Energy Efficiency Battery Charger System Test Procedure

Version 2.1.4, August 1, 2008

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Development funded by: Pacific Gas and Electric, and
California Energy Commission-Public Interest Energy Research (PIER) Program,
and Southern California Edison

Scope

A. General Scope

The purpose of the test procedure is to measure the energy efficiency of battery chargers coupled with their batteries, which together are referred to as ***battery charger systems***. This term covers all rechargeable batteries or devices incorporating a rechargeable battery and the chargers used with them. Battery charger systems include, but are not limited to:

- 1) electronic devices with a battery that are normally charged from ac line voltage or dc input voltage through an internal or external power supply and a dedicated battery charger;
- 2) the battery and battery charger components of devices that are designed to run on battery power during part or all of their duty cycle (such as many portable appliances and commercial material handling equipment);
- 3) dedicated battery systems primarily designed for electrical or emergency backup (such as emergency egress lighting and uninterruptible power supply (UPS) systems);
- 4) devices whose primary function is to charge batteries, along with the batteries they are designed to charge. These units include chargers for power tool batteries and chargers for automotive, AA, AAA, C, D, or 9 V rechargeable batteries, as well as chargers for batteries used in motive equipment, such as golf carts, electric material handling equipment and vehicles, including lift trucks (forklifts), airport electric ground support equipment (EGSE), port cargo handling equipment; tow tractors, personnel carriers, sweepers and scrubbers are examples of these types of motive equipment.
- 5) The scope of this procedure is limited to battery charger systems that are rated for ac input of 600 volts or less and that connect to the utility grid with a plug or are permanently connected.
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B. Part 1 and Part 2

This test procedure contains two parts: Part 1 and Part 2. Battery charger systems are to be tested using either Part 1 or Part 2, based upon the specific scopes in C and D. Note that the test procedures in Parts 1 and 2 share common reference and definition sections.

If a battery charger system appears to be described by the scope of both parts, it is to be tested using Part 2.

C. Part 1 Scope

The scope of Part 1 is limited to those battery charger systems that operate on single-phase ac input power or dc input power and that have a nameplate input power rating of 2 kW or less. The procedures described by Part 1 are also limited to battery charger systems whose battery has a rated energy capacity of 50 kWh or less. Battery chargers capable of charging batteries both less than and greater than 50 kWh shall be tested using Part 1 of this test procedure only with suitable batteries of 50 kWh or less. This scope for Part 1 specifically excludes any battery charger system which meets the criteria of Part 2 in Section D of this Scope.

Laboratory testing equipment used to test and analyze batteries is specifically excluded from the scope of this test procedure. However, battery charger systems that provide power for portable laboratory testing equipment are included.

The scope of Part 1 includes any battery charger that meets the other criteria and that is packaged or sold without batteries. Part 1, Section II.C herein specifies the selection of suitable batteries for test using the procedures contained in Part 1.
Some examples of battery charger systems included in the scope of Part 1 are: cellular and cordless telephones, cordless power tools, laptop computers, cordless shavers, uninterruptible power supplies emergency egress lighting, portable lawn tools, rechargeable toys, and marine and recreational vehicle chargers,.

Note: The charging circuitry of battery charger systems may or may not be located within the housing of the end-use device itself. In many cases, the battery may be charged with a dedicated external charger and power supply combination that is separate from the device that runs on power from the battery.

Note: This test procedure is not intended to test batteries in the absence of a corresponding charger.

D. Part 2 Scope

Part 2 includes test and analysis methods to evaluate the energy usage and impact of battery chargers for batteries powering motive equipment.

Some examples of battery charger systems included in the scope of Part 2 are chargers for batteries used in motive equipment, such as golf carts, electric material handling equipment and vehicles, including lift trucks (forklifts), airport electric ground support equipment (EGSE), port cargo handling equipment; tow tractors, personnel carriers, sweepers and scrubbers. .

Part 2 of this procedure does not cover the following:

a) Consumer electronics products and/or household-type devices, with either internal or external charger.
b) Battery chargers for on-road full-function electric or plug-in hybrid-electric vehicles.
c) Battery chargers for automotive, marine and/or recreational vehicle starter batteries, or batteries used in conjunction with starting or running internal combustion engines and their accessories.
d) Battery chargers for signaling devices.

e) Systems rated for input greater than 600V.

If they meet the criteria in Section C, above, these excluded devices may be covered by the scope of Part 1.

References

The following list includes documents used and/or referenced in the development of this test method:

ANSI/NCSL Z540-1-1994, *American National Standard for Calibration – Requirements for Calibration of measuring and Test Equipment,* ANSI and NCSL, 1994.

BCIS-05: Battery Council International, *BCI Specifications for Electric Vehicle Batteries*, BCIS-05 Rev. DEC02.

BCIS-14: Battery Council International, *Determination of Capacity of Lead-Acid Industrial Storage Batteries for Motive Power Service,* BCIS-14 Rev. DEC02.

BCIS-16: Battery Council International, *Standard for Deep Cycle Battery Chargers*, BCIS-16 Rev. DEC02.

Buchmann, Isidor, *Batteries in a Portable World: A Handbook on Rechargeable Batteries for Non-Engineers*, Cadex Electronics Inc., 2001.

IEC 60050-300: International Electrotechnical Commission, *International Electrotechnical Vocabulary- Electrical and Electronic Measurements and Measuring Instruments*, IEC 60050-300, Edition 1.0, 2005.

IEC 60051: International Electrotechnical Commission, *Direct Acting Indicating Analogue Electrical Measuring Instruments and their Accessories*, IEC 60051, parts 1-9, Edition 5.0, 1997.

IEC 60254-1: International Electrotechnical Commission, *Lead-acid traction batteries – Part 1: General requirements and methods of tests*, IEC 60254-1, Edition 4.0, 2005.

IEC 61056-1: International Electrotechnical Commission, *General Purpose Lead-Acid Batteries (Valve Regulated Types) – Part 1: General Requirements, Functional Characteristics – Methods of Test,* IEC 61056-1, Edition 2.0, 2002.

IEC 61951-1: International Electrotechnical Commission, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells – Part 1: Nickel-cadmium*, IEC 61951-1. Edition 2.0, 2003-2004.

IEC 61951-2: International Electrotechnical Commission, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells – Part 2: Nickel-metal hydride*, IEC 61951-2, Edition 2.0, 2003.

IEC 61960: International Electrotechnical Commission, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications*, IEC 61960, Edition 1.0, 2003.

IEC 62133: International Electrotechnical Commission, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications*, IEC 62133, Edition 1.0, 2002.

IEC 62301: International Electrotechnical Commission, *Household Electrical Appliances - Measurement of Standby Power*, IEC 62301, Edition 1.0, 2005.

IEEE 100: Institute of Electrical and Electronics Engineers, *The Authoritative Dictionary of IEEE Standards Terms*, IEEE 100, Edition 7.0, 2006.

IEEE 1625: Institute of Electrical and Electronics Engineer Power Engineering Society, *Livium: IEEE Standard for Rechargeable Batteries for Portable Computing*, IEEE 1625-2004.

USABC *Electric Vehicle Battery Test Procedures Manual*, DOE/ID-10479, Rev. 2, INEL, U.S. DOE, 1996.

Definitions

A. Active Power (P)
Active power is the average value, taken over one or more cycles, of the instantaneous power (which is the product of instantaneous voltage and current).

B. Ambient Temperature
Ambient temperature is the temperature of the ambient air surrounding the UUT.

C. Ampere-hour Capacity
See "Rated Charge Capacity."

D. Apparent Power (S)
The apparent power (S) is the product of rms voltage and rms current (VA).

E. Batch Charger
A batch charger is a battery charger that charges two or more identical batteries simultaneously in a series, parallel, series-parallel, or parallel-series configuration. A batch charger does not have separate voltage or current regulation nor does it have any separate indicators for each battery in the batch. When testing a batch charger, the term “battery” is understood to mean, collectively, all the batteries in the batch that are charged together. A charger can be both a batch charger and a multi-port charger or multi-voltage charger.

F. Battery Chemistry
The chemistry of the rechargeable battery, such as nickel cadmium, nickel metal hydride, lithium ion, lithium polymer, rechargeable alkaline, or lead-acid.

Note: The chemistry of the battery is typically printed on the label of the battery itself, can be found in the manufacturer’s instructions, or can be obtained from the manufacturer of the battery system.

G. Battery Conditioning
A special procedure performed on a battery to ensure optimal performance.

H. Battery Discharge Energy
The energy, in watt-hours (Wh) delivered by the battery as measured by this test procedure.

Note: This is the *measured* battery discharge energy as distinct from the *Rated Battery Energy* defined below.

I. Battery Maintenance Mode
The state in which the battery charger system is connected to input power, and the battery charger may be delivering current to the battery in order to counteract or compensate for self-discharge of the battery.

Note: In this state, the battery is at or near 100% capacity.

J. Battery Rest Period
A period of time, between discharge and charge or between charge and discharge, during which the battery is resting in an open-circuit state in ambient air.

K. Charge Energy Management
The interactive way in which the battery is returned to proper charge and health with the optimum amount of energy.

L. Charge Mode
The state in which the battery charger system is connected to input power, and the battery charger is delivering current in order to bring the battery from a state of discharge to a state at or near 100% capacity.

Note: a battery charger system may have more than one charge mode.

M. Charge Return Factor
The number of ampere-hours returned to the battery during the charge cycle divided by the number of ampere-hours delivered by the battery during discharge.

N. C-Rate
The rate of charge or discharge, expressed in terms of the rated charge capacity of the battery. A discharge rate of one-C draws a current (in amperes or milliamperes) equal to the rated charge capacity (in ampere-hours or milliampere-hours) and would theoretically discharge the battery in one hour. Other currents are expressed as multiples of one-C, so 0.2C is one fifth of that current.

O. Cradle
Electrical interface between integral battery product and the rest of the battery charging system designed to hold the product between uses.

P. Crest Factor
For an ac or dc voltage or current waveform, the crest factor is the ratio of the peak instantaneous value to the root-mean-square (rms) value.

Note: Crest factor is expressed as a ratio, for example a pure sine wave has a crest factor of 1.414.

Q. Detachable Battery
A battery which is separable from the appliance and is intended to be removed from the appliance for charging purposes. The battery pack may contain additional circuitry.

R. End-of-Discharge Voltage
Specified closed-circuit battery voltage at which discharge of a battery is terminated.

S. Equalization
A process whereby a battery is overcharged, beyond what would be considered “optimum” charge return, so that cells can be balanced, electrolyte mixed, and plate sulfation removed.

T. External Power Supply (EPS)
An external power supply is an external module which connects to ac line power and provides power to other components of the battery charger system. In this test procedure, this term is used broadly and generically. It is not limited to nor does it exclude power supplies that may be regulated by any particular jurisdiction or standard.

External power supplies are designed to covert ac line voltage into low voltage output (either ac or dc) and are contained in a separate housing from the product they are powering.

Note: For further clarification, see Test Method for Calculating the Energy Efficiency of Single Voltage External Ac-Dc and Ac-Ac power Supplies, August 11, 2007, at www.efficientpowersupplies.org.

U. Integral Battery
A battery which is contained within the appliance and is not intended to be removed from the appliance for charging purposes. A battery that is to be removed from the appliance for disposal or recycling purposes only is considered to be an integral battery.

V. Instructions
The instructions (or “manufacturer’s instructions”) shall mean the documentation packaged with the product in printed or electronic form and any information about the product listed on a website maintained by the manufacturer and accessible by the general public. “Instructions” includes any information on the packaging or on the product itself. “Instructions” also includes any service manuals or data sheets that the manufacturer offers for sale to independent service technicians, whether printed or in electronic form.

W. Maintenance Management
The way in which the charger maintains the battery when the battery is left connected and not used for long periods.

X. Measured Capacity
Measured capacity of a battery is the product of the discharge rate in amperes and the time in decimal hours required to reach final voltage.

Y. Multi-port Charger
A multi-port charger is a battery charger which charges two or more batteries (which may be identical or different) simultaneously. The batteries are not connected in series or in parallel. Rather, each port has separate voltage and/or current regulation. If the charger has status indicators, each port has is own indicator(s). A charger can be both a batch charger and a multi-port charger if it is capable of charging two or more batches of batteries simultaneously and each batch has separate regulation and/or indicator(s).

Z. Multi-voltage Charger
A battery charger that, by design, can charge a variety of batteries (or batches of batteries if also a batch charger) that are of different rated battery voltages. A multi-voltage charger can also be a multi-port charger if it can charge two or more batteries simultaneously with independent voltage and/or current regulation.

AA. No-Battery Mode
The state in which the battery charger system is connected to input power, is configured to charge a battery, but there is no battery connected to the charger output.

Note: In this mode the system would begin charging a battery if one were connected.

BB. No-Battery Energy
The energy used by the charger when in no-battery mode.

CC. Off Mode
The state in which the battery charger is switched “off” using a switch located on the charger, if such a switch is included, while the charger is connected to the input power source and used in accordance with the manufacturer’s instructions.

Note: If the charger does not have an on/off switch, off mode is the same as no-battery mode. If the charger does have an on/off switch, the charger will not begin charging a battery if one is connected while the charger is switched off. Products operating in Off Mode may still have some residual power consumption, which is the purpose of measuring power consumption in the Off Mode.

DD. Overcharge
See “Charge Return Factor.”

EE. Periodic Equalization Strategy
A part of charge energy management: the length, power, and frequency of cell overcharge and balancing sessions necessary for the long-term health of a battery.

FF. Power Conversion Efficiency
The instantaneous DC output power of the charger divided by the simultaneous utility AC input power.

GG. Power Factor
The power factor is the ratio of the active power (P) consumed in watts to the apparent power (S), drawn in volt-amperes (VA).

$$PF = \frac{P}{S}$$

Note: This definition of power factor includes the effect of both harmonic distortion and phase angle displacement between the current and voltage.

HH. Power Quality
The nonlinear effects of a battery charger system (power factor, harmonic distortion) on the interactive utility grid – an impact on system energy efficiency.

II. Rated Energy Capacity
The product (in Wh) of the Rated Battery Voltage and the Rated Charge Capacity.

Note: This is distinct from the *measured* Battery Discharge Energy defined above.

JJ. Rated Battery Voltage
The battery voltage specified by the manufacturer and typically printed on the label of the battery itself. If a batch of batteries includes series connections, the Rated Battery Voltage of the batch is the total voltage of the series configuration, that is, the rated voltage of each battery times the number of batteries connected in series. Connecting multiple batteries in parallel does not affect the Rated Battery Voltage.

Note: if not printed on the battery, the rated battery voltage can be derived from the electrical configuration and chemistry of the battery.

KK. Rated Charge Capacity
The capacity, usually given in ampere-hours (Ah) or milliampere-hours (mAh), specified by the manufacturer and typically printed on the label of the battery itself. If a batch of batteries includes parallel connections, the rated charge capacity of the batch is the total charge capacity of the parallel configuration, that is, the rated charge capacity of each battery time the number of batteries connected in parallel. Connecting multiple batteries in series does not affect the rated charge capacity.

Note: it is the quantity of electric charge the manufacturer declares the battery can store under particular pre-specified test conditions.

LL. Rated Input Frequency
Range of ac input frequencies designed to operate the UUT; assigned by the manufacturer and usually printed on the housing of the charging device. If the UUT includes an EPS, this is the frequency of the input to the EPS, not the frequency of the input to the other component(s) of the UUT.

MM. Rated Input Voltage
Range of ac or dc input voltage designed to operate the UUT; assigned by the manufacturer and usually printed on the housing of the charging device. If the UUT includes an EPS, this is the voltage of the input to the EPS, not the voltage of the input to the other component(s) of the UUT (from the EPS).

NN. Specific Gravity
The ratio of the density of a given substance (e.g. battery electrolyte) to the density of water, when both are at the same temperature.

OO. Swappable Battery
A battery that is intended to be charged in the appliance but which may be detached from the appliance so that another battery can be attached to the appliance.

PP. Total Harmonic Distortion (THD)
Total harmonic distortion is a measure of the degree to which a waveform departs from a pure sinusoidal waveform. It is defined as the ratio of the vector sum of all harmonic components (greater than 1) to the magnitude of the fundamental. For instance, for a voltage waveform, THD is defined by the equation:

$$\mathrm{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2}}{V_1}$$

where V_i is the rms voltage of the i^{th} harmonic.

QQ. UPS
Uninterruptible Power Supply

RR. UUT
UUT is an acronym for “unit under test,” which in this document refers to the combination of the battery charger and battery being tested.

PART 1:

I. Standard Test Conditions

A. General

The test sequence is summarized in the table below. Measurements shall be made under test conditions and with the equipment specified below. For some products, multiple tests are required. The required tests may be at different input voltages (see Part 1, Section I.D), different charge rates (see Part 1, Section II.A), and using different batteries (see Part 1, Section II.C). When two or more of these apply, all combinations of specified input voltages, specified charge rates, and specified batteries shall be tested.

Table A: Test Sequence

Step	Description	Data Taken?	Equipment Needed			
			Battery	Charger	Battery Analyzer	Ac Power Meter
1	Record general data on UUT	Yes	X	X		
2	Battery conditioning, Section VI.A	No	X		X	
3	Prepare battery for test, Section VI.B	No	X		X	
4	Battery rest period, Section VI.C	No	X			
5	Conduct Charge Mode and Battery Maintenance Mode Test, Section VI.D	Yes	X	X		X
6	Battery rest period, Section VI.E	No	X			
7	Conduct Battery Discharge Energy Test, Section VI.F	Yes	X		X	
8	Conduct No-Battery Mode Test and Off Mode Test, Section VII	Yes		X		X
9	Compile data into report	No				

B. Measuring Equipment

All input power measurements shall be made with a suitably calibrated power analyzer. Measurements of active power of 0.5 W or greater shall be made with an uncertainty of ≤ 2 %. Measurements of active power of less than 0.5 W shall be made with an uncertainty of ≤ 0.01 W. The power measurement instrument shall have a power resolution of:

- 0.01 W or better for measurements up to 10 W,
- 0.1 W or better for measurements of 10 to 100 W,
- 1 W or better for measurements over 100 W.

Measurements of energy (Wh) shall be made with an uncertainty of ≤ 2%.
Measurements of voltage and current shall be made with an uncertainty of ≤ 1 %.
Measurements of temperature shall be made with an uncertainty of ≤ 2 ℃.
These tolerances comprise the combined accuracy of the measuring instruments, the measurement techniques, and all other sources of error in the test procedure, at the 95% confidence level.

Note: For suggestions on measuring low power levels, see IEC 62301, especially Section 5.3.2 and Annexes B and D.

C. Test Room

All tests, battery conditioning, and battery rest periods shall be carried out in a room with an air speed near the UUT of ≤ 0.5 m/s. The ambient temperature shall be maintained at 20°C ± 5°C throughout the test. There shall be n o intentional cooling of the UUT by use of separately powered fans, air conditioners, or heat sinks. The UUT shall be conditioned, rested, and tested on a thermally non-conductive surface.

Note: Products intended for conditions outside of this specified range may be tested at additional temperatures, provided those are in addition to the conditions specified above and are noted in a separate section on the test report. When not undergoing active testing, batteries shall be stored at 20°C ± 5 ℃.

D. Input Reference Source: Input Voltage and Input Frequency

If the UUT is intended for operation on ac line-voltage input, it shall be tested at two voltage and frequency combinations: 115 V at 60 Hz and 230 V at 50 Hz, if its nameplate input voltage and frequency indicate that it can operate safely under both conditions. If testing at both conditions is not possible, the UUT shall be tested at the one voltage and frequency combination above that is within its nameplate voltage and frequency ranges.

If the UUT is intended for operation on ac input at other than line voltage, it shall be tested once with the following combination of voltage and frequency:

The voltage at the midpoint of its rated input voltage range
The first of the following frequencies that is within its rated input frequency range: 60 Hz, 50 Hz, or the midpoint of its rated input frequency range.

If a charger is powered by a low-voltage dc or ac input, and the manufacturer packages the charger with an EPS, sells, or recommends an optional EPS capable of providing that low voltage input, then the charger shall be tested using that EPS and the input reference source shall be a suitable input for the EPS.

If the UUT is intended for operation only on dc input voltage (and does not include an EPS), it shall be tested with one of the following input voltages: 12.0 V dc for products intended for automotive, recreational vehicle or marine use, 5.0 V dc for products drawing power from a computer USB port, or the midpoint of the rated input voltage range for all other products.

The input voltage shall be within ± 1 % of the specified voltage.

If the input voltage is ac, the input frequency shall be within ± 1 % of the specified frequency. The THD of the input voltage shall be ≤ 2%, up to and including the 13^{th} harmonic. The crest factor of the input voltage shall be between 1.34 and 1.49.

If the input voltage is dc, the ac ripple voltage (rms) shall be:

for dc voltages up to 10 V, ≤ 0.2 V;
for dc voltages over 10 V, ≤ 2 % of the dc voltage.

II. Battery Charger System Setup Requirements

A. General Setup

The battery charger system shall be prepared and set up in accordance with the manufacturer's instructions, except where those instructions conflict with the requirements of this test procedure. If no instructions are given, then factory or "default" settings shall be used, or where there are no indications of such settings, the UUT shall be tested as supplied. If the battery charger unit is powered by an external power supply, it shall be tested with the external power supply packaged with the unit.

If the battery charger has user controls to select from two or more charge rates (such as regular or fast charge) or different charge currents, the test shall be conducted with each of the possible choices. If the charger has user controls for selecting special charge cycles that are recommended only for occasional use to preserve battery health, such as equalization charge, removing memory, or battery conditioning, these modes are not required to be tested. The settings of the controls shall be listed in the report for each test.

B. Age of Battery Charger System

The UUT, including the battery charger and its associated battery, shall be new products of the type and condition that would be sold to a customer. It shall be tested within 3 months of the date of purchase. If the battery is lead-acid chemistry and the battery is to be stored for more than 24 hours between its initial acquisition and testing, the battery shall be charged before such storage.

C. Selection of Batteries to Use for Testing

The battery or batteries to be used for testing are selected by a two-step process. First, the technician shall determine all the batteries that are "associated with" the charger, as described below. Then, from the set of associated batteries, the technician shall select those to be tested, as described below.

1) Batteries "associated with" the charger shall be determined using Table B. For a batch charger, technician shall follow first the procedure for either "packaged with batteries" or "not packaged with batteries," then consider all configurations of those batteries.

Table B. Batteries Associated with a Charger

<table>
<tr><th colspan="2">Conditions</th><th>Associated Batteries</th></tr>
<tr><td colspan="2">Charger comes packaged with batteries</td><td>(1) All batteries included with the product, and
(2) Any and all optional or high-capacity batteries sold by the same manufacturer and identified in the instructions of either the product or the battery as suitable for use with the product.</td></tr>
<tr><td rowspan="3">Charger is not packaged with batteries</td><td>Charger manufacturer also sells batteries</td><td>Any and all batteries sold by the same manufacturer and identified in the instructions of either the product or the battery as suitable for use with the product.</td></tr>
<tr><td>Manufacturer does not sell batteries, but does recommend batteries in the instructions</td><td>Any and all batteries recommended in the instructions as suitable for use with the charger. If more than three manufacturers are recommended, it shall be sufficient to consider only readily available batteries by three major manufacturers.</td></tr>
<tr><td>Manufacturer neither sells nor recommends batteries</td><td>Any and all readily-available batteries made by three major manufacturers and which the charger is capable of charging</td></tr>
<tr><td colspan="2">For any batch charger (whether or not multi-port and whether or not multi-voltage)</td><td>Also include as a separate “associated battery”: every combination of two or more identical batteries (meaning same manufacturer and same model) as determined above, connected in a configuration that the charger is capable of charging.</td></tr>
</table>

Note: Example 1: a AA charger can charge batches of either 2 or 4 AA batteries. It comes packaged with 4 standard AA batteries. The manufacturer also sells high-capacity AA batteries. Result: there are four associated batteries:
2 standard AA
4 standard AA
2 high-capacity AA
4 high-capacity AA
Example 2: Another manufacturer makes a charger that charges batches of 2 or 4 AA batteries, or it can charge 2 C or 2 D batteries. This manufacturer neither sells nor recommends batteries to use with it. A survey of some local retail stores show that manufacturers X, Y and Z are carried at most stores. The survey also finds that: X sells both standard and high-capacity AA batteries and C and D batteries; Y sells one type each of AA, C, and D; Z sells only one capacity of AA batteries. Result: there are twelve associated batteries:
2 standard AA batteries by X
4 standard AA batteries by X
2 high-capacity AA Batteries by X
4 high-capacity AA batteries by X
2 C batteries by X
2 D batteries by X
2 AA batteries by Y
4 AA batteries by Y
2 C batteries by Y
2 D batteries by Y
2 AA batteries by Z
4 AA batteries by Z

2) From the list of associated batteries, technician shall use Table C to select the batteries to be used for testing depending on the type of charger being tested. A charger is considered as:

Single-capacity if all associated batteries have the same rated charge capacity and, if it is a batch charger, all batch configurations have the same rated charge capacity; or Multi-capacity if there are associated batteries or batch configurations that have different rated charge capacities.

In many cases, multiple tests are required with different batteries. Each of these batteries shall be tested at each applicable input voltage and each applicable charge rate, as specified by Part 1, Sections I.D and II.A.

In Table C, below, each row represents a mutually exclusive charger type. Technician shall find the single applicable row for the UUT, and test according to those requirements.

Table C. Battery Selection for Testing

Type of charger			Tests to perform	
Multi-voltage?	Multi-port?	Multi-capacity?	Number of tests	Battery selection (from all configurations of all associated batteries)
No	No	No	1	Any associated battery
No	No	Yes	2	Lowest charge capacity battery
				Highest charge capacity battery
No	Yes	Yes or No	2	Use only one port and use the minimum number of batteries with the lowest rated charge capacity that the charger can charge
				Use all ports and use the maximum number of identical batteries of the highest rated charge capacity that the charger can accommodate
Yes	No	No	2	Lowest voltage battery
				Highest voltage battery
Yes	Yes to either or both		3	Of the batteries with the lowest voltage, use the one with the lowest charge capacity. Use only one port
				Of the batteries with the highest voltage, use the one with the lowest charge capacity. Use only one port.
				Use all ports and use the battery or the configuration of batteries with the highest total rated energy capacity

D. Other Non-Battery-Charger Functions

Any optional functions controlled by the user and not associated with the battery charging process (i.e., a radio integrated into a cordless tool charger) shall be switched off. If it is not possible to switch such functions off, they shall be set to their lowest power-consuming mode during the test. The actions taken by the technician to reduce power use by non-battery charging functions shall be recorded in the report.

If the battery charger unit has other electrical connections associated with its other functionality (such as phone lines, serial or USB connections, Ethernet, cable TV lines, etc.) these connections shall be left disconnected during the testing.

Note: some examples of other functionality are:

Example 1: If there is a radio in the same housing as a tool battery charger, the radio shall be switched off for all the tests. The user is no longer able to listen to the radio, so the only functionality available to the user (to be recorded on the report) is the "On-Off switch for the radio." If the radio also provides a digital clock display that remains operating when the radio is switched off, that shall be noted in the report as well.

Example 2: A cordless phone battery charger also contains the circuitry for monitoring the phone line for a call. This functionality cannot be disabled and so shall be recorded on the test procedure report as "monitoring phone line for incoming call."

E. Duration of the Charging and Maintenance Mode Test

The charging and maintenance mode test, Part 1, Section III.D, shall be 24 hours or longer, as determined by the items below, in order of preference:

1) If the battery charger has an indicator to show that the battery is fully charged, that indicator shall be used as follows: If the indicator shows that the battery is charged after 19 hours of charging, the test shall be terminated at 24 hours. Conversely, if the full-charge indication is not yet present after 19 hours of charging, the test shall continue until 5 hours after the indication is present.
2) If there is no indicator, but the manufacturer's instructions indicate that charging this battery or this capacity of battery should be complete within 19 hours, the test shall be for 24 hours. If the instructions indicate that charging may take longer than 19 hours, the test shall be run for the longest estimated charge time plus 5 hours.
3) If there is no indicator and no time estimate in the instructions, but the charging current is stated on the charger or in the instructions, calculate the test duration as the longer of 24 hours or:

$$\text{Duration} = 1.4 * \frac{\text{RatedChargeCapacity(Ah)}}{\text{ChargeCurrent(A)}} + 5\ \text{Hours}$$

If none of the above applies, the duration of the test shall be 24 hours.

F. Access to the Battery for Discharge Test

The technician may need to disassemble the end-use product to gain access to the battery terminals for the Battery Discharge Energy Test. Manufacturer's instructions for disassembly shall be followed, except those instructions that: a) lead to any alteration of the battery charger circuitry or function or b) that contradict requirements of this test procedure. Care should be taken by the technician during disassembly to follow appropriate safety precautions. If the functionality of the device or of its safety features is damaged, the product shall be discarded after testing.

Some products may include protective circuitry between the battery cells and the remainder of the device. If the manufacturer provides a description for accessing the connections at the output of the protective circuitry, these connections shall be used to discharge the battery and measure the discharge energy. The energy consumed by the protective circuitry during discharge is not to be measured.

If the battery terminals are not clearly labeled, technician shall use a voltmeter to identify the positive and negative terminals. If there are more than two terminals, the additional ones are usually a temperature sensor and/or data lines. Technician shall search for the two terminals that give largest voltage difference and are able to deliver significant current (0.2C) into a load.

If the technician, despite diligent effort and use of the manufacturer's instructions:

a) is unable to access the battery terminals;
b) determines that access to the battery terminals destroys charger functionality; or
c) is unable to draw current from the battery

then the Battery Discharge Energy and the Charging and Maintenance Mode Efficiency shall be reported as "zero." The notes on the report shall describe the problems encountered.

G. Batteries with No Rated Charge Capacity.
If there is no rating for the battery charge capacity on the battery or in the instructions, then the technician shall determine a discharge current which meets the following requirements. The battery shall be fully charged and then discharged at this constant-current rate until it reaches the end-of-discharge voltage specified in Table D. The discharge time must be not less than 4 hours nor more than 5 hours. In addition, the discharge test (Part 1, Section III.F) (which may not be starting with a fully-charged battery) shall reach the end-of-discharge voltage within 5 hours. The same discharge current shall be used for both the preparations step (Part 1, Section III.B) and the discharge test (Part 1, Section III.F). The test report shall include the discharge current used and the resulting discharge times for both a fully-charged battery and for the discharge test.

For this section, the battery is considered as "fully charged" when either (a) it has been charged by the UUT until an indicator on the UUT shows that the charge is complete, or (b) it has been charged by a battery analyzer at a current not greater than the discharge current until the battery analyzer indicates that the battery is fully charged.

Note: When there is no capacity rating, a suitable discharge current must generally be determined by trial and error. Since the conditioning step does not require constant-current discharges, the trials may also be counted as battery conditioning. Further, the preparation step may be used as the proof that a discharge current is suitable, provided that the battery is "fully charged."

III. Measuring the Battery Charger System Efficiency

A. Condition the Battery

No conditioning is to be done on lead-acid or lithium-based batteries.

NiCd or NiMH batteries that have not been previously cycled are to be conditioned as follows: The batteries are to be fully charged and then fully discharged. This cycle is repeated once, then the battery is fully charged again. This amounts to three charges separated by two discharges. Either a battery analyzer or the UUT may be used to perform the battery conditioning.

NiCd or NiMH batteries that are known to have been through at least two previous full charge/discharge cycles shall be charged only once.

Note: The full discharge, which is the battery preparation step, should erase any memory effect in NiCd or NiMH batteries. Any conditioning necessary for lead-acid or lithium batteries is generally done by the manufacturer before the product is packaged.

B. Prepare the Battery for Testing

Prior to testing, the battery shall be discharged. This discharge shall be done using a battery analyzer that draws a constant discharge current of 0.2C. When the battery voltage reaches the end-of-discharge voltage for that battery chemistry or the UUT circuitry terminates the discharge, the discharge shall be terminated by opening the battery circuit.

If the battery has been previously used for testing (for example, testing the charger in another mode) and the battery has just completed the Battery Discharge Energy Test (section VI.F below), that battery may be considered as having just completed this preparation step.

If the discharge time required to reach the end-of-discharge condition is less than 30 minutes, these additional steps shall be taken: The battery shall be recharged to 30% or more of its rated charge capacity. Then the battery preparation shall be conducted again. If the discharge time is again less than 30 minutes, the battery shall be considered defective. Technician shall repeat the test procedure with another suitable battery.

C. Battery Rest Period

The battery or batteries shall be rested between preparation and charging. The rest period shall be at least one hour and not more than 24 hours. For batteries with flooded cells, the electrolyte temperature shall be < 30 ℃ before charging, even if the rest period must be extended longer than 24 hours.

D. Charge Mode and Battery Maintenance Mode Test

The Charge and Battery Maintenance Mode test measures the energy consumed during charge mode and some time spent in the maintenance mode of the UUT. Functions required for battery conditioning that happen only with some user-selected switch or other control shall **not** be included this measurement. (The technician shall manually turn off any battery conditioning cycle or setting.) Regularly occurring battery conditioning/maintenance functions that are not controlled by the user will, by default, be incorporated into this measurement.

During the measurement period, power values shall be recorded at least every minute. If possible, technician shall set the data logging to record the average power during the sample interval. This allows the total energy to be computed as the sum of power samples (in watts) times the sample interval (in hours). If this setting is not possible, then the power analyzer shall be set to integrate or accumulate the input power over the measurement period and this result shall be used as the total energy.

Technician shall follow these steps:

1) Ensure that the battery(ies) used in this test have been conditioned, prepared, and rested as described above.
2) Connect the metering equipment to the battery charger.
3) Ensure that user-controllable device functionality not associated with battery charging and any battery conditioning cycle or setting are turned off.
4) Record the start time of the measurement period, and begin logging the input power.
5) Connect battery(ies) to the battery charger within 3 minutes of beginning logging.
6) After the battery(ies) are in inserted, record the initial time, power (W), power factor, and crest factor of the input current. These measurements should be taken within the first 10 minutes of active charging.
7) Record the input power for the duration of the "Charging and Maintenance Mode Test" period, as determined by Part 1, Section II.E. The actual time that power is connected to the battery charger system shall be within ±5 minutes of the specified "Charging and Maintenance Mode Test" period, as determined by Part 1, Section II.E.
8) During the last 10 minutes of the test, record the power factor and crest factor of the input current.
9) Disconnect power for the battery charger and terminate data logging. Record the final time.

After the measurement period is complete, technician shall determine the average maintenance mode power consumption as follows: Examine the power-versus time data. If the last 4 hours show the power consumption to be steady or slowly varying, use the average power value over the last 4 hours. If the maintenance mode power is cyclic or shows periodic pulses, compute the average power over a time period that spans an integer number of cycles and includes at least the last 4 hours.

E. Battery Rest Period
The battery or batteries shall be rested between charging and discharging. The rest period shall be at least one hour and not more than 4 hours. For batteries with flooded cells, the electrolyte temperature shall be < 30 °C before charging, even if the rest period must be extended longer than 4 hours.

F. Battery Discharge Energy Test
The purpose of this test is to measure the extractable energy from the battery associated with the battery charger system. The battery used in this test shall be the same battery used for previous tests in this section.

If multiple batteries were charged simultaneously, the discharge energy is the sum of the discharge energies of all the batteries:

For a multi-port charger: batteries that were charged in the separate ports shall be discharged independently.
For a batch charger: batteries that were charged as a batch may be discharged individually, as a batch, or in sub-batches connected in series and/or parallel. The position of each battery in the batch configuration need not be maintained.

During discharge, the battery voltage and discharge current shall be sampled and recorded at least once per minute. The values recorded may be average or instantaneous values.

For this test, technician shall follow these steps:

Ensure that the battery has been charged by the UUT and rested according to the procedures above.
Set the battery analyzer for a constant discharge current of 0.2C and the end-of-discharge voltage in Table D for the relevant battery chemistry.
Connect the battery to the analyzer and begin recording the voltage and current.
When the end-of-discharge voltage is reached or the UUT circuitry terminates the discharge, the battery shall be returned to an open-circuit condition. If for any reason, current continues to be drawn from the battery after the end-of-discharge condition is first reached, this additional energy is not to be counted in the battery discharge energy.

The battery discharge energy (Wh) is calculated by multiplying the voltage (V), current (A) and sample period (h) for each sample, and then summing over all sample periods until the end-of-discharge voltage is reached.

Table D: Required Battery Discharge Rates and End-of-Discharge Battery Voltage

Battery Chemistry	**Discharge Rate**	**End-of-Discharge Voltage**
Valve-Regulated Lead Acid (VRLA)	0.2 C	1.75 volts per cell
Flooded Lead Acid	0.2 C	1.70 volts per cell
Nickel Cadmium (NiCd)	0.2 C	1.0 volts per cell
Nickel Metal Hydride (NiMH)	0.2 C	1.0 volts per cell
Lithium Ion (Li-Ion)	0.2 C	2.5 volts per cell
Lithium Polymer	0.2 C	2.5 volts per cell
Rechargeable Alkaline	0.2 C	0.9 volts per cell
Other Chemistries	0.2 C	Per appropriate IEC standard

IV. No-Battery Mode and Off Mode Tests

These tests measure the power consumed by the charger when it is not charging a battery. The tests shall be conducted after the Charging and Battery Maintenance Mode Test (Part 1, Section III.D), while the battery is resting or being discharged.

If Part 1, Section II.C requires testing with more than one battery, the No-Battery Mode and Off Mode tests do not need to be repeated with each battery. If the charger has multiple charging modes, as described in Part 1, Section II.A, the No-Battery Mode Test shall be performed for each mode and at each input voltage (see Part 1, Section I.D). The Off Mode Test needs to be performed only once at each input voltage (see Part 1, Section I.D).

A. Setup

Technician shall determine which of these three categories best describes the product:

1) The charger, the battery, and the product being powered are never disconnected during normal use of the product. There is only a power cord between the power source and the single housing that contains all of these components.

   Examples: Most emergency egress lights, UPSs and standby power supplies, many electric shavers and electric vehicles.

   Note: In these products, it may be possible for the consumer to disconnect the battery for battery replacement, but the battery is not disconnected during normal use.

2) The charger and the product being powered are not connected. The batteries are moved between them for charge and product end use.

   Examples: Many cordless power tools and most AA and universal battery chargers.

3) The battery and the product being powered stay connected during normal use. The product can be readily connected to or removed from a charger or a charging base.

   Examples: most cordless phones, cell phones, laptop computers, and electric toothbrushes, many cordless vacuums and most automotive and golf cart chargers.

   Note: This category applies even if the charge control circuitry is in the device with the battery and the external "charger" is really a constant-voltage power supply, such as most laptop computers.

<u>Category 1 Products</u>

The no-battery test does not apply to products in Category 1. The no-battery mode power shall be reported as "not applicable" (N/A). The off mode test may or may not apply depending on the following:

- If the product does not have an “on/off” switch that turns the charger off, the off mode does not apply. The off-mode power shall be reported as “not applicable.”the off mode power and a separate test shall not be conducted.

  Note: the battery should be resting open circuit at this stage in preparation for the battery discharge energy test of Section VI.F.

Category 2 Products
Both the no-battery mode and off mode tests shall be conducted for products in category 2. After completion of the Battery Charging and Maintenance Mode Test, the batteries shall be removed from the charger and the charger shall be connected to input power. Do not change any settings or controls on the charger for the no-battery mode test.

Category 3 Products
Both the no-battery mode and off mode tests shall be conducted on products in category 3. After completion of the Battery Charging and Maintenance Mode Test, set up the product for the no-battery mode test as follows:

- If the product has a charging base: the portable device shall be removed from the charging base and the charging base shall be connected to input power. If the charging base uses an EPS, the EPS shall be connected to input power and to the charging base.
- If the product does not have a charging base but does have an external charger or an EPS: the product shall be disconnected from the charger or the EPS. The charger or EPS shall be connected to input power.

Technician shall not change any settings or controls on the charger or charging base for the no-battery mode test.

B. No-Battery Mode Test

1) After connecting and powering the UUT in its no-battery mode setup, allow it to operate for at least 30 minutes.
2) Integrate the energy consumed over a time period of at least 10 minutes,
3) Record the power factor and the crest factor of the input current at some time during or after the 10-minute period.
4) Divide the energy (Wh) by the integration time (in hours) to get the No-battery Mode Power (W).

C. Off Mode Test

If there is not an “on/off” control which turns the battery charger off, the Off Mode Test is not applicable. In this case, report the Off Mode power, power factor, and crest factor as “not applicable” (N/A). If there is an “on/off” control for the charger, perform the following steps:

1) After completion of the No-Battery Test, if applicable, set the “on/off” control in the “off” setting.
2) Allow the charger to operate for at least 30 minutes.
3) Integrate the energy consumed over a time period of at least 10 minutes,
4) Record the power factor and the crest factor of the input current at some time during or after the 10-minute period.
5) Divide the energy (Wh) by the integration time (in hours) to get the Off Mode Power (W).

V. Reporting Requirements

The following information shall be recorded about each UUT and each test performed. Quantitative values shall be reported to the precision of the measurement, not rounded by technician.

A. General

1) Name of technician performing the test
2) Organization performing the test
3) Location of the test (physical address)
4) Time and date of each test
5) Make and model of measurement equipment
6) Input power voltage (V)
7) Input frequency (hertz), if ac
8) Manufacturer and model number of battery charger
9) Other functionality of battery charger, if any (see section V.D for more details)
10) Manufacturer and model number of battery
11) Standard size or type of battery (AA, C, D, etc.) if applicable
12) Number of batteries employed in the test
13) Battery chemistry
14) Rated battery voltage (V)
15) Rated battery capacity (Ah or mAh)
16) Any information provided by the manufacturer regarding access to the battery, particular safety requirements, etc.
17) Whether the battery charger system is detachable, integral, swappable, or does not meet any of these definitions.
18) Whether the battery charger system includes a cradle.

B. Charge and Maintenance Mode Test

1) Total charger input energy (Charge and Maintenance Energy) accumulated over the entire duration of the test (Wh)
2) The total time duration of the charging test (at least 24 hours)
3) Average power during maintenance mode (W)
4) The time duration used for the maintenance mode power (at least 4 hours)
5) True power factor at beginning and end of the charge test
6) The crest factor of the input current at the beginning and end of the charge test
7) The length of the rest period before charging (hr:min) and, if applicable, the electrolyte temperature at the beginning of charging (℃).
8) Sample rate used during test(s)

9) The steps taken, if any, to turn off or reduce the power consumption of other functionality and a description of the other functionality that could not be turned off, if any.

C. Battery Discharge Test

1) Energy delivered during discharge (Wh)
2) Starting battery voltage (V)
3) Ending battery voltage (V)
4) The length of the rest period before discharge (hr:min) and, if applicable, the electrolyte temperature at the beginning of discharge (℃)
5) Sample rate used during test(s)
6) A brief description of the steps taken, if any, to gain access to the battery terminals.

D. No-Battery Mode and Off Mode Tests

1) Category of product
2) Average no-battery mode power (W)
3) No-battery mode power factor and input current crest factor
4) Average off mode power (W)
5) Off mode power factor and input current crest factor

E. Additional Information

1) Any observations, notes or comments by the lab technician, in general or as required for certain special cases and exceptions.

PART 2:

I. Standard Test Conditions:

A. Measuring Equipment

The following minimum list of test equipment is recommended.

1) Power meter (AC and DC) with kWh integration and with a sampling rate of at least 128 samples per cycle.
2) Power analyzer integrated with data logger (for continuous recording of Total Harmonic Distortion & Power Factor).
3) An ampere-hour counter or meter on the battery side.
4) A device to discharge a battery at a specified rate and duty cycle down to a specific depth of discharge. This can be a battery cycler, load bank, or vehicle driving a repeatable cycle.
5) Personal computer.
6) Thermometers – for ambient and battery conditions.
7) Barometer – for environmental pressure.
8) Hygrometer – for environmental humidity.
9) Temperature compensated specific gravity meter – used to verify condition and state of charge of a flooded, lead-acid battery.
10) Volt meter.
11) Timer.
12) AC current measurement (for verification only).

Note: the state of health of the battery must be ascertained. The battery must be in a state of condition to provide a minimum of 80% of nameplate capacity at the nominal rate in order to be used in this test procedure, and must maintain that level of health throughout the procedure. To determine state of health, have the battery certified by a qualified agency, or perform the state of health verification per BCIS-14 (see References). For electric vehicle batteries, see *USABC Electric Vehicle Battery Test Procedures Manual* in References Section.

B. Equipment Tracking and Accuracy

All equipment used to conduct the tests must be identified and recorded by tracking or serial number. It is recommended that equipment be calibrated and traceable to the National Institute of Standards and Technology (NIST) standards and meet the intent of ANSI/NCSL Z540-1-1994. Each reported (voltage, power, energy, temperature, etc.) measurement should have an associated accuracy less than or equal to 1% of the value. Total measurement uncertainty should be calculated according to standard methods.

C. Nameplate Data and Operational Considerations

Nameplate data and operational characteristics of all devices under test will be recorded, along with test equipment ID and calibration date. Pertinent charger observations, or accompanying instructional manual descriptions should also be recorded on the test forms. A sample form is given in the appendix

D. Input Reference Source: Input Voltage and Input Frequency

In order to help separate the local infrastructure effects on the readings, follow these guidelines to ensure accurate power quality assessment:

1) Test voltage harmonic distortion: Must be less than 2% total under normal operating conditions, from no load to full load.
2) Voltage (RMS) Tolerance: ± 3%
3) Frequency: 50 or 60 Hz ± 2%

II. Battery Charger System Setup Requirements

A. Charger/Battery Selection and Qualification

A battery and charger combination to use for the test must be selected and qualified. A sufficient statistical sample should be evaluated for each model or family of models (for example, grouped by topology-- high frequency, ferro-resonant, silicon-controlled rectifier, etc.—and including the highest and lowest cell count for each topology). The battery should be matched to the charger capabilities. If the charger is capable of charging a range of battery sizes, test both the highest and lowest capacity values, as well as the highest and lowest voltage levels for the battery, if applicable.

Determine that the charger/battery system performs in a way that charges the battery properly and maintains the health of the battery by reading the specifications and operational parameters and verifying with the manufacturers of both the battery and the charger that they are compatible and effective as described in BCIS-16 (see References Section). Report the specifications and operational parameters, of both the battery and the charger, regarding periodic equalization, as published by the manufacturers. Verify from the information provided by the BCS manufacturer, that the charger, or charger/battery system, performs regular equalization in a way that maintains the health of the battery, i.e. verify that the battery used in the test is appropriate for the BCS being tested according to the manufacturer. Have the battery certified, or perform the state of health verification per BCIS-14 (see References).

B. Nameplate Data Collection

Record all nameplate data from the charger and battery. Record the ID of all test equipment along with calibration date. Documentation of operational characteristics, manuals, if any, of all devices under test will be retained. Pertinent charger observations should also be recorded on the test forms.

C. Battery Conditioning

After receiving a qualified battery (see the note in Part 2, Section I.A., above) conduct some preparatory cycles on the battery and charger. This is for battery conditioning in the test environment, as the performance can change for various reasons. The battery should be depleted by driving or other means of discharge to roughly 80% depth of discharge, and then recharged with the charger under test. Do this three times. If available per manufacturers instructions, one of those times should include the equalization cycle. Rest time should be included to avoid overheating the battery (according to battery specifications). The final full charge must be completed within

24 hours of beginning the discharge test procedure. Record environmental parameters at the beginning and end of each charge and discharge.

D. Battery Preparation

The discharge test must be begun no sooner than 3 hours, and no more than 24 hours after the last full charge.

Verify full charge of the battery using one of two methods:

1) Flooded batteries – At least one hour after the full charge is completed, and before beginning the discharge test, take temperature-compensated specific gravity measurements of the electrolyte in each cell, and ensure that the specific gravity corresponds to full charge according to the battery manufacturer's specifications.
2) Valve regulated batteries (VRLA) – At least one hour after the full charge is completed, take voltage measurements and ensure that the voltage corresponds to full charge according to the battery manufacturer's specifications.

Measure the temperature of the electrolyte (preferred, for flooded batteries, or negative terminal post for VRLA batteries). The battery temperature at the start of discharge must be between 17oC and 33oC. Configure the battery (or pack) with the appropriate data acquisition equipment to record voltage and current at 1 minute intervals.

E. Charger Preparation

The charger should be in proper working condition, and connected and adjusted properly for the battery and the utility, as verified in the battery preparation process. Configure the data acquisition equipment on both the input and the output side of the charger to measure AC and DC power and power quality. Set up to record the DC power for the entire charge to view the charge profile.

It is important to locate the PQ monitoring device as close as possible to the tested charger, but avoid being too close to service entrance equipment such as step-down transformers or UPS equipment. The monitoring device must see the same electrical variations the charger does. Harmonic content, in particular can be significantly different if there is a large separation between the monitor and the charger. The monitoring equipment should be placed after any circuit protection device, and as close as possible to the charger.

III. Test Procedure: Part 2

A. Testing Sequence

1) Assure compatibility and effectiveness of charger/battery combination
2) Receive certified battery to be used for the procedure
3) Record Nameplate and equipment data
4) Set-up test
5) Prepare battery with preliminary cycles
6) Discharge battery – 3 scenarios
7) Charge battery – 3 scenarios
8) Monitor Battery Charge Maintenance – 72 hours
9) Monitor "No-Battery" state – 1 hour
10) Compile data and analyze
11) Report

B. Test Data

The following minimum data is recommended.

<u>AC Input Data</u>

AC power at peak power
Total energy consumption
True power factor
Voltage and current total harmonic distortion

<u>DC Output Data</u>

DC power at peak power
Total energy delivered
Ampere-hours delivered

<u>Battery Data</u>

Battery temperature
Battery voltage
Specific gravity at start
Ampere-hours discharged

<u>Environmental</u>

Temperature
Humidity
Pressure

C. Battery Discharge/Recharge Sequence

The discharge/recharge sequence is completed at three different levels of battery discharge: fully discharged, 40% depth of discharge (DOD), and 80% DOD. After the proper amount of rest and within temperature limits, according to Part 2, Section II.D, proceed with the battery discharge. After each discharge (as in Part 2, Section III.C.1), recharge the battery (as in Part 2, Section III.C.2.).

1) **Battery Discharge**

Using a battery cycler or load bank, discharge the battery pack at a constant nominal current rate ± 3% (C_6/6 for lift truck batteries, C_5/5 for golf cart-type batteries, unless specified otherwise by the battery manufacturer) (measured with an accuracy of 1%) to 100% DOD, or upon reaching the cutoff voltage (as specified in Part 1, Section III.F. "Table D" of this Test Procedure). Measure and record the following data on the data sheet:

- Initial and final:
  - Time
  - Voltage
  - Battery temperature
  - Ambient conditions
- Discharge rate or type
- Total ampere-hours discharged.

Repeat this Battery Discharge Test sequence (after recharging according to Part 2, Section III.C.2.) by discharging the battery to each of the following levels and then recharging:

- 40% DOD of measured charge capacity (within ± 10%) as determined by voltage reading on vehicle gauge, ampere-hour counter, specific gravity measurements, or discharge meter reading of ampere-hour capacity.
- 80% DOD of measured charge capacity (within ± 10%) as determined by voltage reading on vehicle gauge, ampere-hour counter, specific gravity measurements, or discharge meter reading of ampere-hour capacity.

2) **Battery Recharge**

During the recharge test, the ambient environment should be maintained between 18^{o}C and 27^{o}C. The battery recharge must start within 1 to 6 hours of the completion of the discharge, depending on the temperature of the battery. Measure and record the following data on the data sheet:

- Initial and final:
  - Time
  - Voltage
  - Battery temperature
  - Ambient conditions

For a valid test, the battery temperature during charging (as measured in Part 2, Section II.D.) must be between 18^{o}C and 46^{o}C.

The equalization phase of the charger should be disabled, if possible. If the equalization phase is carried out, this will be noted, but the results will not be saved under this section.

Start the recharge. After five minutes, record the AC and DC power. Record the total power factor, current THD, and voltage THD. Repeat these measurements after one hour, three hours, and five hours. The five-minute, one-hour, three-hour, and five-hour measurements are taken for the full discharge test only.

After each battery recharge is complete (noted by charger indicators, and verified by DC current measurement below 2% of the battery rated capacity) verify the full charge of the battery with specific gravity and temperature measurements, as in Part 2, Section II.D. Record the total energy and ampere-hours delivered from the output of the charger to the battery. Record the total AC energy consumed by the charger.

The discharge/recharge sequence is completed at three different levels of battery discharge, as described in this Section III.C of Part 2. The charge return factor is obtained by dividing the number of ampere-hours returned to the battery pack during the charge cycle (but not an equalization charge) by the number of ampere-hours delivered by the battery pack during discharge.

D. Battery Maintenance Charge Test

After completing the battery charger test, leave the battery connected and leave test equipment recording data for a 72-hour period and record data at 1-minute intervals. Determine the power and amount of AC kWh drawn by the battery charger and the amount of DC kWh delivered by the battery charger to the battery pack, and the frequency and duration of any intermittent activity over the period. Note energy consumption by any auxiliary systems, such as a thermal management system maintaining the temperature of the battery. “No Battery losses,” if any (next section) will be included by the nature of the test, but listed separately from the results of this test.

E. Charger No-Battery Test

With the battery disconnected from the charger, and the charger connected to AC power, measure the demand of the charger on the AC side for a period of up to one hour, depending on the nature of the demand (instantaneous if steady, long enough to characterize if intermittent).

IV. Reporting Requirements

A. Task List

- Determine the power conversion efficiency at peak power (DC kW / AC kW)
- Plot the battery charging profile (submit on Battery Charging Profile worksheet)
- Determine the charge return factor at low, medium, and high starting SOC (optional).
- Report power factor at five minutes, one hour, three hours and five hours
- Report current and voltage THD at five minutes, one hour, three hours and five hours
- Determine character and energy of maintenance mode
- Report No-Battery power level (if constant) and 24-hour calculated energy loss

B. Battery Charging Profile

The battery charging profile will show the characteristics of the charge and whether any anomalies (such as equalization) occurred.

C. Charging Parameters

Power Conversion Efficiency
From the collected AC and DC power data, calculate the power conversion efficiency for the battery charger by dividing the DC kW delivered to the battery at peak power, by the simultaneous AC kW demanded by the charger. The greatest impact of poor power conversion efficiency is during the highest power portion of the charge, so that is of highest value. In general, the power conversion efficiency should be relatively constant throughout the charge.

Charge Energy Management
Determine the charge return factor by dividing the number of ampere-hours returned to the battery pack during the charge cycle by the number of ampere-hours delivered by the battery pack during discharge. This is calculated for all three depth of discharge levels tested.

Periodic Equalization Strategy
Report the documentation that shows battery/charger compatibility and effectiveness.

Power Factor
True power factor is the ratio of total active power for all frequencies to the apparent power delivered by the utility.

Harmonic Distortion
Document the total harmonic current distortion (THDI) and total harmonic voltage distortion (THDV) recorded on the battery charger/utility system at full power, mid- and low-power levels.