TEST METHODOLOGY FOR DETERMINING THE ENERGY PERFORMANCE OF BATTERY CHARGING SYSTEMS

December 2005

1.0 Scope

This document specifies a test procedure for determining the Energy Ratio (ratio of energy used to maintain a battery and operate a charger, normalized to stored battery energy) of devices that charge and maintain secondary batteries. This document applies to the testing of a wide range of products such as power tools, small household appliances, floor care products, flashlights, and other devices using battery charging systems. For ENERGY STAR® qualification, please refer to the ENERGY STAR Eligibility Criteria for Products with Battery Charging Systems (BCS) to determine product eligibility and performance requirements.

External power supplies fitting the definition contained in **ENERGY STAR Program Requirements for Single Voltage External Ac-Dc and Ac-Ac Power Supplies** are not covered in this procedure, even if they are primarily used to charge a battery.

2.0 References

The following documents were used in the development of this test specification.

International Electrotechnical Commission, *Household Electrical Appliances - Measurement of Standby Power*, IEC 62301

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

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

International Electrotechnical Commission, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells – Part 1: Nickel-metal hydride*, IEC 61951-2

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

Linden and Reddy, *Handbook of Batteries, Third Edition*, McGraw Hill. New York, NY. 2002.

3.0 Definitions

Unless otherwise specified, all terms used in this document are consistent with the definitions contained in the ENERGY STAR® Eligibility Criteria for Products with Battery Charging Systems (BCSs).

C-Rate

C-rate is a charge or discharge current normalized to battery capacity. A charge or discharge rate of one C draws a capacity equal to the battery capacity in one hour. For example, a rate of C/2 for a 1.2 amp-hour battery is 0.6 amps, a one C rate is 1.2 amps, and a 2C rate is 2.4 amps.

End-of-Discharge Voltage

The specified closed circuit voltage at which discharge of a battery is terminated.

4.0 Standard Testing Conditions

4.1 Supply Requirements

The following requirements shall apply to the power source from which the unit under test (UUT) derives its operating energy for the test.

4.1.1 Voltage

The power supply shall provide stable voltage at nominal +/- 1% with total harmonic content less than 2% (as specified in IEC 62301). The crest factor of the voltage waveform must be between 1.34 and 1.49.

4.1.2 Frequency

The power supply shall provide stable output power at a frequency of nominal +/- 1%.

4.2 Ambient Requirements

The following requirements apply to the room or immediate environment in which the testing is conducted.

- Air speed shall be <0.5 m/s.
- Ambient temperature shall be maintained at 23 +/-5 degrees Celsius.

4.3 Measurement and Instrumentation Requirements

All measuring equipment used must be calibrated according to manufacturer recommendations.

4.3.1 Precision Requirements

Measurement of energy consumption shall be made with a precision equal to the greater of 0.1 Watt-hour or 1% of full-scale measurement.

4.4 UUT Requirements

Both the UUT and the associated battery shall be new products, representative of the type and condition of product that a consumer would purchase in a retail setting. The battery(ies) shall have experienced no more than 5 complete charge/discharge cycles prior to testing.

5.0 Determining BCS Energy Ratio

Testing shall be conducted with the following steps. Note that there are two discrete testing procedures provided below: an abbreviated and full test methodology. The abbreviated test method may be conducted in cases where the UUT's energy consumption in both maintenance and standby modes does not vary significantly over time. Specifically, all maintenance and standby functions must occur at the same magnitude and frequency for as long as the device remains in that mode in order for the abbreviated test to be applicable. Products utilizing a current pulse to maintain charge are not precluded from using the abbreviated method, so long as the magnitude and frequency of the pulse remain constant indefinitely while in both maintenance and standby modes. Those wishing to use the abbreviated test must submit a written statement indicating that the UUT qualifies for the abbreviated test methodology and include this documentation with the test report.

5.1 Measuring Nonactive Energy

In cases of dispute/verification, and in any case but the specific cases stated in Section 5.2 below, the full test method shall be used. Testing shall commence with a fully discharged battery, consistent with end of discharge voltages specified in Table 1.

Table 1. End of Discharge Voltage by Chemistry

Battery Chemistry	End of Discharge Voltage
Nickel-based (NiCD/NiMh)	1.0V/cell (IEC 61951)
Lead Acid (all types)	1.75V/cell
All Others	Follow manufacturer specifications

1. Charge battery with the UUT for the period specified by the UUT manufacturer as the time needed to fully charge the battery under test. All limited time functions used to deliver the primary charge to the battery, including cell equalization, are to be excluded from the measurement of battery maintenance mode. If these events are known to occur for a time period beyond the manufacturer specified charge time, the battery is to be left in place until all such functions are complete. In cases where no charge time is specified, the battery(ies) is to be charged for a period of at least 24 hours.
2. At the end of this period, begin measurement of energy used by UUT for battery maintenance mode. If the UUT is disconnected from AC input power during this time (e.g., to move it from a charging station to a metering station) then the UUT and battery must be connected to the AC mains for not less than 15 consecutive minutes prior to the start of the maintenance mode measurement. The time that the UUT spends disconnected from the AC mains between charging and

measuring of battery maintenance mode energy shall not exceed 1 hour. Testing shall proceed according to one of the following methods:

a. Full Test - Continue measurement for a period of 36 hours (+/- 1 minute). It is acceptable to meter for longer and to only use the first 36 hours of the collected data. Energy use may be measured as a time series integral of power or as an accumulated watt-hour total.
b. Abbreviated Method - Measure energy consumption for at least 6 hours. Energy use may be measured as a time series integral of power or as an accumulated watt-hour total, extrapolated to 36 hours.

3. Remove battery from charger and continue measurement of standby power using one of the following options:
    a. Full Test - Measure energy used for 12 hours (+/- 1 minute). It is acceptable to meter for longer and to only use the first 12 hours of the collected data. Energy use may be measured as a time series integral of power or as an accumulated watt-hour total.
    b. Abbreviated Method - Measure energy used for a period of not less than 1 hour. Energy use may be measured as a time series integral of power or as an accumulated watt-hour total, extrapolated to 12 hours.

    Note: For some types of cord/cordless products, the charging circuitry is contained within the device itself and the only detachable part of the system is an AC power cord. In this case, the standby power/energy is zero, since the product/charger will draw no power when the battery is not being either charged or maintained. This does not apply to cradle products with a separable cord, as the cradle may still draw some power when the device/battery is removed.
4. Add the accumulated energy values obtained for the two periods to calculate the nonactive energy use for the period.

5.2 Exceptions and Special Cases

Multi-Voltage A La Carte Chargers: For chargers that are capable of charging different voltage batteries and are separately packaged without batteries or a product, the test procedure must be repeated using three batteries manufactured or produced by the UUT manufacturer for use with the UUT. The test must include the batteries with both the highest and lowest nominal battery energy (watt-hours) that are manufactured for use with the UUT. The Energy Ratio is then determined by taking the sum of the accumulated energy drawn in the three tests and dividing by the sum of the battery energies for all of the batteries tested (see Section 5.4, Table 1, Equation 2). To determine ENERGY STAR qualification, this Energy Ratio is then compared to the specification at the arithmetic average voltage of all batteries tested.

Multi-Port Chargers: For chargers with multiple charging ports, the maximum number of identical batteries the charger can accommodate will be used in place of the single battery indicated throughout this test procedure. The Energy Ratio is then calculated by dividing the accumulated energy drawn during the test by the sum of the battery energies for all of the batteries tested (see Section 5.4, Table 1, Equation 3). Chargers with batteries charged in series will be qualified using the highest voltage corresponding to the sum of

the battery voltages charged in series. For example, a charger that charges 4 single cell NiCd batteries in series would be treated as if charging a single 4.8V battery for purposes of determining ENERGY STAR qualification.

For those multi-port chargers that are also multi-voltage, the measured Energy Ratio and specification level should be determined using the multi-voltage a la carte method, except the maximum number of identical batteries the charger can accommodate should be used for each test (consistent with the single voltage multi-port charger method). In other words, the UUT must be tested with three full sets of identical batteries, including batteries with both highest and lowest battery energies (watt-hours).

5.3 Measuring Battery Energy

Measurement of battery energy shall be conducted according to IEC 61951-1 for nickel cadmium cells, IEC 61951-2 for nickel metal hydride cells or IEC 61960 for lithium cells. For other cell chemistries, measurement of battery energy shall be conducted according to an equivalent, industry-accepted standard.

The battery shall be charged, according to Section 5.1 of this test methodology. After charging, the battery shall be stored in an ambient temperature of 20 °C ± 5 °C for not less than 1 hour and not more than 4 hours. The battery shall then be discharged in an ambient temperature of 20 °C ± 5 °C at a rate of 0.2C, where C is the rated Ampere-hour capacity of the battery. The test shall continue until the battery pack reaches its end of discharge voltage, according to Table 1.

During this period, voltage shall be logged, integrated at the end of discharge, and multiplied by the discharge rate to obtain battery energy. The test may be repeated a maximum of 5 times, as in IEC 61951, with the best result being chosen as the final measured energy value.

5.3.1 Battery Conditioning

Prior to testing, a battery may undergo a maximum of 5 charge/discharge cycles. These cycles are optional and must be completed according to the charge (Section 5.1) and discharge (Section 5.3) procedures outlined in this test procedure. At the conclusion of the conditioning process, the battery shall be in a discharged state, consistent with Table 1.

5.4 Obtaining Energy Ratio

Energy Ratio shall be calculated with the following equations found in Table 2. The reference voltage is the voltage used to determine the maximum allowable Energy Ratio per the ENERGY STAR Eligibility Criteria for Products with Battery Charging Systems (BCSs).

Table 2. Energy Ratio Equations

Equation	Energy Ratio Formula	Reference Voltage (V)
1. Normal (Single Battery)	$ER = \frac{\text{Nonactive Energy}}{\text{Battery Energy}}$	$V = V_{Battery}$
2. Multi-Voltage A La Carte	$ER = \frac{\sum \text{Nonactive Energies}}{\sum \text{Battery Energies}}$	$V = V_{Average}$*
3. Multi-Port	$ER = \frac{\text{Nonactive Energy}}{\sum \text{Battery Energies}}$	$V = V_{Single\ Pack}$*

* Voltage of Batteries in series shall be treated as a single battery with a voltage equal to the sum of all batteries in series for all analysis.

6.0 Reporting Requirements

The following fields (at a minimum) must be reported in the test report. Please note that these requirements are in addition to, and not replacements to, the requirements set forth in the ENERGY STAR Partnership Agreement documents.

- Battery Energy (with test results attached)
- Maintenance Mode Energy
- Standby Energy
- Total Nonactive Energy
- Energy Ratio
- Battery Voltage (nominal)
- Manufacturer/Model Number of Battery/Charger/Product
- Testing Technician and Laboratory
- Statement of Qualification for Abbreviated Test Method (if applicable)
- List of all currently manufactured batteries rated for use with UUT
- List of batteries tested with UUT

7.0 Acknowledgements

Special thanks to the International Electrotechnical Commission (IEC) for permission to reproduce extracts from page 7 of its International Standard IEC 62301 1st edition 2005-06 Household electrical appliances - Measurement of standby power.