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Material Handling (Industrial Truck) Battery Chargers

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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Foreword

User input has been considered throughout the development of this standards publication.

These standards have been developed by the Industrial Battery and Charger Section of NEMA which periodically reviews them for any revisions necessary to keep them up-to-date with advancing technology. Comments or proposed revisions are welcomed and should be submitted to:

Manager, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
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Purpose

The purpose of this standards publication is to provide practical information concerning the construction, test performance and safety of industrial truck battery chargers. The performance and safety tests included in this document form a part of the attempt to provide protection for the operator, the battery and the battery charger.

Scope

This standards publication covers semiconductor rectifying battery chargers which are intended to recharge lead-acid cycling-type batteries (commonly called "industrial batteries") used in applications such as:

1. Material handling trucks
2. Floor sweepers
3. Push or pull tractors
4. Cranes

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Section 1
DEFINITIONS

The terms in Section 1 are defined as they apply to the battery chargers covered in this standards publication. Definitions marked with an asterisk (*) are in accordance with IEEE "Standard Dictionary of Electrical and Electronic Terms" ANSI/IEEE Std. 100-1977.

AMBIENT TEMPERATURE
The temperature of the surrounding medium that comes into contact with the device or equipment.

AMPEREHOUR CAPACITY
The number of amperehours which a storage battery can deliver under specified conditions such as temperature, rate of discharge and final voltage. For the purpose of this standard ampere/hr capacity is determined by a six hour discharge cycle.

AUDIBLE NOISE
The sound level produced by the battery charger, measured in decibels.

BATTERY CHARGER
An apparatus used to recharge a storage battery.

CHARGE*
The conversion of electrical energy to chemical energy within a battery.

CHARGING RATE*
The current, expressed in amperes, at which a battery is charged.

CHARGER EFFICIENCY
The DC output in watts divided by the AC input in watts, expressed in percent.

CHARGER POWER FACTOR
The input in watts divided by the input volt ampere product.

CONSTANT CURRENT CHARGE*
A charge in which the current to the battery is maintained at a constant value.

CONSTANT POTENTIAL CHARGE
A charge in which the voltage or potential at the output terminals of the battery charger is maintained at a constant value.

DISCHARGE RATE (6-HOUR)
Rated amperehour capacity of the battery divided by 6 hours.

DISCHARGED BATTERY
A battery is said to be discharged when, after being fully charged, it is discharged at a six-hour rate to a final average cell voltage under load of 1.70 volts per cell. The electrolyte temperature at start of discharge shall be 25°C (77°F).

EQUALIZING CHARGE
A prolonged charge, usually at the finishing rate or less, that is delivered to a storage battery to correct any inequalities in voltage and specific gravity which have developed between the cells during service.

FINISHING RATE
The rate of charge, expressed in amperes, to which the charging current is reduced near the end of a charge.

INDUSTRIAL STORAGE BATTERY
A battery which is designed for cycling service to provide power for material handling trucks, tractors, etc., and which is rated in number of cells and in amperehours delivered at the six-hour discharge rate.

LIVE PART
For the purpose of this standard a live part is one which has an open circuit potential exceeding 30 volts rms (42.4 volts peak) and which will deliver more than 0.75 milliampere to ground through a noninductive 2000-ohm resistor.

NOMINAL VALUE
An arbitrary reference value which is selected to establish equipment ratings.

RMS (ROOT MEAN SQUARE) VALUE
The effective value of an alternating current that corresponds to the direct-current value which produces the same heating effect.

SHORT-CIRCUIT CURRENT
The current magnitude at the output terminals when the terminals are short-circuited and nominal input voltage is supplied to the battery charger.

START RATE
The initial rate of current, expressed in amperes, delivered to a discharged storage battery.

TAPER CHARGE
The reduction of the charging current to a storage battery as the battery potential rises.

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Section 2
COMPONENTS

2.1 GENERAL

All component parts shall be operated within their design ratings.

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2.2 COMPONENTS

The battery charger shall contain at least the following components:

1. Semiconductor rectifying elements.
2. Means to protect the semiconductor rectifying elements from transient overvoltages. The necessary transient protection will depend upon the specific power circuit design and the particular power components that have been selected.
3. Transformer to electrically isolate the battery being charged from the alternating-current source.
4. Means for manually terminating the charging current.
5. A device for automatically disconnecting the battery charger from the battery if the alternating-current supply is interrupted or if the charging current is terminated. This device is required if the reverse direct current exceeds 0.2 percent of the starting rate.
6. A direct-current ammeter of the average reading type or other means of indicating charger operation.
7. Input and output overcurrent protective devices.
8. Means for resuming the charger cycle automatically from the point of interruption when the alternating-current power is restored following an interruption.
9. (In battery chargers that utilize forced air cooling) means to shut down or otherwise limit the output current from the charger if and when the component temperatures exceed safe operating values.

Component parts that are expected to be replaceable in the field shall be capable of being removed and replaced with hand tools.

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Section 3
RATINGS

3.1 OUTPUT CURRENT RATINGS

3.1.1 Charging Rate

The charger output current shall not exceed a value which will cause an increase in battery temperature of more than 30°F during the charge.

3.1.2 Finishing Rate

The finishing output current shall not exceed 5 amperes for each 100 amperehours of the rated amperehour capacity of the battery.

NEMA Standard 1-12-1983.

3.2 OUTPUT VOLTAGE RATINGS

The output voltage ratings of battery chargers shall be determined by the product of the nominal voltage of the battery cells (2 volts per cell) and the number of series-connected cells in the battery.

NEMA Standard 1-12-1983.

3.3 ALTERNATING-CURRENT SUPPLY VOLTAGE

The nominal ratings of the 60 Hz alternating-current supply voltage shall be:

1. Single Phase - 120, 208, 240, 277, 480 or 575 volts.
2. Three Phase - 208, 240, 480, or 575 volts.

NEMA Standard 1-12-1983.

The manufacturer should be consulted for operation on other voltages.

Authorized Engineering Information 1-12-1983.

3.4 ALTERNATING-CURRENT FREQUENCIES

The nominal ratings of the alternating-current supply frequency shall be 50, 60 or 400 hertz (Hz).

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The manufacturer should be consulted for operation on other frequencies.

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Section 4
PERFORMANCE

4.1 CLASSIFICATIONS

Battery chargers shall be of one of the following classes:

1. NEMA Class AR - automatically line compensated, load regulated.
2. NEMA Class MR - manually (tap changing) line compensated, load regulated.

NEMA Standard 1-12-1983.

4.2 INPUT SUPPLY VOLTAGE RANGES

With alternating-current supply voltages within the range shown in Table 4-1, with output currents in accordance with 3.1, and with service conditions in accordance with 4.3, battery chargers shall be capable of performing without the operation of protective devices and without the need for manual tap changes for Class AR chargers and with manual tap changing for Class MR chargers.

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Table 4-1
60 Hz ALTERNATING-CURRENT SUPPLY VOLTAGES, (Volts)

Nominal Voltage	Minimum	Maximum
120	106	127
208	184	220
240	212	254
277	245	293
480	424	508
575	508	600*

4.3 USUAL SERVICE CONDITIONS

Usual service conditions shall include:

1. Ambient air temperature at the equipment between 0°C (32°F) and 40°C (104°F).
2. Altitudes not exceeding 1000 meters (3300 feet) above sea level.
3. Alternating-current supply voltages given in 3.3 and Table 4-1.
4. Alternating-current supply frequencies given in 3.4

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4.4 UNUSUAL SERVICE CONDITIONS

The following unusual service conditions may require specific design considerations and should be brought to the attention of the manufacturer:

1. Exposure to damaging fumes (corrosive air contaminants)
2. Exposure to excessive moisture
3. Exposure to excessive dust
4. Exposure to abrasive dust
5. Exposure to steam
6. Exposure to oil vapor
7. Exposure to explosive mixtures of dust or gases
8. Exposure to salt air
9. Exposure to outdoor use
10. Exposure to abnormal vibration, shocks or tilting
11. Exposure to dripping water
12. Exposure to unusual transporation or storage
13. Unbalanced alternating-current voltages
14. Departure of alternating-current system voltages from a substantially sinusoidal waveform
15. Input supply voltage outside ranges shown in Table 4-1
16. Departure by more than 0.2 percent from the nominal alternating-current supply frequency
17. Operation in ambient temperatures higher than 40°C (104°F) or below 0°C (32°F)
18. Operation at altitudes more than 100 meters (3300 feet) above sea level
19. Batteries with electrolyte temperatures below 10°C (50°F) or higher than 46.1°C (115°F).

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4.5 CHARGING CURVE

4.5.1 A charging curve, if published, shall be based on amperes/100 amperehours of the amperehour capacity and volts per cell; at an initial battery temperature of 25°C (77°F); shall show the typical performance of the battery charger at nominal input voltage, and shall include the following:

1. Direct current output current (amperes/100 amperehours of the amperehour capacity) versus time.
2. Direct current voltage (volts per cell) versus time.
3. Percent of amperehours returned versus time.
4. Electrolyte temperature versus time.
5. Specific gravity versus time, temperature corrected to 25°C (77°F).

4.5.2 The battery used for the charging curve test shall have the same amperehour capacity rating as the charger used. The charger shall be capable of returning in eight hours or a specified number of hours, at least 105 percent of the ampere hours removed from the battery after it has been discharged 100 percent and no more than 115 percent of the ampere hours removed after it has been discharged 80 percent. Both requirements shall be met with charger controls identically set.

* Certain kinds of control and protective equipment presently available have a maximum voltage limit of 600 volts; the manufacturer or power supplier, or both, should be consulted to assure proper application. (This note is classified as Authorized Engineering Information 1-12-1983.)

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4.5.3 The battery charger shall be capable of providing an equalizing charge, except when not recommended by the battery manufacturer.

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4.6 BATTERY ELECTROLYTE TEMPERATURE

A battery charger shall not cause the electrolyte temperature of a battery which is matched to its rating to exceed 46.1°C (115°F) based on an initial battery electrolyte temperature of 29.4°C (85°F) prior to charging.

NEMA Standard 1-12-1983.

The battery electrolyte temperature directly affects battery life. Initial electrolyte temperatures above 29.4°C (85°F) can be expected to cause the maximum temperature to exceed 46.1°C (115°F) during charging and should be avoided.

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Section 5
SAFETY REQUIREMENTS

5.1 BATTERY CHARGER ENCLOSURES

The enclosure shall be constructed in such a manner that, in normal use, it will meet the safety requirements outlined in Section 5. The enclosure shall completely house all current-carrying parts other than input and output leads.

A door or cover providing access to uninsulated live parts shall have means for holding it securely in place. A door or cover providing access to fuses or other parts whose normal functioning requires renewal or replacement shall be hinged, sliding or similarly attached so as to prevent its being easily removed. Opening the door or removing the cover shall require the use of a tool.

The enclosure shall be so constructed as to minimize the possibility of adjustment or tampering by unauthorized personnel. Components such as tap switches, throwover switches, potentiometers and rheostats which are used to adjust or vary the output characteristic of the battery charger shall be located within the enclosure.

Ventilating openings in an enclosure (including perforated holes, louvers and openings protected by means of wire screening, expanded metal or perforated covers) shall conform to requirements shown in Table 5-1. Electrical spacings shall conform to dimensions shown in Table 5-2.

All enclosures which are composed of wire mesh, perforated screens, grille work or a combination thereof, shall be provided with a supporting frame or other means which is rigid enough to prevent the mesh, screens or grille work from being deformed and making contact with live parts under normal use.

Table 5-1
VENTILATION OPENINGS

	Closest live part to any opening Up to 101.6 mm (4 inches)	Closest live part to any opening Greater than 101.6 mm (4 inches)
Minimum rod diameter that will not pass through any opening.	12.7 mm (0.500 inch)	19.1 mm (0.750 inch)
Minimum wire size for screened opening	1.5 mm (0.059 inch)	2.5 mm (0.100 inch)
Minimum thickness for expanded steel mesh and perforated steel ventilation opening.	1.1 mm (0.042 inch)	2.5 mm (0.100 inch)

If non-ferrous or non-metallic materials are used they shall have strength equivalent to the specified steel.

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5.2 ELECTRICAL SPACINGS

Spacings between live parts of different potentials and between live and dead metal parts shall not be less than specified in Table 5-2.

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Table 5-2
ELECTRICAL SPACINGS

Potential Involved Volts, RMS	Through Air mm	Through Air In.	Over Surface mm	Over Surface In.
50 or less	1.6	1/16	1.6	1/16
51 - 150	3.2	1/8	6.4	1/4
151 - 300	6.4	1/4	9.5	3/8
301 - 600	9.5	3/8	12.7	1/2

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5.3 MARKINGS

External precautionary markings on battery chargers shall be readily visible to the operator.

Battery chargers which are not equipped with input or output cords, cables, plugs or connectors, shall have their connecting cables (if supplied) or their input and output terminals sufficiently and permanently identified or marked so that the charger may be properly connected for service. If multiple transformer primary windings or taps are incorporated in the battery charger, these leads or terminals shall also be properly identified or marked to permit proper installation.

A marking that is required to be permanent shall be molded, die-stamped, paint-stenciled, stamped, etched-on-metal or another method that is permanently secured; or be indelibly stamped on a pressure sensitive label.

Interconnecting wiring (other than printed wiring on circuit boards) shall be either numbered in a permanent and legible manner at both ends of each wire or color coded to facilitate servicing and trouble-shooting of the battery charger. Terminals and terminal blocks for use by the equipment user (i.e., remote control, etc.) shall be permanently marked or identified in such a manner as to enable the user to make proper connections.

The polarity of the output shall be plainly identified by: (1) the abbreviations "POS" and "NEG", or (2) the sign "+" for positive and "−" for negative, or (3) color coding of "red" for positive and "black" for negative.

The alternating-current input power terminals or point of entry of the battery charger shall be labeled or tagged to indicate the original factory setting of the alternating-current input voltage.

Overcurrent protection devices shall be identified by permanently affixed markings or labels indicating type- and current ratings as near as possible to the device(s).

NEMA Standard 1-12-1983.

5.4 PRECAUTIONARY MARKING CHARACTERISTICS

5.4.1 Signal Words

The word "DANGER" or the word "WARNING" should be used to call attention to:

1. The immediate hazards of equipment or conditions such as accessible high voltage, exposed live parts, etc., which if not avoided could result in personal injury, loss of life, fire or explosion.

2. Potential hazards or to operating procedures, practices, etc., which if not strictly adhered to could directly result in personal injury, loss of life, fire or explosion.

5.4.2 Color Requirements

Vivid red* Munsell Notation 7.5R 4.0/14 should be the predominant visual color for either the signal word "DANGER" and the symbol or for the background. Black, white or metallic may be used for contrast. These colors may be used either for the lettering or the background, for contrast to the red.

This requirement is not intended to rule out the use of other labels or markings which are required to comply with other nationally recognized standards or applicable law or regulations, which may be deemed necessary by the manufacturer.

* This vidid red is defined in Munsell Notation as follows:

Color	Red
Central	7.5R 4.0/14
Tolerances	
Hue	+8.5R, −6.5R
Value	+4.5/, −3.5/
Chroma†	+/16, −/12

† Colors may be stronger (more saturated) than the Chroma color as long as they comply with the hue and value tolerances.

5.4.3 Symbol

The symbol denoting hazard of electrical shock or burn is shown as Figure 5-1. The use of the symbol on the front of the battery charger is not intended to rule out the use of other labels or markings either internal or external, which are required to comply with this standard, other nationally recognized standards, laws or regulations.

5.4.4 Size of Letters

The signal words should be 3.2mm (⅛ inch) high or larger; the remaining words should be no less than 1.6mm (1/16 inch) high.

Authorized Engineering Information 1-12-1983.

5.5 REQUIRED PRECAUTIONARY MARKINGS

5.5.1 Shock Hazard

1. A battery charger shall have a precautionary marking indicating the presence of potentially lethal AC supply voltage using the following words or equivalent:

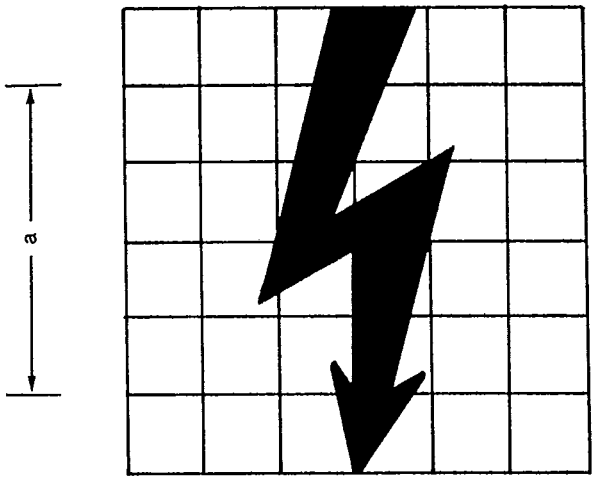
DANGER—HAZARD OF ELECTRIC SHOCK. Disconnect from input power before servicing or dismantling. See Instruction Manual.

2. A battery charger having output voltage greater than 30 V rms (42.4 V peak) shall have a precautionary marking, indicating the presence of potentially lethal DC voltage with the following words or equivalent:

DANGER—HAZARD OF ELECTRIC SHOCK. Do not touch uninsulated portion of output connector or uninsulated battery terminal. Disconnect battery before servicing. See Instruction Manual.

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SYMBOL PROPORTION
HEIGHT = 1.48a
WIDTH = 0.58a

Figure 5-1
ELECTRICAL HAZARD SYMBOL

5.5.2 Grounding

The battery charger shall be permanently marked with the following wording or equivalent, which will be readily visible to the electrical installer:

WARNING, ELECTRIC SHOCK CAN KILL. Install and ground the charger in accordance with the "National Electrical Code," using the grounding screw terminal. Before installing or operating, see Instruction Manual.

5.5.3 Class MR Charger

Class MR chargers shall be permanently marked with the maximum AC voltage deviation from the AC voltage tap setting that will result in properly charging the battery (see 4.5.2).

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5.6 NAMEPLATE MARKING

The following minimum information shall be given on the nameplate of the battery charger in letters which are 3.2mm (⅛ inch) high or larger:

1. Manufacturer's name, model number and serial number.
2. Type of battery for which the charger was designed, i.e. lead-acid.
3. Number(s) of cells in series.
4. Nominal output voltage.
5. Amperehour capacity and charge time of battery.
6. Rated output direct current.
7. Nominal alternating-current supply voltage(s).
8. Supply frequency.
9. Number of supply phases.
10. Rated alternating-current line amperes.
11. Number of charging circuits (if more than one).

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5.7 OPERATING INSTRUCTIONS

Simplified but sufficient operating instructions to enable the operator of the charger to correctly perform whatever action is necessary to achieve the intended battery charging operation shall be included on the charger.

These instructions shall have letters 3.2mm (⅛ inch) high or larger and shall be so placed on the battery charger that they will be readily visible to the operator.

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Letters or other information placed on legends or on dials (timers, switches, etc.) may be considered as part of the required operating instructions.

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5.8 INSTRUCTION MANUAL

An instruction manual shall be provided with each charger and shall include at least the following information:

Safety Instructions
Installation Instructions
Operating Instructions
Schematic or Wiring Diagrams
Trouble Shooting, Inspection and Maintenance Procedures

NEMA Standard 1-12-1983.

5.9 POTENTIALLY LETHAL SHOCK HAZARDS

Voltages exceeding 42.4 V peak represent a potential for a lethal shock hazard; therefore, efforts should be made to reduce the accessibility to such voltages.

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5.10 TRANSFORMER CONSTRUCTION

5.10.1 The transformer shall have its primary winding electrically isolated from its secondary winding. The transformer windings shall be treated with a sealing and moisture resistant process, such as varnish impregnation and baking.

Each class of insulation shall operate within its design temperature limits as indicated in Table 6-1.

5.10.2 Means shall be taken to prevent the possibility of primary voltage being present in the secondary circuit. This shall be accomplished by either of the following:

a. Coiled winding methods which provide insulated or physical separation between input and output circuits.

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b. A grounded electrostatic or Faraday shield placed between the primary and secondary windings. This shield shall be made of copper or aluminum and shall have at least the ampacity of the primary conductor if the primary conductor is smaller than No. 6 AWG. If the primary conductor is No. 6 AWG or larger, the shield shall have an ampacity of at least 50 percent of the primary conductor. If foil is used it shall have a thickness of not less than .25mm (.010 inch).

5.10.3 The insulating materials used within the transformer at the points described below, shall have dielectric strength rating equal to or greater than 5000 volts (volts per mil rating multiplied by thickness).

a. Between the primary and secondary windings.
b. Between the primary windings and the core.
c. Between the secondary windings and the core.
d. At cross over points between high and low potential windings.
e. At the interface between the shield and adjacent coils.

5.10.4 Primary leads shall be separated from secondary leads and dead-metal parts by spacings shown in Table 5-2 or be provided with insulation having a minimum rating of 5000 volts (volts per mil rating multiplied by thickness).

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5.11 AC AND DC CIRCUIT PROTECTION

The charger shall be provided with protection against overload and short circuit in each ungrounded AC input power conductor.

It is the responsibility of the user to provide protection of the AC input lines.

The charger shall also be provided with protection against overload, short-circuit and reverse battery connection in at least one of the two output leads.

Protective devices shall limit fault and overload currents to prevent damage to the charger.

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5.12 FIELD WIRING TERMINALS

Terminals intended for use by the equipment user (i.e., AC input, DC output, remote controls, etc.) shall be of such size and design that they will accommodate the wiring specified in the "National Electrical Code" for the intended purpose.

The battery charger manufacturer shall describe the voltage and current requirements of these terminations sufficiently to allow the user to properly select the type of wiring necessary or, as an alternative, shall specify the classes, type and sizes of wiring needed.

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5.13 ENCLOSURE SERVICE GROUNDING

A separate, clearly identified grounding terminal shall be provided for the connection of the AC input grounding conductor. The grounding terminal shall be bonded to the inside of the charger enclosure (frame) near the AC input cable entry. All noncurrent-carrying metal parts of the battery charger shall be conductively connected to this grounding terminal or to the battery charger enclosure (frame) to ensure their grounding integrity. The grounding terminal and any grounding stud used in conjunction with the grounding terminal shall have a current-carrying capacity not less than that of the required AC input grounding conductor. The grounding terminal shall be sized to accommodate the required AC input grounding conductor as shown in Table 5-3.

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Table 5-3
SIZE OF EQUIPMENT GROUNDING CONDUCTORS FOR GROUNDING INTERIOR RACEWAY AND EQUIPMENT

Maximum Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Amperes	AWG Size	
	Copper	Aluminum or Copper-Clad Aluminum
15	14	12
20	12	10
30	10	8
40	10	8
60	10	8
100	8	6

5.14 AC INPUT CABLE ENTRY

The charger cabinet shall be provided with an entry hole or knockout located as near as possible to the internal connection terminals. If the charger is supplied with AC input cable a strain relief shall be included.

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5.15 DC OUTPUT CABLE EXIT

The charger cabinet shall be provided with an exit hole(s) or knockout(s) located as near as possible to the internal connection terminals to accommodate the required strain relief. If the charger is supplied with DC output cable(s) a strain relief(s) shall be included.

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5.16 WIRING CONNECTORS OR TERMINALS

All crimp-type connectors shall be suitable for use with the wires to which they are attached and shall be crimped with the proper type of compression tool. Open

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fork terminals, if used, shall be of the type that assist in preventing the terminations from slipping off the terminal and creating a possible hazard.

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5.17 DIRECT-CURRENT OUTPUT CABLE

When battery charger direct-current cables are supplied, they shall be extra flexible (Class K or Class M) and of a size which will safely carry the output current of the charger without causing the cable insulation to exceed a temperature rise of 30°C (54°F) in an ambient of 40°C (104°F).

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Section 6
TEST METHODS

6.1 GENERAL

Section 6 is intended to provide test methods applicable to the evaluation of battery chargers and shall be used to establish the performance and safety characteristics of battery chargers.

Tests shall be divided into three categories:

1. Design tests (See 6.3)
2. Safety tests (See 6.4)
3. Production tests (See 6.5)

NEMA Standard 1-12-1983.

6.2 INSTRUMENTATION

Measuring apparatus shall have sufficient resolution, stability and accuracy so as to ensure a limit of error not exceeding 3 percent of the measured quantity. For each test, sufficient metering and monitoring shall be provided so as to ensure conformance with the test conditions.

NEMA Standard 1-12-1983.

6.3 DESIGN TESTS

Design tests are those which are made once on a representative sample of every battery charger model(s) which represents the worst set of operating conditions (usually the maximum kilowatt output in a particular enclosure) and which are repeated whenever a change is made that modifies the performance of the charger. The substitution of higher rated direct replacement components does not necessitate retesting the representative charger model.

Design tests shall include the following:

1. Operational temperature rise test
2. Charging curve test
3. Charger efficiency test
4. Power factor test

6.3.1 Operational Temperature Rise Test

The battery charger shall be operated for a complete charger cycle to establish the peak temperature rise (see 6.3.2). The charger shall operate at the input voltage within the range specified in Table 4-1 to obtain the worst case conditions.

The operating temperature of insulating materials shall not exceed the values specified in Table 6-1.

The operating temperature of enclosures, buses and connections shall not exceed the values specified in Table 6-2.

Table 6-1
INSULATING MATERIALS

Class of Insulating Material	Limit of Hottest-Spot Temperature Rise, Degrees C*	Limit of Hottest-Spot Total Temperature Degrees C*
90	50	90
105	65	105
130	90	130
155	115	155
180	140	180
220	180	220

Table 6-2
ENCLOSURES, BUSES AND CONNECTIONS

Item	Limit of Hottest-Spot Temperature Rise, Degrees C*	Limit of Hottest-Spot Total Temperature Degrees C*
Buses and Connections with:		
Bare untreated, bolted copper-to-copper connecting joints	65	105
Silver-surfaced or equivalent connecting joints	65	105
Connections to Insulated Cables		
Copper-to-copper connecting joints	30	70
Silver-surfaced or equivalent connecting joints	35	80
Enclosures	35	75

* These temperature limits for insulating materials may not apply to insulation in circuit breakers or other devices. For temperature limitation on devices, refer to the appropriate device standards. (These sentences approved as Authorized Engineering Information).

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Higher connection temperatures corresponding to the temperature rating of the cable are applicable where cables with higher temperature insulation are used. (Total temperatures are limited to a maximum of 105°C).

The same temperature rise limitations shall be used for properly applied aluminum connections. Aluminum shall not be placed in direct contact with silver or copper, without treatment to prevent galvanic corrosion.

The values given in Table 6-2 shall not apply to transformers, diodes or fuses, or to their connections.

6.3.2 Charging Curve Test

In determining the charging curve, the average direct voltage and current, as distinguished from the rms values, shall be used. The direct voltage and current shall be measured at the output terminals of the battery charger. The battery electrolyte temperature and ambient temperature shall be 25°C (77°F) at the start of the test. The test battery shall be a fully charged battery of the size indicated by the 8-hour rating on the battery charger nameplate. The battery shall be discharged at the 6-hour rate of its amperehour capacity to a final average cell voltage of 1.70 volts per cell at 25°C (77°F). The actual amperehour capacity of the battery shall be determined. (See 4.5.2).

The specific gravity readings shall be referenced to 25°C (77°F). The charger shall be connected to the battery and allowed to charge for an 8-hour period or less. The alternating-voltage input to the charger shall be the nominal voltage as specified in Table 4-1. During the charge period, data shall be recorded at least once every half hour. The charger amperehour curve and characteristic curve shall be plotted.

The battery shall be discharged in accordance with paragraph 1.02 of IB-2 1974 to determine the amperehours returned to the battery. The amperehours discharged shall be at least 100 percent of the battery's established amperehour capacity. The charger shall operate over the input voltage range specified in Table 4-1 and shall meet the requirements of 4.5 and 4.6. The charge curves for subsequent models shall be permitted to be plotted by using resistive-capacitive loads once the characteristic charge curve is established by a battery charge-recharge test.

6.3.3 Charger Efficiency Test

The charger efficiency shall be determined by measuring the input watts at the alternating-current input terminals by means of wattmeters and by measuring the average values of the direct voltage and current at the output terminals.

From the values thus measured, the charger efficiency shall be calculated in accordance with the following:

$$\text{Percent Charger Efficiency} = \frac{\text{average dc voltampere output}}{\text{input watts}} \times 100$$

The charger efficiency over the complete charge cycle shall be calculated as follows:

$$\text{Percent Efficiency} = \frac{\text{kilowatt-hours output}}{\text{kilowatt-hours input}} \times 100$$

6.3.4 Power Factor Test

The power factor for single-phase and three-phase battery chargers shall be calculated as follows:

$$\text{Percent Power Factor} = \frac{\Sigma \text{ watts per phase}}{\Sigma \text{ rms voltamperes per phase}} \times 100$$

For single phase rectifiers, the input watts can be measured with a wattmeter and the volt-amperes can be calculated from measurements of the true rms input voltage and true rms input current, using rms responding meters. For a balanced three-phase source and load, the input power factor shall be calculated as follows:

$$\text{Percent Power Factor} = \frac{\text{input watts}}{\sqrt{3} \times \text{line volts} \times \text{line current}} \times 100$$

where the line volts and line current are rms values measured with rms responding meters.

The charger power factor over the complete charge cycle shall be calculated as follows:

$$\text{Percent Power Factor} = \frac{\text{kilowatt-hours input}}{\text{kilovoltampere-hours input}} \times 100$$

NEMA Standard 1-12-1983.

6.4 SAFETY TESTS

Safety tests are those which are made once on a representative sample of every battery charger model(s) and which are repeated whenever a change is made that affects the safety characteristics of the charger.

Design safety tests shall include the following:

1. Dielectric
2. Fire Hazard Test
3. Mechanical Integrity Test
4. Audible Sound Level Limit Test

6.4.1 Dielectric Test

A battery charger shall be capable of withstanding for 1 minute, without breakdown, the application of a 60 Hertz essentially sinusoidal test voltage with the battery charger at the maximum operating temperature which it reaches in normal use. As an alternative, 120 percent of the specified test voltage shall be applied for 1 second.

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The charger shall be tested by one of the following types of test equipment or equivalent:

1. A 500 volt-ampere or larger transformer with voltmeter.

2. A less than 500 volt-ampere transformer having output voltmeter, audible and visual indication of breakdown and reset button.

The test voltage as specified above shall be applied between the following points:

a. Alternating-current input terminals to dead-metal parts.

b. Alternating-current input terminals to direct-current output terminals.

c. Direct-current terminals to dead-metal parts.

For these tests, all semiconductors, capacitors and sensitive control components shall be short-circuited; printed circuit control boards shall be removed. Contactors and relays shall be in their operating mode.

The insulation of primary circuits to dead-metal parts and primary circuits to secondary circuits shall be capable of withstanding the application of 1000 volts + twice the rated primary voltage. For secondary circuits operating at 50 volts or less, the insulation shall be capable of withstanding 500 volts between these circuits and dead-metal parts. Secondary circuits operating at more than 50 volts shall withstand 1000 volts + twice the maximum rated secondary circuit voltage between the circuits and dead-metal parts.

The leakage current for these test voltages shall not exceed 0.75 milliampere on cord connected chargers and 5.0 milliamperes on conduit-connected chargers.

6.4.2 Fire Hazard Test (Destructive Design Test)

6.4.2.1 Test Conditions

The battery charger shall rest on a soft pine board surface covered with white tissue paper. Double layers of cotton cheesecloth shall be draped over all of the top and side openings of the cabinet.

For all of the fire hazard tests, the battery charger shall be operated from a source of supply adjusted to the upper limit of one of its rated input voltages per Table 4-1.

The battery charger enclosure shall be connected directly to AC supply ground.

The battery charger shall not emit flame or molten metal or ignite the test materials when subjected to the following tests:

1. Reverse polarity
2. Misconnection
3. Non-operable fan (when provided)
4. Internal short or malfunction of electromechanical device
5. Output short circuit
6. Charger overload

Each test may be conducted on a separate sample or more than one test may be conducted on the same sample at the manufacturer's choice. (This sentence approved as Authorized Engineering Information)

6.4.2.2 Reverse Polarity

The output leads shall be connected in reverse polarity to a fully charged lead-acid battery. The battery charger shall then be energized and operated until the ultimate condition is observed or for 16 hours if cycling of an automatic protector occurs. A manual reset protector shall be operated for 50 cycles.

6.4.2.3 Misconnection

A battery charger intended for operation from two (2) or more supply voltage levels and/or variations in number of battery cells shall be connected in such a way as to produce the worst set of operating conditions when connected to the highest AC input voltage specified for the charger. The battery charger shall be connected to a discharged battery, all normally supplied protective devices shall be left in the circuit, and the charger shall then be energized.

The test shall be continued until the internal protection opens, constant temperatures are attained, or the circuitry opens. If an automatic reset protector is provided, the test shall be continued for 16 hours. A manual reset protector shall be operated for 50 cycles.

6.4.2.4 Non-operable Fan

A battery charger using a fan for forced cooling shall be tested with the fan stalled. The charger shall be operated under its usual service conditions, but in a mode that will produce the most self-generated heat, i.e., maximum rated input voltage supplied to the charger.

6.4.2.5 Internal Short or Malfunction of Electromechanical Device

Relays or solenoids shall be tested by blocking open the armature or the plunger. The charger shall then be operated at its maximum rated input and output voltage until the coil burns out, protective devices open or the temperatures become constant.

6.4.2.6 Output Short Circuit

The charger shall be operated at maximum rated input and output voltage. The output terminals or leads of the battery charger shall be short circuited. A protective device, such as a fuse or circuit breaker provided as a part of the battery charger, shall remain in the circuit. The test shall be continued until the internal protection opens or constant temperatures are attained. The test shall be continued until the ultimate conditions are reached or for 16 hours, if cycling of an automatic reset

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protector occurs. A manual reset protector shall be operated for 50 cycles.

If the charger is provided with polarity protection circuit that prevents output current flow until a battery is connected, the protection circuit shall be made inoperative to allow the required current to flow.

6.4.2.7 CHARGER OVERLOAD

A resistive load shall be connected directly to the charger output and adjusted to cause the charger to demand three times its normal AC input current. (This test may require making the regulating circuitry inoperable on some types of chargers.*) On reactance-limited transformer type chargers the load shall be adjusted to produce maximum input power. The charger shall be operated continuously until ultimate conditions are observed or for 16 hours, if cycling of an automatic reset protector occurs. A manual reset protector shall be operated for 50 cycles.

6.4.3 Mechanical Integrity Test

6.4.3.1 GENERAL

The following tests shall be carried out on a completely assembled, tested and packaged charger. Upon completion of these tests, the battery charger shall meet the performance and safety requirements of this publication.

6.4.3.2 DROP TEST

a. The package shall be placed on a level concrete surface. The longest edge of the package shall be raised 6 inches, with the other end of the package resting on the concrete surface. The package shall then be allowed to fall freely onto the concrete surface.

b. The entire package shall be raised 2 inches, in an upright position, and allowed to fall freely onto the concrete surface.

NEMA Standard 1-12-1983.

6.4.3.3 TIP-OVER TEST

The package shall be placed on a concrete surface and the rear bottom edge raised until the package tips over. The package shall be allowed to fall freely onto the concrete surface.

6.4.4 Audible Sound Level Test

The charger shall be operated under all combinations of line voltage, line frequency, output voltage and load current in order to determine the conditions which produce the greatest audible sound level.

Measurements shall be made in accordance with American National Standard S1.4-1971 (R-1976) Specification for Sound Level Meters.

No acoustic vibrations greater than 65 decibels (A-weighting) shall be produced at any point 5 feet distant from any vertical surface of the charger.

NEMA Standard 1-12-1983.

6.5 PRODUCTION TESTS

Production tests are those tests which are made on all production units for the purpose of maintainiing safety, quality and performance.

Production tests for battery chargers shall include the following:

1. Dielectric test (see 6.4.1)
2. Cabinet Ground Integrity test
3. Circuit Operation test

6.5.1 Cabinet Ground Integrity Test

The resistance of the ground connections in the charger cabinet shall be checked with a continuity tester that has a current source of 1 ma or greater. One lead from the tester shall be connected to the cabinet grounding terminal and the other lead used to probe the cabinet grounding terminals and exposed dead metal parts.

6.5.2 Circuit Operation Test

The battery charger shall be tested to ensure that all of its components are properly interconnected and adjusted to function according to the typical volt-ampere curve designated for that charger.

NEMA Standard 1-12-1983.

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA Bylaws, which are quoted below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Bylaw—Art. V, Sec. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Bylaw—Art. V, Sec. 2, Subsection A)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.

(NEMA Policy Memorandum 84-2, dated June 7, 1984)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Bylaw—Art. V, Sec. 2, Subsection B)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design.

(Bylaw—Art. V, Sec. 6, 1st Sentence)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval.

(Bylaw—Art. V, Sec. 4, Subsection A)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

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INDUSTRIAL STORAGE BATTERY SECTION

OF THE

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

MEMBER COMPANIES

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An Allied Company
Plymouth Meeting, PA 19462

Chloride Battery Div.
Chloride Inc.
Tampa, FL 33601

Douglas Battery Mfg. Co.
Winston-Salem, NC 27117

East Penn Mfg. Company, Inc.
Lyon Station, PA 19536

Exide Corporation
Horsham, PA 19044

General Battery Corp.
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Div. of Johnson Controls, Inc.
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