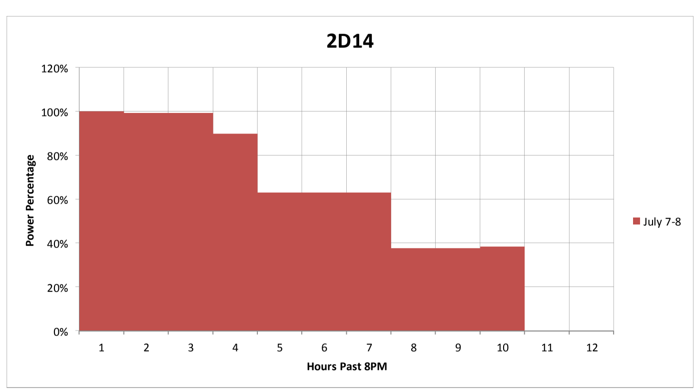


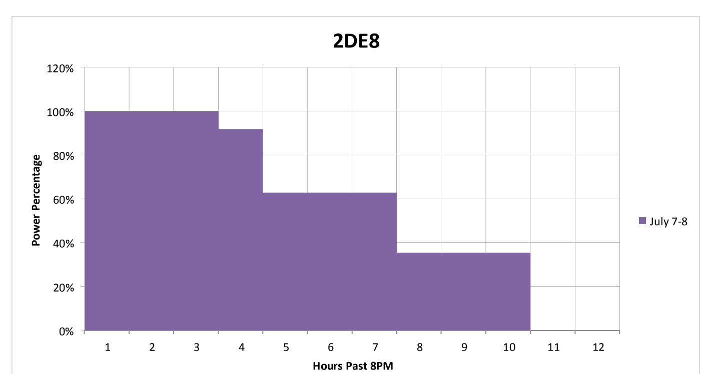


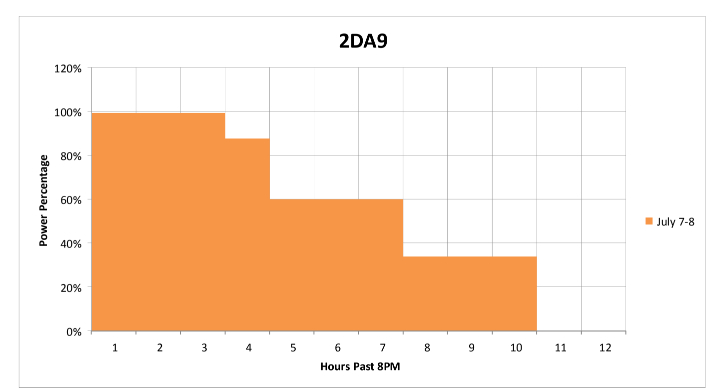


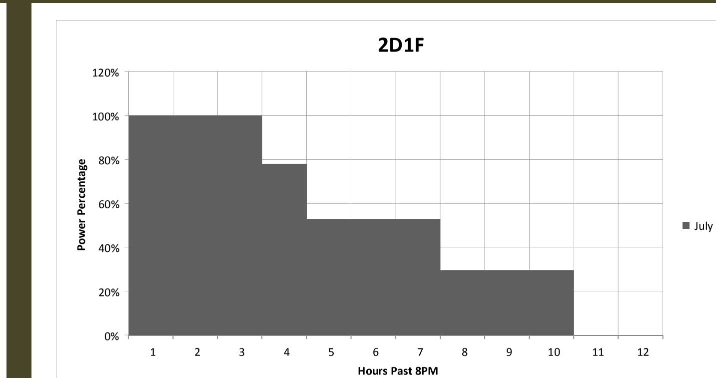


4 Luminaire 4

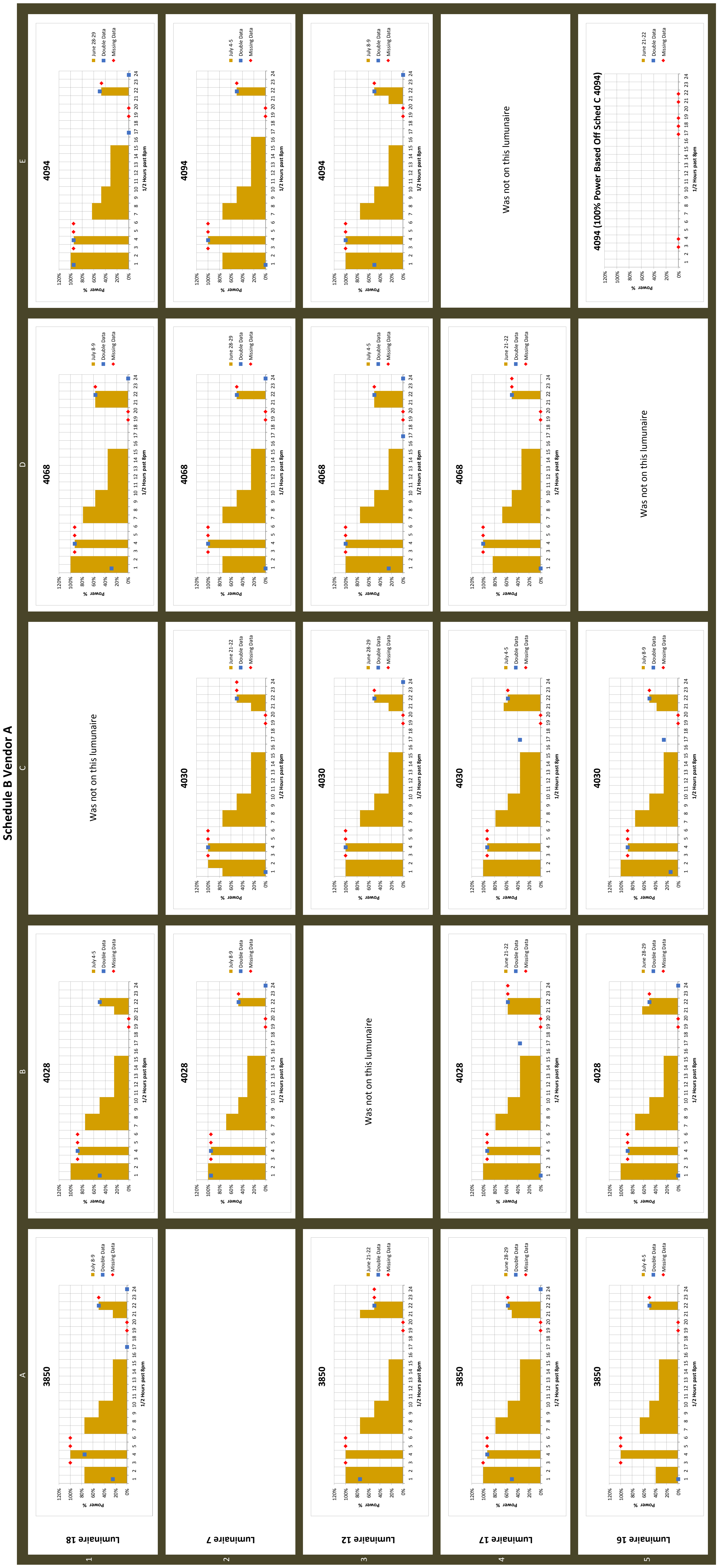








Schedule B Vendor A



Schedule B Vendor B

A | B | C | D

1 Luminaire 5

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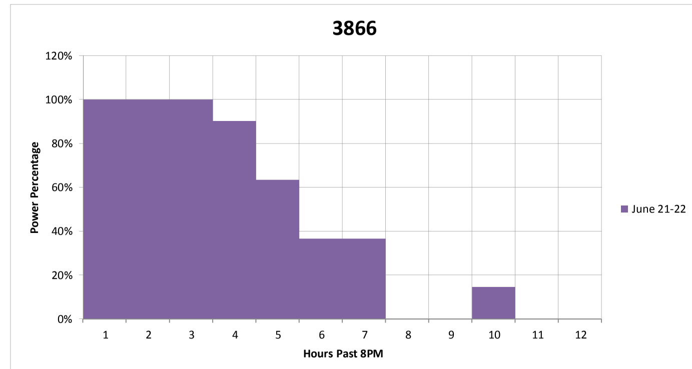

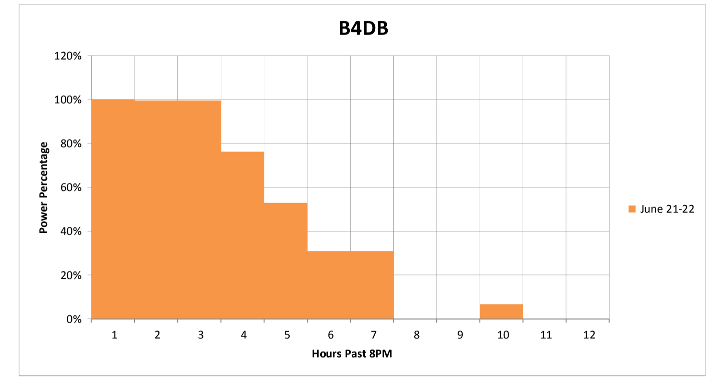

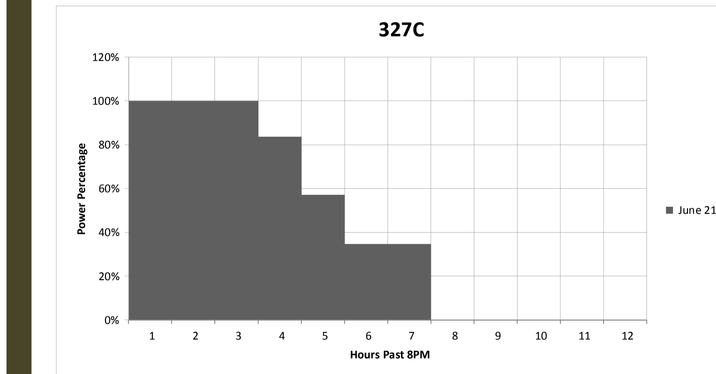

2 Luminaire 1

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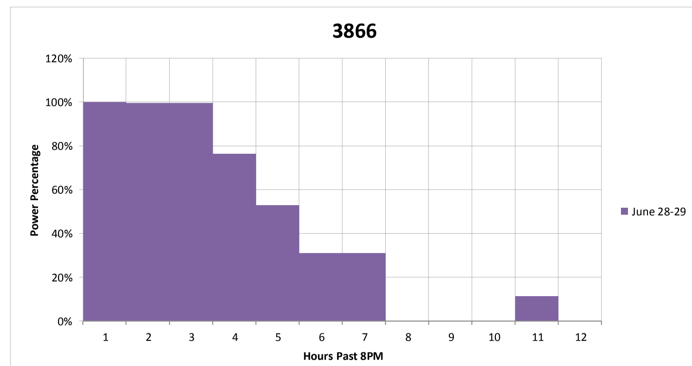
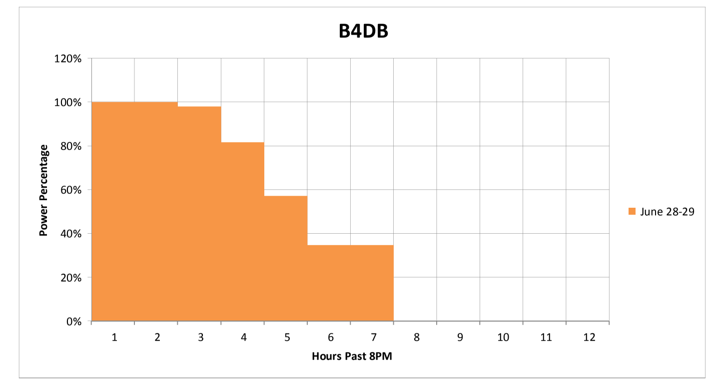
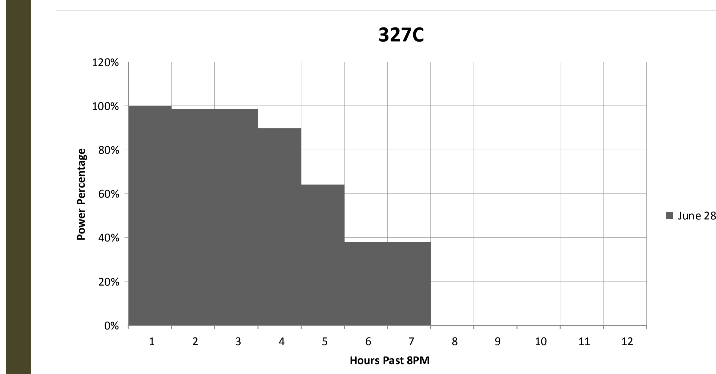
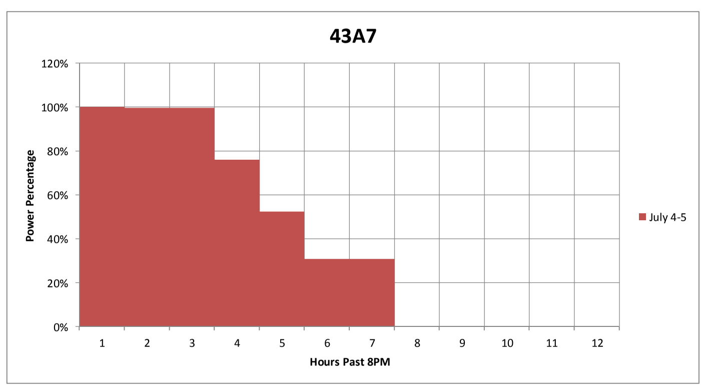
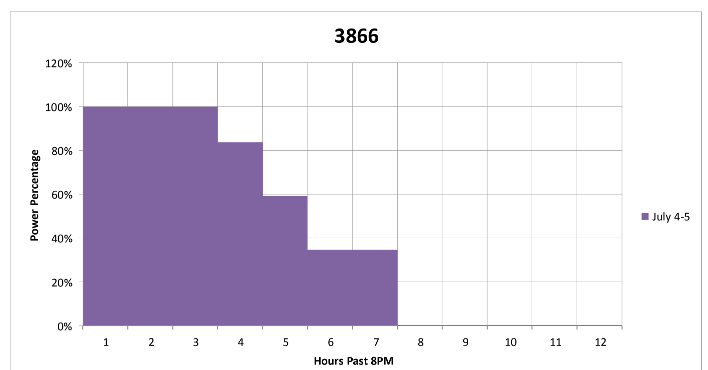


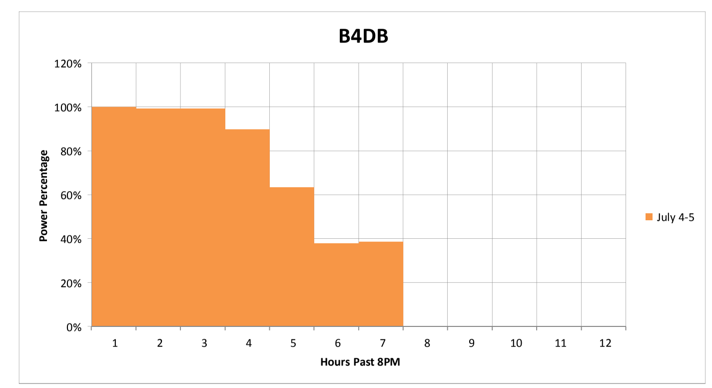


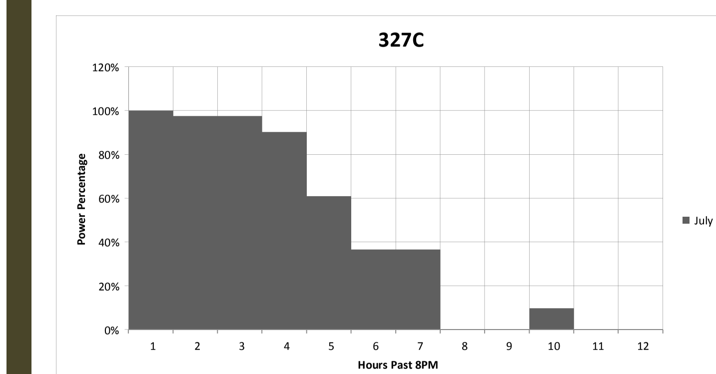


3 Luminaire 14

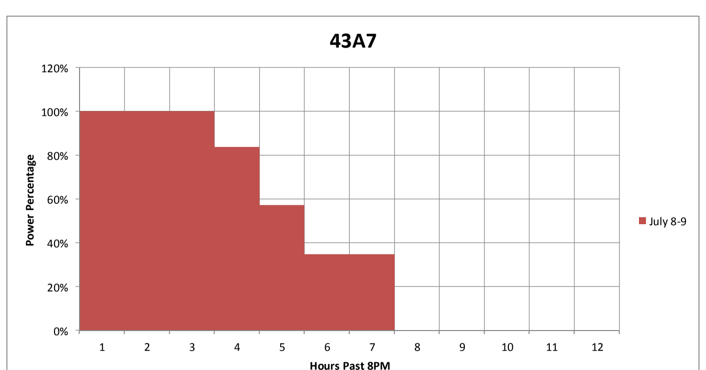


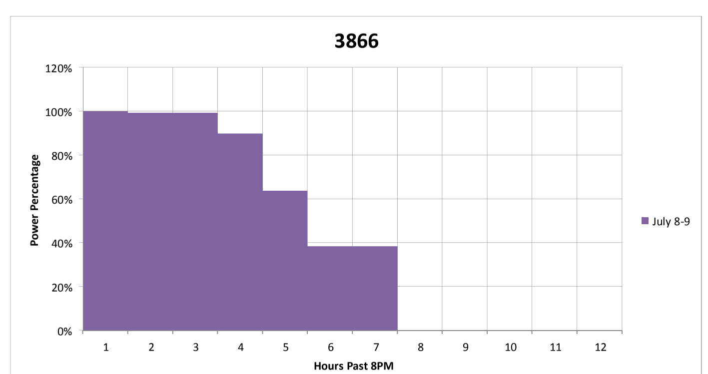


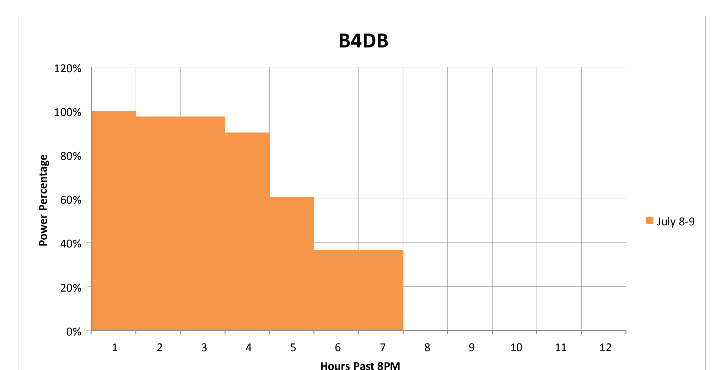


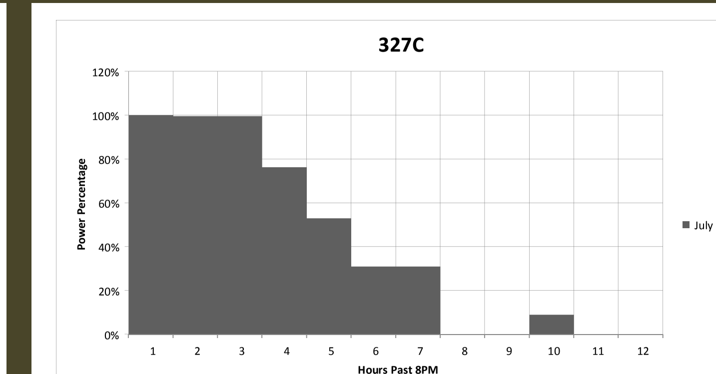


4 Luminaire 8

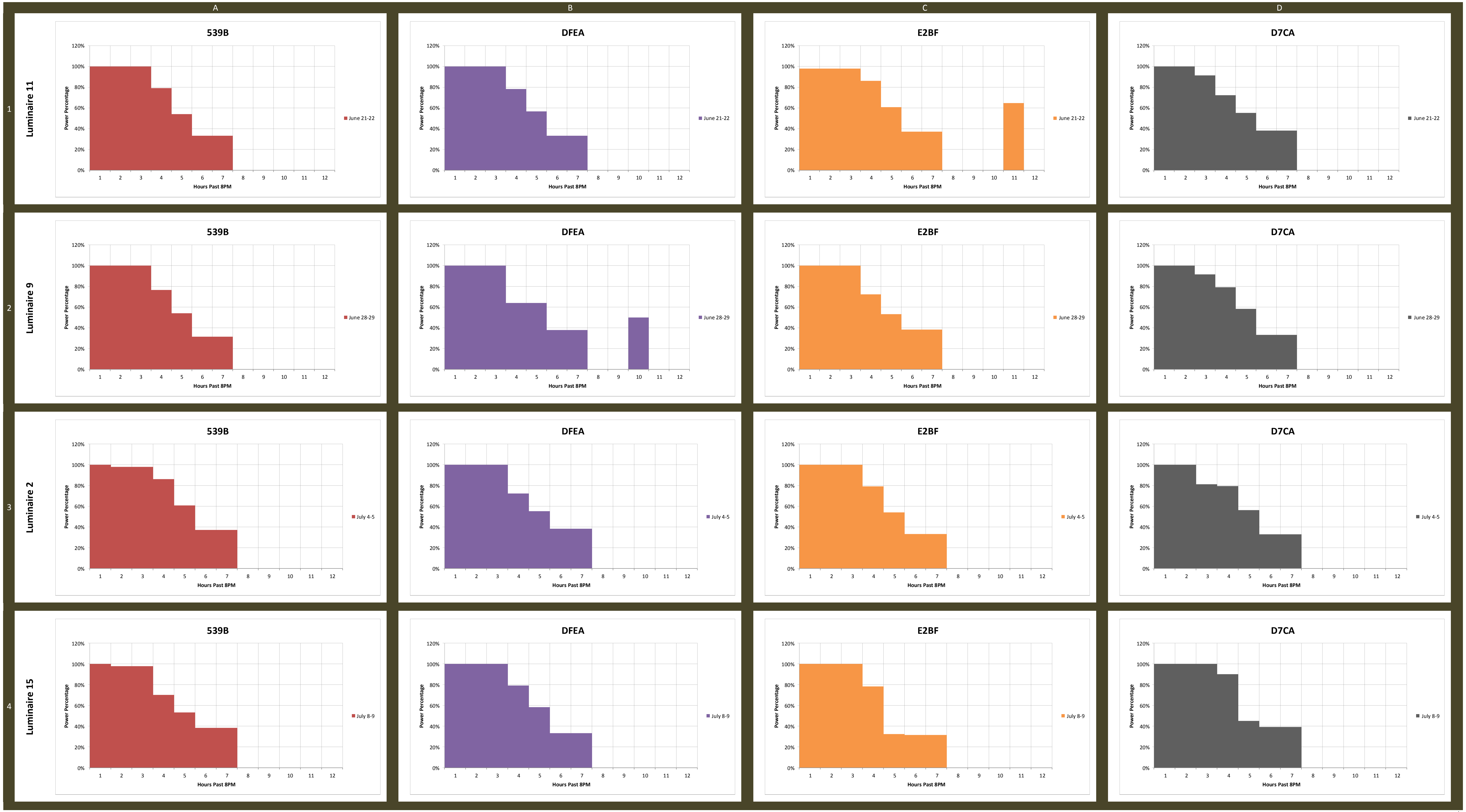








Schedule B Vendor C



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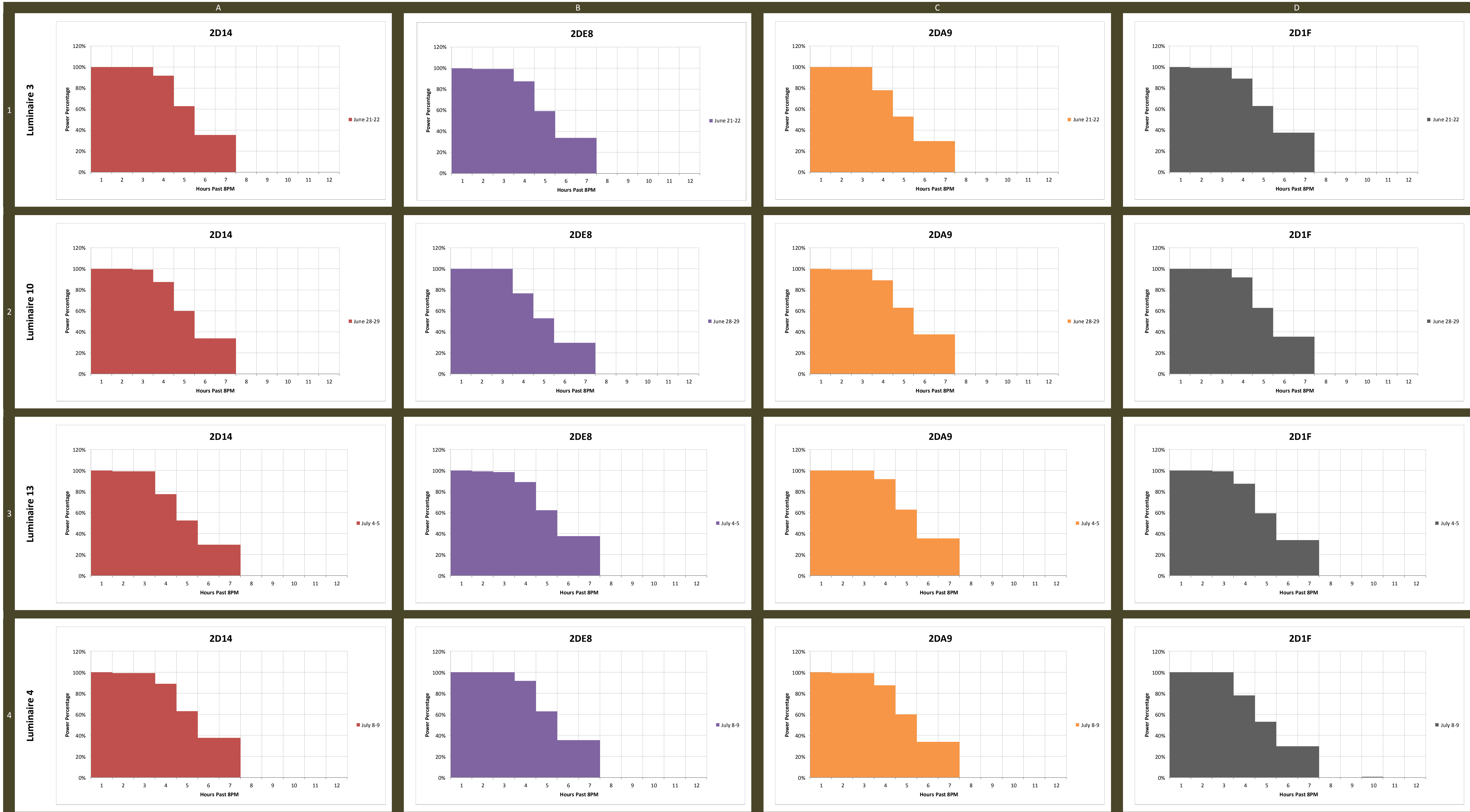

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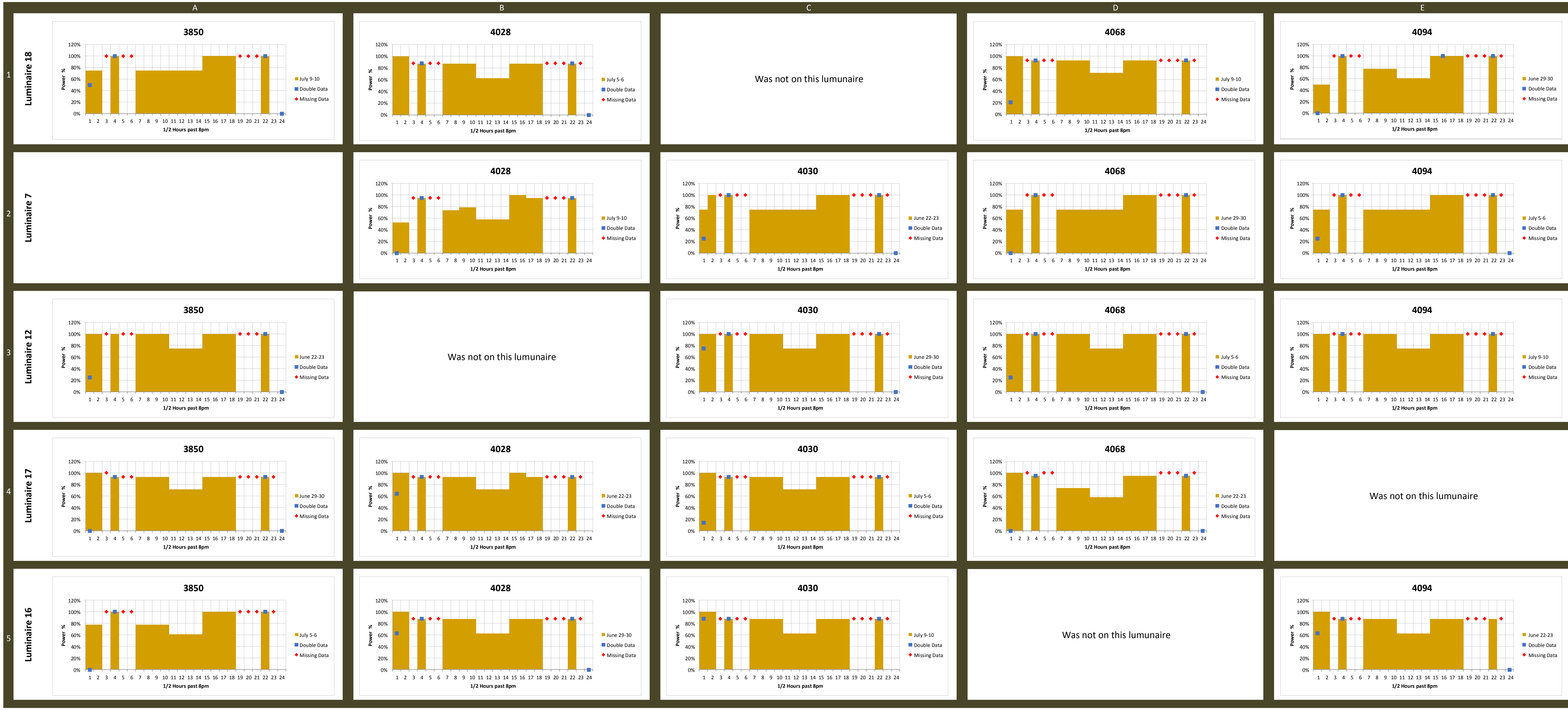

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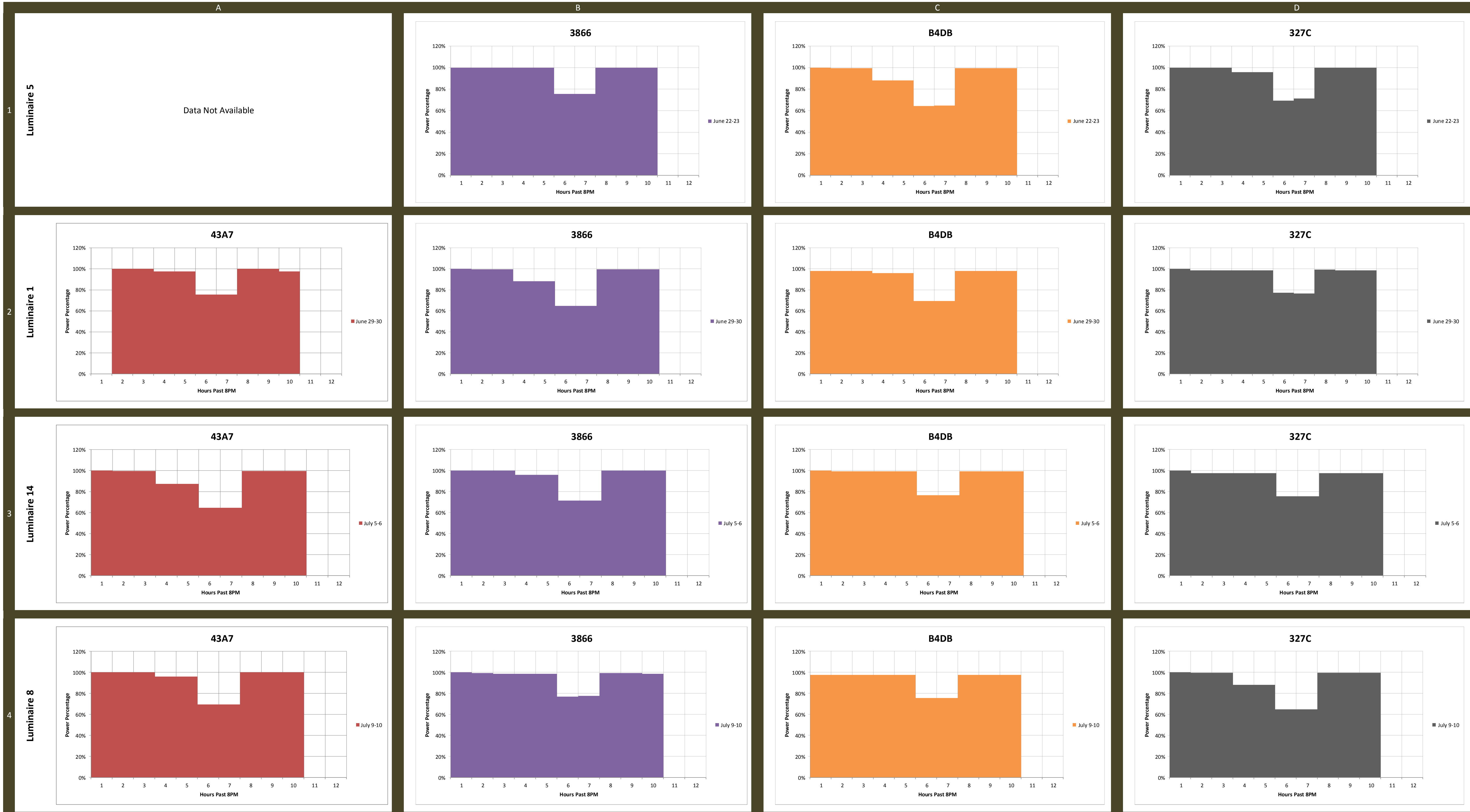
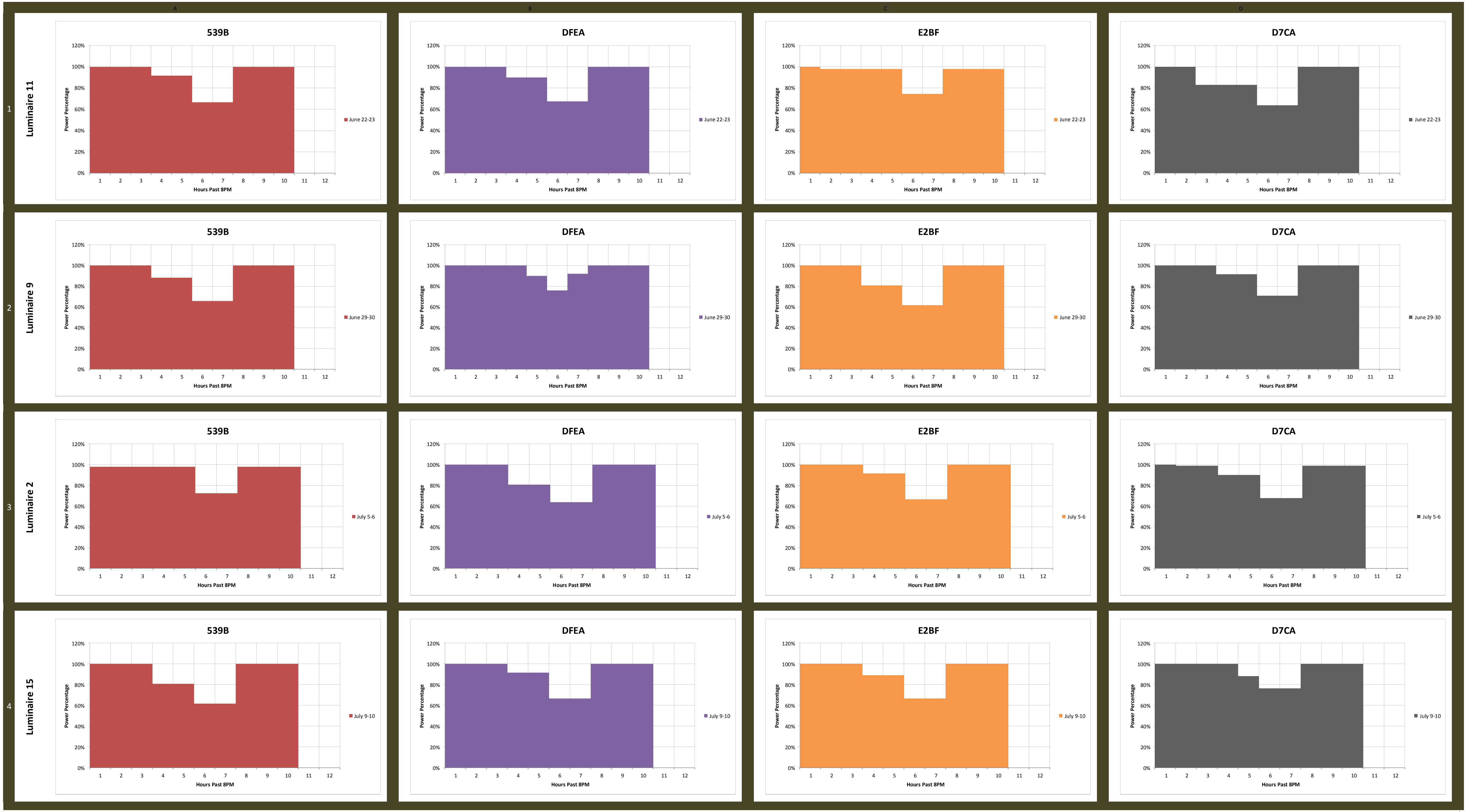
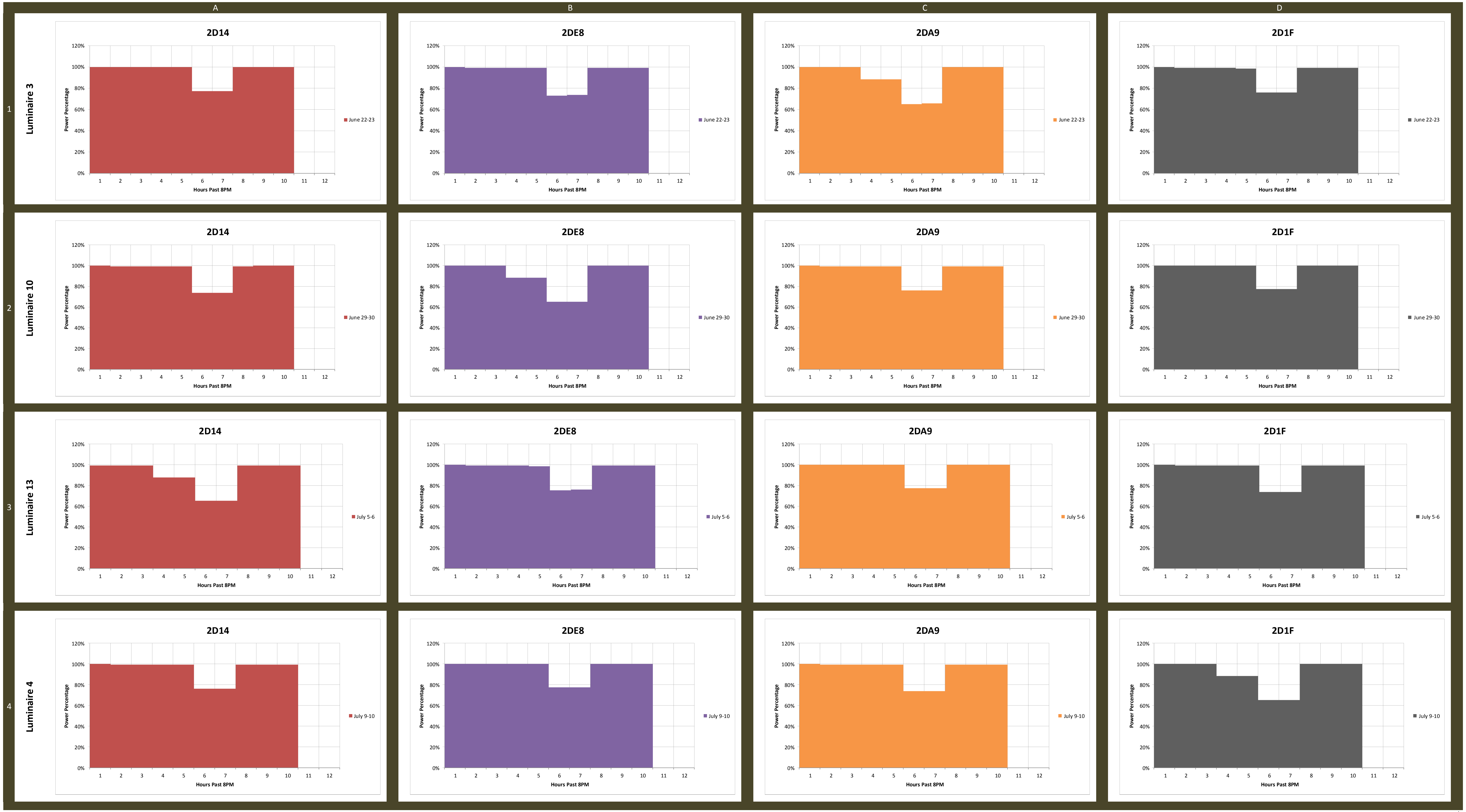


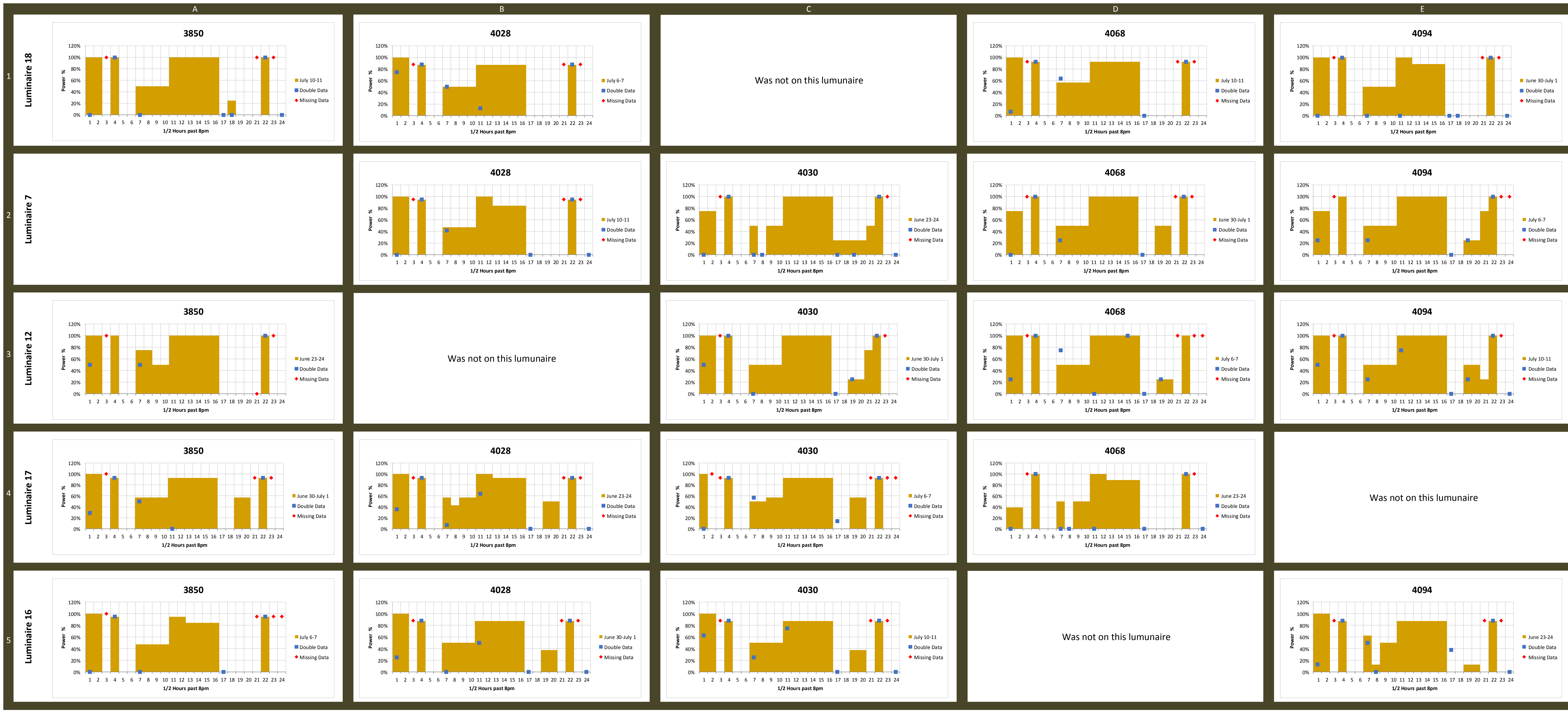
Schedule C Vendor C



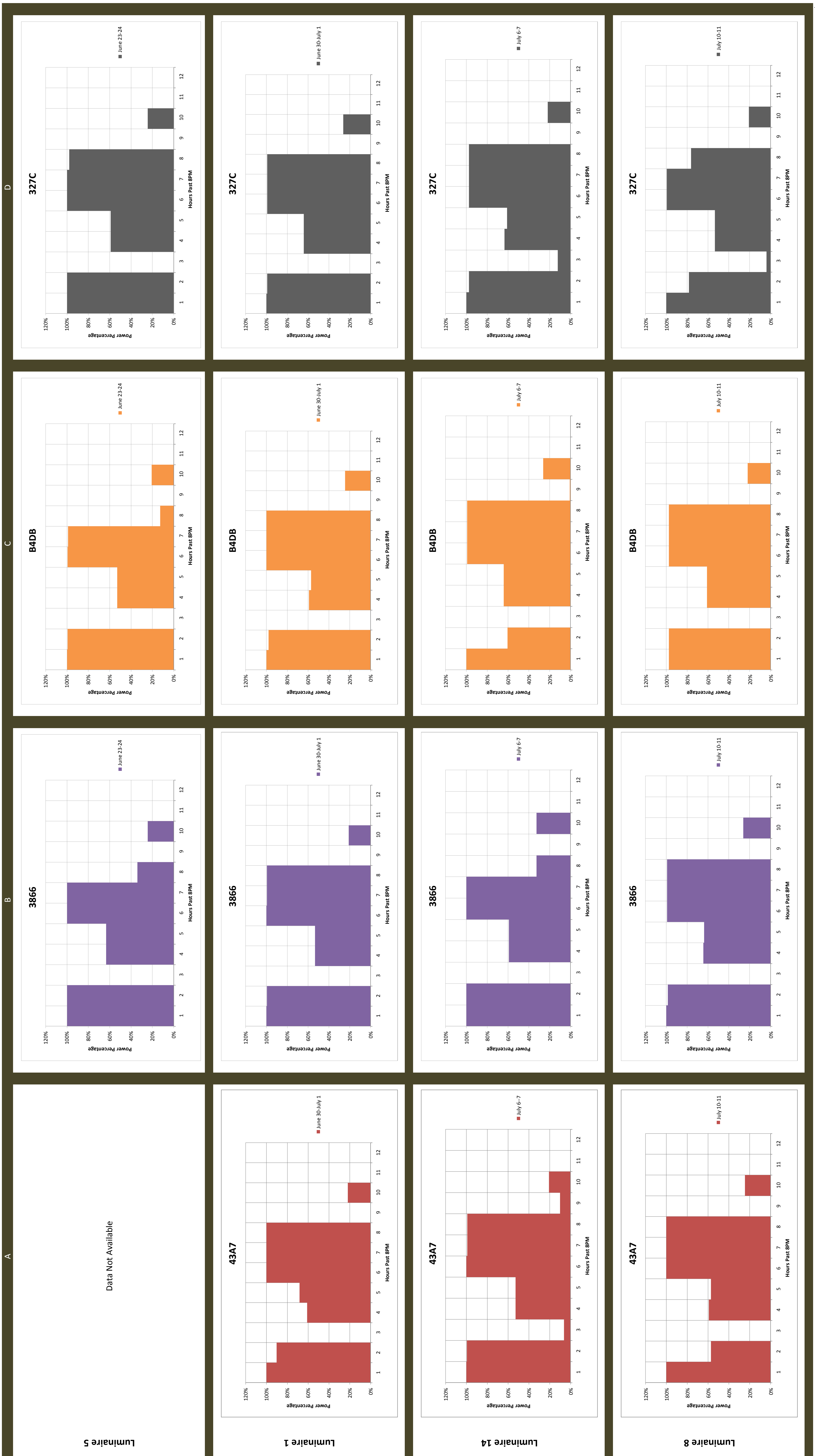
Schedule C Vendor D



Schedule D Vendor A



Schedule D Vendor B



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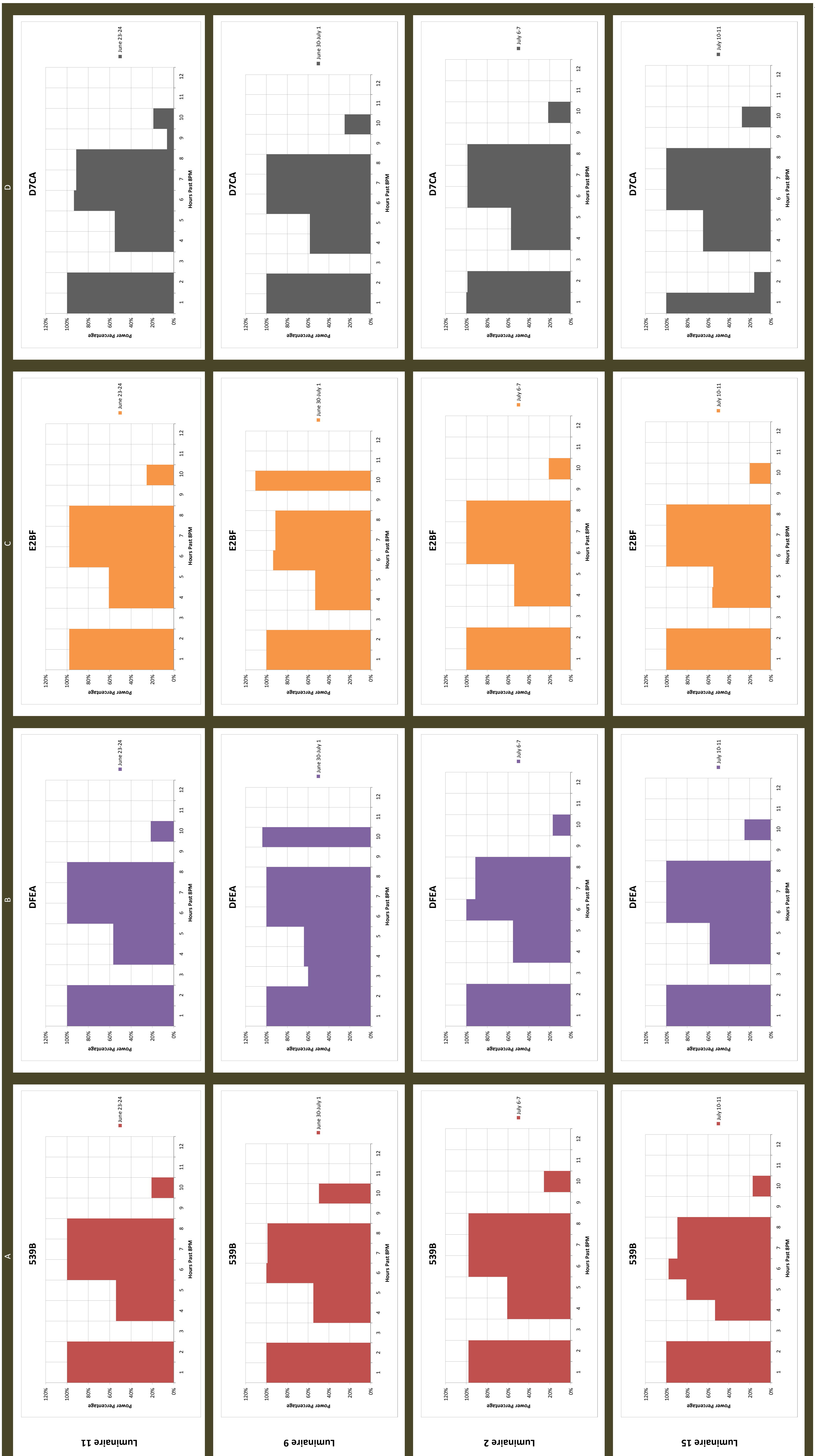
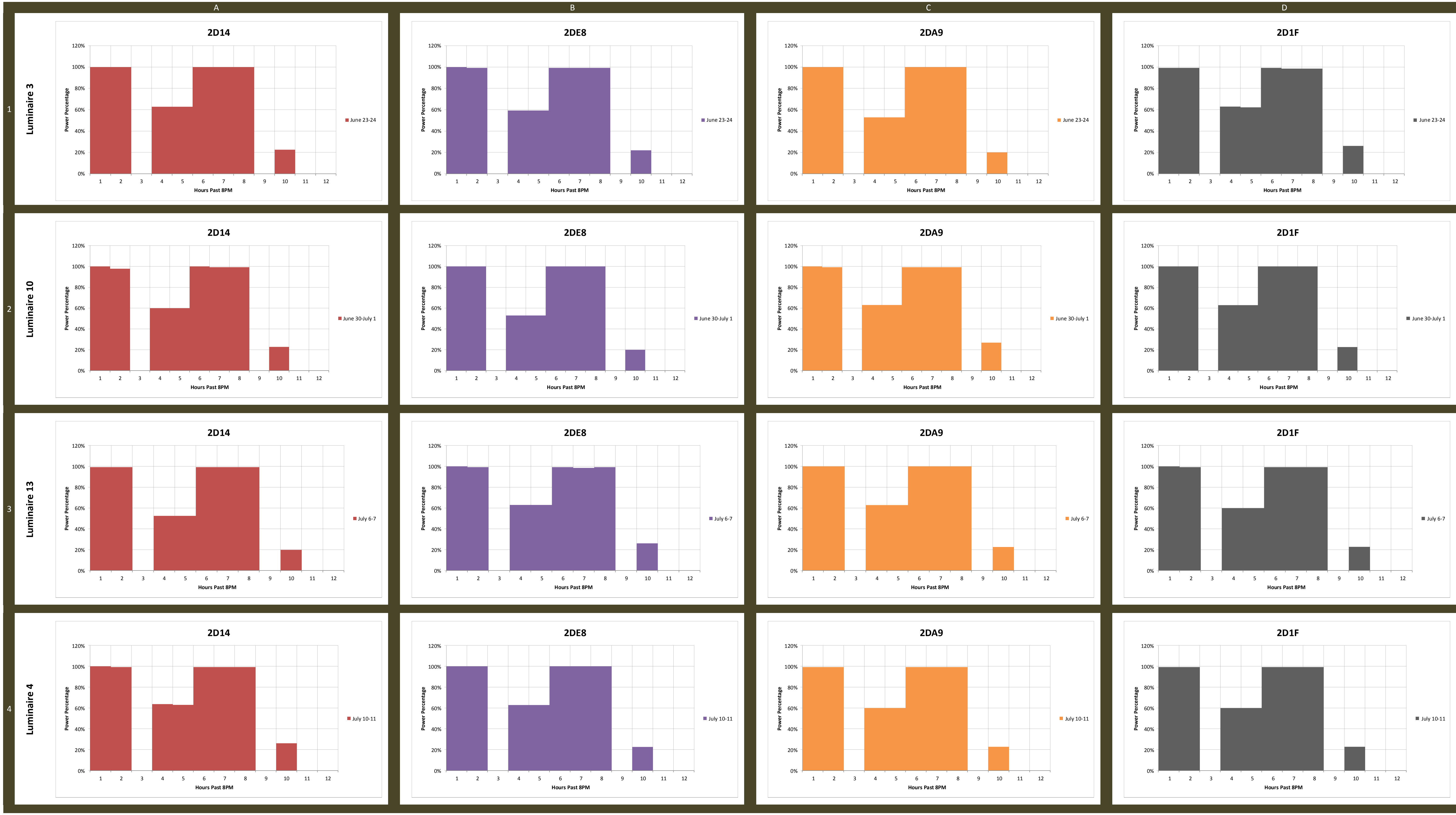


Schedule D Vendor D



Attachment 12

RI-DOT Selected Sites - VERSION 3.0 - E.P. BONETTI
CLOVERLEAF - Route 295 North & South at Route 44

Extracted From SLV Equipment Inventory Tab:
> Interstate 295
> 44
> 142 devices (73 Northbound & 69 Southbound

National Grid		
Rt 295 North	Meter #	89-638-004
Rt 295 South	Meter #	21-057-013

Rt 295 South: This meter also has a camera attached to it. According to RI-DOT this camera is drawing a steady load of 1 amp. Assume 120 volts so about 120 watts.

4/9/17 Excerpt From EXPORT from RI-DOT SLV Equipment Inventory Tab For This Site

geoZone path	idOnController	lat	lng	name	Pole Ht.	Rated Watts	* SLV Metered Power	Route 295 N or S	Comments (Random Sample Watts from "Data History" Tab - Metered Power (W))
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-710/2	41.87121068	-71.5176977	RIDOT-710/2	30	133	132	S	Metered power sample from 4/9/17 @ 07:00:0C
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-683	41.87010803	-71.51452639	RIDOT-683	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-687/1	41.87105161	-71.51323003	RIDOT-687/1	30	133	132	N	Metered power sample from 4/9/17 @ 07:00:0C
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-741/2	41.86827864	-71.51774764	RIDOT-741/2	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-656	41.86950985	-71.51462788	RIDOT-656	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-690	41.87008376	-71.51223924	RIDOT-690	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-741/1	41.86824548	-71.51782374	RIDOT-741/1	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-756	41.86960949	-71.51564023	RIDOT-756	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-691	41.86962891	-71.51241302	RIDOT-691	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-5300	41.8690513	-71.51367417	RIDOT-5300	40	260	266	N	Metered power sample from 4/9/17 @ 06:00:0C
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-693	41.86932736	-71.51292868	RIDOT-693	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-777	41.86473793	-71.51515794	RIDOT-777	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-767	41.87401162	-71.51554543	RIDOT-767	40	260	250	S	Metered power sample from 4/9/17 @ 06:00:0C
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-706	41.87232234	-71.51643156	RIDOT-706	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-732	41.8689531	-71.51741878	RIDOT-732	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-658	41.87115142	-71.51463111	RIDOT-658	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-679	41.86706755	-71.51408332	RIDOT-679	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-5303	41.86869574	-71.51071862	RIDOT-5303	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-759	41.86898948	-71.51166745	RIDOT-759	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-721	41.87144668	-71.51583117	RIDOT-721	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-734	41.86946168	-71.51676139	RIDOT-734	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-733	41.86918218	-71.51717197	RIDOT-733	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-720	41.871603	-71.51621874	RIDOT-720	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-731	41.86856599	-71.51758642	RIDOT-731	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-5305	41.86981468	-71.51536806	RIDOT-5305	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-761	41.86872408	-71.5122076	RIDOT-761	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-729	41.8674181	-71.51612636	RIDOT-729	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-651	41.86445814	-71.51432427	RIDOT-651	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-663	41.86525953	-71.51438724	RIDOT-663	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-724	41.87044714	-71.51547292	RIDOT-724	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-728	41.8676978	-71.51565892	RIDOT-728	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-766	41.8744747	-71.5155374	RIDOT-766	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-672	41.86829626	-71.51154147	RIDOT-672	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-671	41.86813356	-71.51167215	RIDOT-671	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-6118	41.87332707	-71.5156564	RIDOT-6118	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-714	41.87000541	-71.51868093	RIDOT-714	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-740	41.86858564	-71.51789765	RIDOT-740	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-723	41.87083568	-71.51550184	RIDOT-723	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-776	41.8665895	-71.51525291	RIDOT-776	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-773	41.86772946	-71.51535518	RIDOT-773	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-748	41.86653132	-71.51543118	RIDOT-748	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-774	41.86733571	-71.51532945	RIDOT-774	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-750	41.86601135	-71.5153135	RIDOT-750	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-742/2	41.86785763	-71.51764082	RIDOT-742/2	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-668/1	41.86675751	-71.51222522	RIDOT-668/1	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-764	41.86958287	-71.51701418	RIDOT-764	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-660	41.87363767	-71.51473129	RIDOT-660	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-743/1	41.86739034	-71.5170794	RIDOT-743/1	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-689/2	41.870426	-71.51208617	RIDOT-689/2	30	133	130	N	Metered power sample from 4/9/17 @ 07:00:0C
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-703	41.87299031	-71.51567655	RIDOT-703	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-677	41.86665014	-71.51342776	RIDOT-677	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-673	41.86863339	-71.51256609	RIDOT-673	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-680	41.86731639	-71.51435957	RIDOT-680	30	133		N	

LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-765	41.86976246	-71.51776194	RIDOT-765	40	260	262	S	Metered power sample from 4/9/17 @ 06:00:0
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-6119	41.86891174	-71.5129776	RIDOT-6119	40	260	261	N	Metered power sample from 4/9/17 @ 06:00:0
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-675	41.86806806	-71.51213308	RIDOT-675	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-736	41.86967825	-71.51871747	RIDOT-736	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-739	41.86893723	-71.51794534	RIDOT-739	30	133	131	S	Metered power sample from 4/9/17 @ 07:00:0
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-657	41.87057596	-71.51460833	RIDOT-657	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-674	41.8683954	-71.51228616	RIDOT-674	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-678	41.86673022	-71.51388361	RIDOT-678	30	133	132	N	Metered power sample from 4/9/17 @ 07:00:0
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-704	41.87276026	-71.51578707	RIDOT-704	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-654	41.86697316	-71.51444036	RIDOT-654	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-653	41.86641203	-71.51449836	RIDOT-653	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-707	41.87202583	-71.51686759	RIDOT-707	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-754	41.87001446	-71.51784291	RIDOT-754	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-688/2	41.87087063	-71.51264671	RIDOT-688/2	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-711	41.8707968	-71.51788257	RIDOT-711	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-699	41.87173967	-71.51451227	RIDOT-699	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-702	41.8730661	-71.51479114	RIDOT-702	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-701	41.87239916	-71.51472643	RIDOT-701	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-655	41.86881871	-71.51452038	RIDOT-655	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-669/1	41.86733041	-71.51209728	RIDOT-669/1	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-709/1	41.87165594	-71.51736062	RIDOT-709/1	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-682	41.86818695	-71.51457977	RIDOT-682	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-669/2	41.86727851	-71.51191806	RIDOT-669/2	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-698	41.87156457	-71.51421212	RIDOT-698	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-668/2	41.86684791	-71.51238201	RIDOT-668/2	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-667/2	41.86648907	-71.51300103	RIDOT-667/2	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-685	41.87073053	-71.5141568	RIDOT-685	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-757	41.86929697	-71.51379034	RIDOT-757	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-762	41.86910044	-71.51428854	RIDOT-762	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-763	41.86935658	-71.51557513	RIDOT-763	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-687/2	41.87110171	-71.51321705	RIDOT-687/2	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-686	41.87089735	-71.51379001	RIDOT-686	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-684	41.87040522	-71.51440619	RIDOT-684	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-689/1	41.87038779	-71.51217917	RIDOT-689/1	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-743/2	41.86730184	-71.51711465	RIDOT-743/2	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-688/1	41.87094398	-71.51260003	RIDOT-688/1	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-742/1	41.86782218	-71.51768416	RIDOT-742/1	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-692	41.86945325	-71.5126095	RIDOT-692	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-667/1	41.86660579	-71.51305525	RIDOT-667/1	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-710/1	41.87121068	-71.5176977	RIDOT-710/1	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-709/2	41.87161404	-71.51728237	RIDOT-709/2	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-700	41.8720736	-71.51458737	RIDOT-700	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-697	41.87126605	-71.51369344	RIDOT-697	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-661	41.87415541	-71.51472206	RIDOT-661	40	260	252	N	Metered power sample from 4/9/17 @ 06:00:0
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-730	41.86736524	-71.51663245	RIDOT-730	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-5301/1	41.86917437	-71.51316765	RIDOT-5301/1	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-5302	41.8685493	-71.51118395	RIDOT-5302	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-5301/2	41.86911226	-71.51318248	RIDOT-5301/2	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-5304	41.86874008	-71.51000977	RIDOT-5304	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-719	41.8716835	-71.51662682	RIDOT-719	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-715	41.86990661	-71.51698196	RIDOT-715	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-717	41.87037978	-71.51759679	RIDOT-717	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-758	41.86910561	-71.51236407	RIDOT-758	40	260	250	N	Metered power sample from 4/9/17 @ 07:00:0
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-755	41.86975559	-71.51629033	RIDOT-755	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-716	41.87017024	-71.51742063	RIDOT-716	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-650	41.86390618	-71.51434948	RIDOT-650	40	260		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-670	41.86761917	-71.51182765	RIDOT-670	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-666	41.86617715	-71.51379045	RIDOT-666	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-664	41.86560992	-71.51432348	RIDOT-664	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-737	41.86962128	-71.51826477	RIDOT-737	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-738	41.86930855	-71.51799937	RIDOT-738	30	133		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-751	41.86562364	-71.5152104	RIDOT-751	40	260		S	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-696	41.87021077	-71.51203668	RIDOT-696	30	133		N	
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-752	41.86536789	-71.51515961	RIDOT-752	40	260		S	

LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-749	41.86615229	-71.5153485	RIDOT-749	30	133		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-659	41.87181712	-71.51469341	RIDOT-659	40	260		N
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-676	41.86775835	-71.51211672	RIDOT-676	30	133		N
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-665	41.86594449	-71.51409518	RIDOT-665	30	133		N
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-726	41.86831942	-71.51536419	RIDOT-726	40	260		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-722	41.87122183	-71.51571625	RIDOT-722	30	133		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-745	41.86701835	-71.51639946	RIDOT-745	30	133		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-775	41.86693652	-71.51526389	RIDOT-775	40	260		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-725	41.86857183	-71.51537403	RIDOT-725	40	260		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-772	41.86922757	-71.51533579	RIDOT-772	40	260		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-746	41.86694201	-71.51593119	RIDOT-746	30	133		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-662	41.86500798	-71.51438707	RIDOT-662	40	260		N
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-5306	41.86980898	-71.51937436	RIDOT-5306	40	260		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-713	41.87010499	-71.5183905	RIDOT-713	30	133		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-718	41.87093076	-71.51764791	RIDOT-718	30	133		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-747	41.86676446	-71.51563647	RIDOT-747	30	133		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-9002	41.86923817	-71.51159923	RIDOT-9002	30	133		N
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-681	41.86773597	-71.51441404	RIDOT-681	40	260		N
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-727	41.86786974	-71.51551712	RIDOT-727	30	133		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-9001	41.86992188	-71.51194699	RIDOT-9001	30	133		N
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-712	41.87041885	-71.51810098	RIDOT-712	30	133		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-760	41.86862364	-71.51134158	RIDOT-760	40	260		N
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-694	41.86903	-71.51116943	RIDOT-694	30	133	133	N	Metered power sample from 4/9/17 @ 07:00:0C
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-744	41.86719559	-71.51668075	RIDOT-744	30	133		S
LightSmart/Rhode Island/RIDOT/Interstate 295/44	RIDOT-695	41.86954923	-71.51166852	RIDOT-695	30	133		N

Notes:
1) It appears that fixtures rated at 133 watts are on 30 foot poles - ASSUMPTION!
2) It appears that fixtures rated at 260 watts are on 40 foot poles - ASSUMPTION!
3) *SLV Metered Power, where shown, is just a point in time**sample** from Data History Tab.
4) RI-DOT mentioned that they are not running strictly dusk-to-dawn.
5) RI-DOT mentioned that there still may be about 1000 units not communicating
6) RI-DOT mentioned that they still are working through some pole/node discrepancies
7) RI-DOT mentioned that there may be some "day burners."

RI-DOT Selected Sites - VERSION 3.0 - E.P. BONETTI
Straightaway - Route 146 Between Mineral Spring Avenue and Branch Avenue

Extracted From Two Groupings on the SLV Equipment Inventory Tab:
> Route 146
> > Branch Avenue
>   > 82 devices

> Route 146
> > 15
> > 22 devices (Between Mineral Spring Avenue and Branch Avenue)

National Grid	
Meter #	05-053-522

4/11/17 Excerpt From EXPORT from RI-DOT SLV Equipment Inventory Tab For This Site							* SLV	Comments
geoZone path	idOnController	lat	lng	name	Pole Ht.	Rated Watts	Metered	Random Sample Watts from "Data History" Tab - Metered Power (W)
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1758/1	41.85652643	-71.4281837	RIDOT-1758/1	40	260	245	Metered power sample from 4/11/17 @ 06:00:00
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1758/2	41.8565494	-71.42814606	RIDOT-1758/2	40	260	262	Metered power sample from 4/11/17 @ 06:00:01
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1780/1	41.85707008	-71.42848629	RIDOT-1780/1	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1780/2	41.85708597	-71.42842387	RIDOT-1780/2	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1781/1	41.85766094	-71.42877723	RIDOT-1781/1	40	260	246	Metered power sample from 4/11/17 @ 06:00:00
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1781/2	41.8576642	-71.4287352	RIDOT-1781/2	40	260	256	Metered power sample from 4/11/17 @ 06:00:01
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1782/1	41.85828781	-71.42906189	RIDOT-1782/1	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1782/2	41.85829505	-71.42899599	RIDOT-1782/2	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1783/1	41.85880661	-71.42926025	RIDOT-1783/1	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1783/2	0.000885129	-0.000203848	RIDOT-1783/2	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1784/1	41.85952695	-71.42949272	RIDOT-1784/1	40	260	262	Metered power sample from 4/11/17 @ 06:00:01
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1784/2	41.85952762	-71.42944634	RIDOT-1784/2	40	260	262	Metered power sample from 4/11/17 @ 06:00:02
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1785/1	41.86011044	-71.42964533	RIDOT-1785/1	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1785/2	41.86011181	-71.42959981	RIDOT-1785/2	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1786/1	41.8606714	-71.42976903	RIDOT-1786/1	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1786/2	41.86067273	-71.42972231	RIDOT-1786/2	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1787/1	41.86130879	-71.42987164	RIDOT-1787/1	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1787/2	41.86134338	-71.42980194	RIDOT-1787/2	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1788/1	41.86198425	-71.42998505	RIDOT-1788/1	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/Branch Avenue	RIDOT-1788/2	41.86193249	-71.42990867	RIDOT-1788/2	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/15	RIDOT-1790/1	41.86318673	-71.43011883	RIDOT-1790/1	40	260		
LightSmart/Rhode Island/RIDOT/Route 146/15	RIDOT-1790/2	41.86318073	-71.43007665	RIDOT-1790/2	40	260	249	Metered power sample from 4/11/17 @ 06:00:00

Notes:
1) It appears that fixtures rated at 133 watts are on 30 foot poles - ASSUMPTION!
2) It appears that fixtures rated at 260 watts are on 40 foot poles - ASSUMPTION!
3) *SLV Metered Power, where shown, is just a point in time **sample** from Data History Tab.
4) RI-DOT mentioned that they are not running strictly dusk-to-dawn.
5) RI-DOT mentioned that there still may be about 1000 units not communicating.
6) RI-DOT mentioned that they still are working through some pole/node discrepancies.
7) RI-DOT mentioned that there may be some "day burners."

RI-DOT Selected Sites - VERSION 3.0 - E.P. BONETTI
Park & Ride at Frenchtown Road

Extracted From SLV Equipment Inventory Tab:
> Rt4 & Rt 403 Demo Area
> Frenchtown Park and Ride
> 8 devices

National Grid	
Meter #	98-769-153

4/9/17 Excerpt From EXPORT from RI-DOT SLV Equipment Inventory Tab For This Site

geoZone path	idOnController	lat	lng	name	Pole Ht.	Rated Watts	* SLV Metered Power	Comments Random Sample Watts from "Data History" Tab - Metered Power (W)
LightSmart/Rhode Island/RIDOT/Rt 4 and Rt 403 Demo Area/Frenchtown Park and Ride	RIDOT-49	41.62834	-71.48447	RIDOT-49	30	133	132	Metered power sample from 4/9/17 @ 06:00:00
LightSmart/Rhode Island/RIDOT/Rt 4 and Rt 403 Demo Area/Frenchtown Park and Ride	RIDOT-48	41.62833	-71.48417	RIDOT-48	30	133	132	Metered power sample from 4/9/17 @ 07:00:00
LightSmart/Rhode Island/RIDOT/Rt 4 and Rt 403 Demo Area/Frenchtown Park and Ride	RIDOT-50	41.62837	-71.48494	RIDOT-50	30	133	129	Metered power sample from 4/9/17 @ 07:00:00
LightSmart/Rhode Island/RIDOT/Rt 4 and Rt 403 Demo Area/Frenchtown Park and Ride	RIDOT-51	41.6285	-71.48513	RIDOT-51	30	133	131	Metered power sample from 4/9/17 @ 06:00:00
LightSmart/Rhode Island/RIDOT/Rt 4 and Rt 403 Demo Area/Frenchtown Park and Ride	RIDOT-52	41.62855	-71.48488	RIDOT-52	30	133	125	Metered power sample from 4/9/17 @ 07:00:00
LightSmart/Rhode Island/RIDOT/Rt 4 and Rt 403 Demo Area/Frenchtown Park and Ride	RIDOT-53	41.6286	-71.48451	RIDOT-53	30	133	126	Metered power sample from 4/9/17 @ 07:00:00
LightSmart/Rhode Island/RIDOT/Rt 4 and Rt 403 Demo Area/Frenchtown Park and Ride	RIDOT-54	41.62859	-71.48417	RIDOT-54	30	133	125	Metered power sample from 4/9/17 @ 07:00:00
LightSmart/Rhode Island/RIDOT/Rt 4 and Rt 403 Demo Area/Frenchtown Park and Ride	RIDOT-55	41.62837	-71.48399	RIDOT-55	30	133	132	Metered power sample from 4/9/17 @ 07:00:00

Notes:
1) It appears that fixtures rated at 133 watts are on 30 foot poles - ASSUMPTION!
2) It appears that fixtures rated at 260 watts are on 40 foot poles - ASSUMPTION!
3) *SLV Metered Power, where shown, is just a point in time **sample** from Data History Tab.
4) RI-DOT mentioned that they are not running strictly dusk-to-dawn.
5) RI-DOT mentioned that there still may be about 1000 units not communicating.
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7) RI-DOT mentioned that there may be some "day burners."

Attachment 13

May 18,2017 Version 1B
E.P. Bonetti

RIDOT- Frenchtown Road Park & Ride - PROPOSED TEST OPERATING SCHEDULE

Schedule	Schedule Reference	Luminaire Wattage	Schedule Time	7:00:00 PM - 7:29:59 PM	7:30:00 PM - 7:59:59 PM	8:00:00 PM - 8:29:59 PM	8:30:00 PM - 8:59:59 PM	9:00:00 PM - 9:29:59 PM	9:30:00 PM - 9:59:59 PM	10:00:00 PM - 10:29:59 PM	10:30:00 PM - 10:59:59 PM	11:00:00 PM - 11:29:59 PM	11:30:00 PM - 11:59:59 PM	12:00:00 AM - 12:29:59 AM	12:30:00 AM - 12:59:59 AM
Photosensing	Dusk-to-Dawn			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Programmed	Dimming 70a			100%	100%	100%	100%	100%	100%	80%	80%	80%	80%	60%	60%
Programmed	Part Night b			100%	100%	100%	100%	0%	0%	50%	50%	50%	50%	100%	100%

Schedule	1:00:00 AM - 1:29:59 AM	1:30:00 AM - 1:59:59 AM	2:00:00 AM - 2:29:59 AM	2:30:00 AM - 2:59:59 AM	3:00:00 AM - 3:29:59 AM	3:30:00 AM - 3:59:59 AM	4:00:00 AM - 4:29:59 AM	4:30:00 AM - 4:59:59 AM	5:00:00 AM - 5:29:59 AM	5:30:00 AM - 5:59:59 AM	6:00:00 AM - 6:29:59 AM	Tool
Photosensing	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
Programmed	60%	60%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
Programmed	90%	90%	90%	90%	0%	0%	20%	20%	100%	100%	100%	

NOTES: **1. % = % illumination. Thus 70% = 70% illumination or 30% dimming.**

Attachment 14

WORKING SCHEDULE - Version 2
May 18, 2017- E.P. Bonetti

FRENCHTOWN ROAD PARK & RIDE - ALTERNATE NODES, DIMMING & PART NIGHT TESTING

The Narragansett Electric Company
Docket 4513
Street Light Meter Pilot Schedule

Task Function	Responsibility Of:		90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107
LEGEND: **GREY - Scheduled** **COMPLETE - ✓** **GREEN - On Schedule** **ORANGE - Delays** **RED - Behind** **BLUE - Added To Origninal Timeline** **Moved out to Later Date - >>>** **Moved in to Earlier Start Date - <<<**		**Week Of:**	**May 1, 2017**	**May 8, 2017**	**May 15, 2017**	**May 22, 2017**	**May 29, 2017**	**June 5, 2017**	**June 12, 2017**	**June 19, 2017**	**June 26, 2017**	**July 3, 2017**	**July 10, 2017**	**July 17, 2017**	**July 24, 2017**	**July 31, 2017**	**August 7, 2017**	**August 14, 2017**	**August 21, 2017**	**August 28, 2017**
STAGE 1 - Phase 2 Field Application Testing - **Frenchtown Rd Park & Ride Testing**																				
> RI-DOT - Park & Ride - Frenchtown Rd. - **Vendor X IC Devices (Vendor X Nodes)**																				
> Collect & Monitor National Grid ERT Meter Data	NGRID			✓																
> Collect & Monitor IC Meter Performance Data - Vendor X IC Devices - **Dusk-to-Dawn (D2D) - Photosensor**	NGRID																			
> Collect & Monitor IC Meter Performance Data - Vendor X IC Devices - **Dimming Schedule - Program Nodes!**	NGRID, LightSmart																			
> Collect & Monitor IC Meter Performance Data - Vendor X IC Devices - **Part Night Schedule - Program Nodes!**	NGRID, LightSmart																			
> RI-DOT - Park & Ride - Frenchtown Rd. - **Vendor Y IC Devices (Vendor Y Nodes)**																				
> Alternate IC Device Installations & Replacements - **Replace 8 Vendor X Nodes with 8 Vendor Y Nodes**	NGRID, LightSmart																			
> Collect & Monitor IC Meter Performance Data - Vendor Y IC Devices - **Dusk-to-Dawn (D2D) - Photosensor**	NGRID																			
> Collect & Monitor IC Meter Performance Data - Vendor Y IC Devices - **Dimming Schedule - Program Nodes!**	NGRID, LightSmart																			
> Collect & Monitor IC Meter Performance Data - Vendor Y IC Devices - **Part Night Schedule - Program Nodes!**	NGRID, LightSmart																			
> RI-DOT - Park & Ride - Frenchtown Rd. - **Vendor Z IC Devices (Vendor Z Nodes)**																				
> Alternate IC Device Installations & Replacements - **Replace 8 Vendor Y Nodes with 8 Vendor Z Nodes**	NGRID, LightSmart																			
> Collect & Monitor IC Meter Performance Data - Vendor Z IC Devices - **Dusk-to-Dawn (D2D) - Photosensor**	NGRID																			
> Collect & Monitor IC Meter Performance Data - Vendor Z IC Devices - **Dimming Schedule - Program Nodes!**	NGRID, LightSmart																			
> Collect & Monitor IC Meter Performance Data - Vendor Z IC Devices - **Part Night Schedule - Program Nodes!**	NGRID, LightSmart																			
> RI-DOT - Park & Ride - Frenchtown Rd. - **Restore Original RI-DOT IC Devices (RI-DOT Nodes)**																				
> Alternate IC Device Installations & Replacements - **Replace 8 Vendor Z nodes with Original 8 RI-DOT Nodes**	NGRID, LightSmart																			

Attachment 15

Streetlight Metering Pilot

IS Effort

The Information Services effort to support the RI Streetlight Metering Pilot project includes the following:

1. Scope definition: identification of IS systems that would be impacted if National Grid were to enable its portfolio to accommodate the metered streetlights for billing. We were unclear on which applications would be affected, and therefore projected that approximately 8 applications would be impacted. We must assess the system model without knowing who will own the various aspects of the systems (streetlight, metering device, mesh network). National Grid has identified the following most likely ownership scenarios. The IS evaluation includes looking at these systems under each scenario.

	NG Owned devices & network	Hybrid			Customer Owned
		NG owned devices; Private Company owned network	Private Co owned devices and network	Customer Owned devices; Private Co owned network	
Aggregated Data Model	N/A	NG bills Metered	NG bills Metered	NG bills Metered	NG bills Metered
Granular Data Model	NG bill Metered	N/A	N/A	N/A	N/A

2. Requirements definition: build out high level requirements in order to engage our individual application Subject Matter Experts (SME's). This also includes definition of Security requirements to accommodate interfaces to other systems.
3. Architecture Definition: determine changes necessary to the system architecture under each of the models.
4. High Level Design: create high level design for the following systems under each of the 5 ownership models. Ensure that the system flow between systems provides a cohesive system. The systems include:
   a. Security: provide security design recommendations.
   b. Billing system: our billing system currently bills for unmetered streetlights. We need to modify our system to allow for metered streetlights:however our billing system does not allow for more than 99 meters per account. Therefore a separate association system needs to be built and maintained. This has ripple effects into other systems, such as Meter Inventory, Streetlight Inventory, Bill Calculation, and Service Orders (comprised of several systems). Additionally a new module is required to summarize the streetlight usage into a single bill account since this is not how currently metered accounts are billed (where all meters are stored with the bill account within the billing system). Consideration is given to the possibility of a re-bill situation if usage information needs to be corrected, and this also depends on the ownership model and who will provide that information to National Grid for billing purposes.
   c. Bill Print
   d. GIS: Global Information System: changes needed to accommodate a meter that is not tied directly to a bill account in our customer system.
   e. CSS Orders: service orders such as new streetlight, new streetlight account, remove streetlight, update streetlight account, etc.

f. Meter Inventory, Streetlight Inventory: The changes to these systems vary depending on the ownership model. The owner of the meters is responsible for the accuracy of the usage information that is used in billing.

g. Meter Data System Information (MDSI): this system contains the meter usage information. The owner of the meters is responsible for the meter data quality as well as providing correcting any information found to be inaccurate and providing that information to the billing system in order to re-bill. If National Grid owns the meters, we are responsible for this information and would require a granular level of data to perform the quality checks. If National Grid does not own the meters, we would look for a monthly meter read (usage) per meter and system changes would be needed to accommodate this information since it cannot be stored at the bill account level as other metered accounts due to the 99 meter limit.

5. Develop cost estimates for high level designs. Review each of the designs to ensure alignment prior to estimation to ensure no rework is needed on the designs. High level estimates are needed for requirements, design, development, testing and deployment of each system, for each of the 5 scenarios.
6. Finalize timeline and cost estimates for each of the 5 ownership models. Develop overall timeline for each scenario, ensuring interdependencies are taken into account as each timeline was provided in a vacuum. Timeline and costs need to include all IS deliverables, including startup, requirements, design, testing and deployment, with oversight from project management, security and architecture.
7. Contribute to final White Paper. Provide the business (John Walter) with a summary of system changes for each of the 5 scenarios along with the National Grid IS cost and timeline for delivering each of them. Provide the assumptions made in developing the cost and timeline for each scenario.

NOTE: Items 1-4 are complete as of July 2016. Work still to be performed is items 5, 6 and 7. This work will resume if/when approved to do so by the business, and as resources are available.

Attachment 16

RIDOT Test Sites (Burn Hour Calcs)

Rt 295 North			Meter # 89-638-004									
SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	1/27/2017	1/31/2017	133	1	14.258	4	57.032	100%	100%	47	356.50703	
DUSK TO DAWN	1/31/2017	2/27/2017	133	2	13.107	27	353.889	100%	100%	47	2212.16013	
DUSK TO DAWN	1/27/2017	1/31/2017	260	1	14.258	4	57.032	100%	100%	26	385.53632	
DUSK TO DAWN	1/31/2017	2/27/2017	260	2	13.107	27	353.889	100%	100%	26	2392.28964	
	1/27/2017	2/27/2017				31				Calculated Total kWh:	5346.493	84.2%
										XML Data Total kWh:	5013.107	78.9%
										NGrid Meter kWh:	6538	
										MINUS KNOWN ADDITIONAL LOAD:	186.000	
										Netted NGrid Meter kWh for Lights:	6352.000	

Rt 295 North			Meter # 89-638-004									
SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	2/27/2017	2/28/2017	133	2	13.107	1	13.107	100%	100%	47	81.93185	
DUSK TO DAWN	2/28/2017	3/28/2017	133	3	11.710	28	327.880	100%	100%	47	2049.57788	
DUSK TO DAWN	2/27/2017	2/28/2017	260	2	13.107	1	13.107	100%	100%	26	88.60332	
DUSK TO DAWN	2/28/2017	3/28/2017	260	3	11.710	28	327.880	100%	100%	26	2216.46880	
	2/27/2017	3/28/2017				29				Calculated Total kWh:	4436.582	82.1%
										XML Data Total kWh:	4230.298	78.3%
										NGrid Meter kWh:	5575	
										MINUS KNOWN ADDITIONAL LOAD:	174.000	
										Netted NGrid Meter kWh for Lights:	5401.000	

Rt 295 South			Meter # 21-057-013									
SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	1/27/2017	1/31/2017	133	1	14.258	4	57.032	100%	100%	46	348.92177	
DUSK TO DAWN	1/31/2017	2/27/2017	133	2	13.107	27	353.889	100%	100%	46	2165.09290	
DUSK TO DAWN	1/27/2017	1/31/2017	260	1	14.258	4	57.032	100%	100%	23	341.05136	
DUSK TO DAWN	1/31/2017	2/27/2017	260	2	13.107	27	353.889	100%	100%	23	2116.25622	
	1/27/2017	2/27/2017				31				Calculated Total kWh:	4971.322	91.3%
										XML Data Total kWh:	4484.125	82.3%
										NGrid Meter kWh:	5721	
										MINUS KNOWN ADDITIONAL LOAD:	275.280	
										Netted NGrid Meter kWh for Lights:	5445.720	

Rt 295 South			Meter # 21-057-013									
SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	2/27/2017	2/28/2017	133	2	13.107	1	13.107	100%	100%	46	80.18862	
DUSK TO DAWN	2/28/2017	3/29/2017	133	3	11.710	29	339.590	100%	100%	46	2077.61162	
DUSK TO DAWN	2/27/2017	2/28/2017	260	2	13.107	1	13.107	100%	100%	23	78.37986	
DUSK TO DAWN	2/28/2017	3/29/2017	260	3	11.710	29	339.590	100%	100%	23	2030.74820	
	2/27/2017	3/29/2017				30				Calculated Total kWh:	4266.928	88.2%
										XML Data Total kWh:	3967.849	82.1%
										NGrid Meter kWh:	5102	
										MINUS KNOWN ADDITIONAL LOAD:	266.400	
										Netted NGrid Meter kWh for Lights:	4835.600	

Route 146			Meter # 05-053-522									
SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	2/9/2017	2/28/2017	260	2	13.107	19	249.033	100%	100%	22	1424.46876	
DUSK TO DAWN	2/28/2017	3/13/2017	260	3	11.710	13	152.230	100%	100%	22	870.75560	
	2/9/2017	3/13/2017				32				Calculated Total kWh:	2295.224	100.5%
										XML Data Total kWh:	2059.241	90.2%
										NGrid Meter kWh:	2476	
										MINUS KNOWN ADDITIONAL LOAD:	192.000	
										Netted NGrid Meter kWh for Lights:	2284.000	

Park & Ride			Meter # 98-769-153									
SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	1/27/2017	1/31/2017	133	1	14.258	4	57.032	100%	100%	8	60.68204	
DUSK TO DAWN	1/31/2017	2/27/2017	133	2	13.107	27	353.889	100%	100%	8	376.53789	
	1/27/2017	2/27/2017				31				Calculated Total kWh:	437.220	101.2%
										XML Data Total kWh:	419.745	97.2%
										NGrid Meter kWh:	432	

Park & Ride			Meter # 98-769-153									
SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	2/27/2017	2/28/2017	133	2	13.107	1	13.107	100%	100%	8	13.94584	
DUSK TO DAWN	2/28/2017	3/28/2017	133	3	11.710	28	327.880	100%	100%	8	348.86432	
	2/27/2017	3/28/2017				29				Calculated Total kWh:	362.810	98.9%
										XML Data Total kWh:	354.767	96.7%
										NGrid Meter kWh:	367	

RI TARIFF BURN HOURS CHART

MONTH	MO_DAYS	BURN_HOURS	DAILY
1	31	442	14.258
2	28	367	13.107
3	31	363	11.710
4	30	309	10.300
5	31	280	9.032
6	30	251	8.367
7	31	267	8.613
8	31	301	9.710
9	30	338	11.267
10	31	392	12.645
11	30	418	13.933
12	31	447	14.419

Attachment 17

Park and Ride Site (Burn Hour Calcs)

SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	5/29/2017	5/31/2017	133	5	9.032	2	18.064	100%	100%	8	19.22009	
DUSK TO DAWN	5/31/2017	6/5/2017	133	6	8.367	5	41.835	100%	100%	8	44.51244	
										Calculated Total kWh:	63.733	99.6%
										XML Data Total kWh:	62.312	97.4%
										NGrid Meter kWh:	64	

SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
NON-CONFORM	6/7/2017	6/12/2017	133	6	2	5	10.000	100%	100%	8	10.64000	
DIMMING 70A	6/12/2017	6/13/2017	133	6	3	1	3.000	100%	100%	8	3.19200	
DIMMING 70A	6/12/2017	6/13/2017	133	6	2	1	2.000	80%	99%	8	2.10672	
DIMMING 70A	6/12/2017	6/13/2017	133	6	2	1	2.000	60%	72%	8	1.53216	
DIMMING 70A	6/12/2017	6/13/2017	133	6	4.5	1	4.500	100%	100%	8	4.78800	
										Calculated Total kWh:	22.259	92.7%
										XML Data Total kWh:	21.792	90.8%
										NGrid Meter kWh:	24	

Note: Lights were not operating according to the prescribed schedule at the start of this period

SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
PART NIGHT B	6/15/2017	6/20/2017	133	6	2	5	10.000	100%	100%	8	10.64000	
PART NIGHT B	6/15/2017	6/20/2017	133	6	1	5	5.000	0%	0%	8	0.00000	
PART NIGHT B	6/15/2017	6/20/2017	133	6	2	5	10.000	50%	59%	8	6.27760	
PART NIGHT B	6/15/2017	6/20/2017	133	6	1	5	5.000	100%	100%	8	5.32000	
PART NIGHT B	6/15/2017	6/20/2017	133	6	2	5	10.000	90%	99%	8	10.53360	
PART NIGHT B	6/15/2017	6/20/2017	133	6	1	5	5.000	0%	0%	8	0.00000	
PART NIGHT B	6/15/2017	6/20/2017	133	6	1	5	5.000	20%	21%	8	1.11720	
PART NIGHT B	6/15/2017	6/20/2017	133	6	1.5	5	7.500	100%	100%	8	7.98000	
										Calculated Total kWh:	41.868	95.2%
										XML Data Total kWh:	41.04	93.3%
										NGrid Meter kWh:	44	

SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	6/24/2017	6/27/2017	133	6	8.367	3	25.101	100%	100%	8	26.70746	
										Calculated Total kWh:	26.707	102.7%
										XML Data Total kWh:	21.147	81.3%
										NGrid Meter kWh:	26	

Note: 1 device RIDOT-54 was not reporting during this time despite light being on

SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	6/27/2017	6/30/2017	133	6	8.367	3	25.101	100%	100%	7	23.36903	
DUSK TO DAWN	6/30/2017	7/3/2017	133	7	8.613	3	25.839	100%	100%	7	24.05610	
										Calculated Total kWh:	47.425	100.9%
										XML Data Total kWh:	45.214	96.2%
										NGrid Meter kWh:	47	

SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DIMMING 70A	7/3/2017	7/10/2017	133	7	3	7	21.000	100%	100%	7	19.55100	
DIMMING 70A	7/3/2017	7/10/2017	133	7	2	7	14.000	80%	83%	7	10.81822	
DIMMING 70A	7/3/2017	7/10/2017	133	7	2	7	14.000	60%	65%	7	8.47210	
DIMMING 70A	7/3/2017	7/10/2017	133	7	4.5	7	31.500	100%	100%	7	29.32650	
										Calculated Total kWh:	68.168	94.7%
										XML Data Total kWh:	69.384	96.4%
										NGrid Meter kWh:	72	

SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
PART NIGHT B	7/10/2017	7/17/2017	133	7	2	7	14.000	100%	100%	7	13.03400	
PART NIGHT B	7/10/2017	7/17/2017	133	7	1	7	7.000	0%	0%	7	0.00000	
PART NIGHT B	7/10/2017	7/17/2017	133	7	2	7	14.000	50%	54%	7	7.03836	
PART NIGHT B	7/10/2017	7/17/2017	133	7	1	7	7.000	100%	100%	7	6.51700	
PART NIGHT B	7/10/2017	7/17/2017	133	7	2	7	14.000	90%	94%	7	12.25196	
PART NIGHT B	7/10/2017	7/17/2017	133	7	1	7	7.000	0%	0%	7	0.00000	
PART NIGHT B	7/10/2017	7/17/2017	133	7	1	7	7.000	20%	19%	7	1.23823	
PART NIGHT B	7/10/2017	7/17/2017	133	7	1.5	7	10.500	100%	100%	7	9.77550	
										Calculated Total kWh:	49.855	94.1%
										XML Data Total kWh:	50.378	95.1%
										NGrid Meter kWh:	53	

SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DUSK TO DAWN	7/24/2017	7/31/2017	133	7	8.613	7	60.291	100%	100%	8	64.14962	
										Calculated Total kWh:	64.15	94.3%
										XML Data Total kWh:	65.156	95.8%
										NGrid Meter kWh:	68	

SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
DIMMING 70A	7/31/2017	8/8/2017	133	8	3	8	24.000	100%	100%	8	25.53600	
DIMMING 70A	7/31/2017	8/8/2017	133	8	2	8	16.000	80%	84%	8	14.30016	
DIMMING 70A	7/31/2017	8/8/2017	133	8	2	8	16.000	60%	61%	8	10.38464	
DIMMING 70A	7/31/2017	8/8/2017	133	8	4.5	8	36.000	100%	100%	8	38.30400	
										Calculated Total kWh:	88.525	93.2%
										XML Data Total kWh:	90.656	95.4%
										NGrid Meter kWh:	95	

SCHEDULE	START DATE	END DATE	BILLABLE WATTS	MONTH	DAILY HOURS	DAYS_BILLED	BURN_HOURS	DIM%	POWER	QTY LIGHTS	kWh	
PART NIGHT B	8/8/2017	8/16/2017	133	8	2	8	16.000	100%	100%	8	17.02400	
PART NIGHT B	8/8/2017	8/16/2017	133	8	1	8	8.000	0%	0%	8	0.00000	
PART NIGHT B	8/8/2017	8/16/2017	133	8	2	8	16.000	50%	49%	8	8.34176	
PART NIGHT B	8/8/2017	8/16/2017	133	8	1	8	8.000	100%	100%	8	8.51200	
PART NIGHT B	8/8/2017	8/16/2017	133	8	2	8	16.000	90%	93%	8	15.83232	
PART NIGHT B	8/8/2017	8/16/2017	133	8	1	8	8.000	0%	0%	8	0.00000	
PART NIGHT B	8/8/2017	8/16/2017	133	8	1	8	8.000	20%	21%	8	1.78752	
PART NIGHT B	8/8/2017	8/16/2017	133	8	1.5	8	12.000	100%	100%	8	12.76800	
										Calculated Total kWh:	64.266	91.8%
										XML Data Total kWh:	65.706	93.9%
										NGrid Meter kWh:	70	

RI TARIFF BURN HOURS CHART

MONTH	MO_DAYS	BURN_HOURS	DAILY
1	31	442	14.258
2	28	367	13.107
3	31	363	11.710
4	30	309	10.300
5	31	280	9.032
6	30	251	8.367
7	31	267	8.613
8	31	301	9.710
9	30	338	11.267
10	31	392	12.645
11	30	418	13.933
12	31	447	14.419