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STANDARDS PUBLICATION/NO. IB 9-1981

nema

Mining Vehicle 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 mining vehicle 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 static, above ground, and underground off-board battery chargers used to recharge lead-acid cycling type batteries. These batteries, commonly called industrial or group batteries, are used in applications such as: locomotives, tractors, load-haul and dump machines, personnel carriers and other industrial battery powered equipment that may be used in the mining industry to transport personnel or material.

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MINING VEHICLE BATTERY CHARGERS

Section 1
DEFINITIONS

The terms listed 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.

1.1 AMBIENT TEMPERATURE

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

NEMA Standard 9-17-1981.

1.2 AMPERE-HOUR CAPACITY*

The number of ampere-hours that can be delivered under specialized conditions as to temperature, rate of discharge, and final voltage.

NEMA Standard 9-17-1981.

1.3 AUDIBLE NOISE

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

NEMA Standard 9-17-1981.

1.4 BATTERY CHARGER

An apparatus used to recharge a storage battery.

NEMA Standard 9-17-1981.

1.5 CHARGE*

The conversion of electrical energy into chemical energy within the battery.

NEMA Standard 9-17-1981.

1.6 CHARGING RATE*

The current expressed in amperes at which a battery is charged.

NEMA Standard 9-17-1981.

1.7 CHARGER EFFICIENCY

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

NEMA Standard 9-17-1981.

1.8 CHARGER POWER FACTOR

The input in watts divided by the input volt ampere product.

NEMA Standard 9-17-1981.

1.9 CLASS I BATTERY CHARGER

A battery charger designed for above ground use and intended to be installed indoors.

NEMA Standard 9-17-1981.

1.10 CLASS II BATTERY CHARGER

A battery charger designed for use in underground mines where permissible (explosion proof) equipment is not required.

NEMA Standard 9-17-1981.

1.11 CONSTANT CURRENT CHARGE*

A charge in which the current is maintained at a constant value.

NEMA Standard 9-17-1981.

1.12 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.

NEMA Standard 9-17-1981.

1.13 DISCHARGE RATE (6-HOUR)

Rated ampere-hour capacity of the battery divided by 6 hours.

NEMA Standard 9-17-1981.

1.14 DISCHARGED BATTERY

A normal battery is said to be discharged when, after being fully charged, it is discharged at a 6-hour rate to a final average cell voltage of 1.70 volts per cell. The electrolyte temperature at start of discharge shall be 25 °C (77 °F).

NEMA Standard 9-17-1981.

1.15 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 may have developed between the cells during service.

NEMA Standard 9-17-1981.

1.16 FINISHING RATE

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

NEMA Standard 9-17-1981.

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1.17 STORAGE BATTERY (INDUSTRIAL OR GROUP)

A battery which is designed for cycling service to provide power for mining vehicles, and which is rated in number of cells and in ampere-hours delivered at the 6-hour discharge rate.

NEMA Standard 9-17-1981.

1.18 LIVE PART

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.

NEMA Standard 9-17-1981.

1.19 NOMINAL VALUE

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

NEMA Standard 9-17-1981.

1.20 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.

NEMA Standard 9-17-1981.

1.21 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.

NEMA Standard 9-17-1981.

1.22 START RATE

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

NEMA Standard 9-17-1981.

1.23 TAPER CHARGE

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

NEMA Standard 9-17-1981.

Section 2
COMPONENTS

2.1 GENERAL

All component parts shall be operated within their design ratings.

NEMA Standard 9-17-1981.

2.2 MINIMUM COMPONENTS

The battery charger shall contain at least the following components:

1. Semiconductor rectifying elements.
2. The 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. A transformer (two-winding type) to isolate electrically the battery being charged from the alternating-current source.
4. The means for terminating the charging current prior to disconnecting the battery.
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 only 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 operating.
7. Input and output overcurrent protective devices.
8. The means for resuming the charger cycle automatically when the alternating-current power is restored following an interruption.
9. (In battery chargers that utilize forced air cooling) the 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 Starting Rate

The starting output current of battery chargers with continuous dc output current shall not exceed 26 amperes for each 100 ampere-hours of the rated ampere-hour capacity of the battery for an 8-hour recharge.

3.1.2 Finishing Rate

The finishing output current shall not exceed 5 amperes for each 100 ampere-hours of the rated ampere-hour capacity of the battery.

NEMA Standard 9-17-1981.

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 9-17-1981.

3.3 ALTERNATING-CURRENT SUPPLY VOLTAGE

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

1. Single phase - 120, 208, 240, 277, 480, and 575 volts.
2. Three phase - 208, 240, 480, and 575 volts.

NEMA Standard 9-17-1981.

3.4 ALTERNATING—CURRENT SUPPLY FREQUENCY

The nominal rating of the alternating-current supply frequency shall be 25, 50, or 60 hertz.

NEMA Standard 9-17-1981.

Section 4
PERFORMANCE

4.1 CLASSIFICATION

Battery chargers shall be classified as follows: Class I - Above ground applications; Class II - Below ground applications.

NEMA Standard 9-17-1981.

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 usual conditions in accordance with 4.3, battery chargers shall be capable of performing without the operation of protective devices.

NEMA Standard 9-17-1981.

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.

NEMA Standard 9-17-1981.

Table 4-1
ALTERNATING-CURRENT SUPPLY VOLTAGES

Rated Voltage	Minimum	Maximum
120	106	127
208	184	220
240	212	254
277	245	293
480	424	508
575	508	600[1]

NEMA Standard 9-17-1981.

[1]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.

Authorized Engineering Information 9-17-1981.

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4.4 UNUSUAL SERVICE CONDITIONS

The unusual service conditions listed in Figure 4-1 *may require specific design considerations* and should be brought to the attention of the manufacturer.

An x denotes an unusual service condition. If a space is unmarked, the service condition is considered usual.

4.5 CHARGING CURVE

4.5.1 A charging curve, if published, shall be based on amperes/100 ampere-hours of the ampere-hour capacity and volts per cell, 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 ampere-hours of the ampere-hour capacity) versus time.
2. Direct-current voltage (volts per cell) versus time.
3. Percent of ampere-hours 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 charger shall be capable of returning, in 8 hours or less, 105 percent of the ampere-hours removed from a battery of equal capacity that has discharged 100 percent of its rated capacity, and not more than 115 percent of the ampere-hours removed from the same battery when it has discharged 80 percent of its rated capacity. Both requirements shall be met with charger controls identically set.

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

NEMA Standard 9-17-1981.

4.6 BATTERY ELECTROLYTE TEMPERATURE

A battery charger, when operating at its 8-hour charge rating, shall not cause the electrolyte temperature of a battery which is matched to this 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 9-17-1981.

4.7 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.

Authorized Engineering Information 9-17-1981.

Figure 4-1
UNUSUAL SERVICE CONDITIONS

	Condition	Class I	Class II
1.	Exposure to damaging fumes	x	x
2.	Exposure to excessive moisture	x	x
3.	Exposure to corrosive dust and moisture	x	
4.	Exposure to steam	x	x
5.	Exposure to oil vapor	x	x
6.	Exposure to explosive mixtures of dust or gases	x	x
7.	Exposure to salt air	x	x
8.	Exposure to weather	x	x
9.	Exposure to dripping water	x	
10.	Exposure to unusual transportation or storage	x	x
11.	Unbalanced alternating-current voltages	x	x
12.	Departure of alternating-current system voltages from a substantially sinusoidal waveform.	x	x
13.	Input supply voltage outside ranges shown in Table 4-1	x	x
14.	Departure by more than 0.2 percent from the nominal alternating-current supply frequency	x	x
15.	Operation at ambient temperatures higher than 40 °C (104 °F) or below 0 °C (32 °F)	x	x
16.	Operation at altitudes more than 1000 meters (3300 feet) above sea level	x	x
17.	Batteries with electrolyte temperatures below 10 °C (50 °F) or higher than 46.1 °C (115 °F)	x	x
18.	Exposure to rough handling	x	x

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Section 5
SAFETY REQUIREMENTS

5.1 BATTERY CHARGER ENCLOSURES

The enclosure shall completely house all current-carrying parts other than input and output leads.

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

The enclosure shall be constructed 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.

5.1.1 Class I - Above Ground Application

The enclosures shall be designed for indoor use and constructed in such a manner that, in normal use, they will meet the safety requirements outlined in Section 5.

The thickness of the steel enclosure shall be not less than 1.5 mm (0.059 inch) unless supported or formed to provide equivalent strength.

5.1.2 Class II - Below Ground Application

The enclosure shall be designed for underground use and constructed in such a manner that, in normal use, it will meet the safety requirements outlined in Section 5.

The enclosure shall be designed to provide a degree of protection against limited amounts of falling and splashing water. The battery charger shall be designed for both dragging and carrying without damage to the enclosure, operating controls, or internal components. Provisions shall be made for attaching a drag-line or cable through an eye bolt or other suitable means. Ventilating openings in skid-mounted enclosures shall not be located on the top or skid pan. The skid pan shall cover the entire bottom of the charger enclosure.

The thickness of steel enclosures shall not be less than 4.3 mm (0.110 inch), and thickness of skids or dragging pans shall be not less than 6.4 mm (0.250 inch) unless supported or formed to provide equivalent strength. Operating controls and instruments, such as timers and meters, shall be protected from damage due to accidental contact while being dragged or operated.

NEMA Standard 9-17-1981.

Table 5-1
VENTILATION OPENINGS

	Closest live part to any opening Less than 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)	2.5mm (0.100 inch)

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

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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.

NEMA Standard 9-17-1981.

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

NOTE: Spacings shall apply to circuits other than low voltage electronic circuits.

NEMA Standard 9-17-1981.

5.3 MARKINGS

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

Battery chargers which are not equipped with input and output cords, cables, plugs and connectors, or a combination thereof 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 shall be permanently secured by other methods; or shall 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 shall be color coded to facilitate servicing and trouble-shooting of the battery charger. Terminals and terminal blocks for use by the equipment user (that is, 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"; (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.

Fuses, when used, shall be identified by permanently affixed markings or labels indicating current ratings on or as near as possible to the fuse holders.

NEMA Standard 9-17-1981.

5.4 PRECAUTIONARY LABELS

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[1] 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, such as radiation warnings, or which may be deemed necessary by the manufacturer.

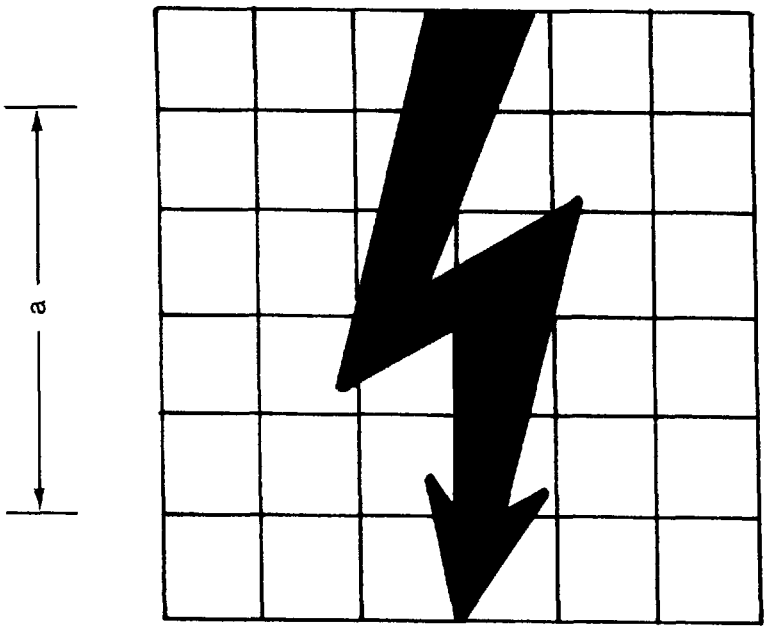
[1]This vivid red is defined in Munsell Notation as follows:

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

Vivid red is shown in the Hazardous Materials Label and Placard Color Tolerance Charts available from T.E.S. 231, Office of Hazardous Materials, Department of Transportation, Trans Point Building, Room 6215, Washington, DC 20590, telephone (202) 426-2075. These charts were also called the Combined Standard Safety Color Code Color Tolerance Charts (CSSCC).

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

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SYMBOL PROPORTION
HEIGHT = 1.48a
WIDTH = 0.58a

Figure 5-1
ELECTRICAL HAZARD SYMBOL

5.4.3 Symbol

The symbol denoting hazard of electrical shock or burn is shown as Figure 5-1.

5.4.4 Size of Letters

The signal words should be 3.2mm (0.125 inch) high or larger; the remaining words should be no less than 1.6mm (0.063 inch) high.

5.4.5 Other Labels or Markings

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 other nationally recognized standards, laws, or regulations.

Authorized Engineering Information 9-17-1981.

5.5 NAMEPLATE MARKING

The following minimum information shall be given on the nameplate of the battery charger in letters which are 3.2mm (0.125 inch) high or larger:

1. Manufacturer's name and model number.
2. Type of battery for which the charger was designed, that is, lead-acid.
3. Number(s) of cells in series.
4. Nominal output voltage.
5. Ampere-hour 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.

NEMA Standard 9-17-1981.

5.6 OPERATING INSTRUCTIONS

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

These instructions shall have letters 3.2mm (0.125 inch) high or larger and shall be placed so that they will be readily visible to the operator.

NEMA Standard 9-17-1981.

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

Authorized Engineering Information 9-17-1981.

5.7 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, or both; and trouble shooting procedures.

NEMA Standard 9-17-1981.

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5.8 POTENTIALLY LETHAL SHOCK HAZARDS

Higher voltages present a greater potential for a lethal shock hazard; therefore, efforts should be made to reduce the accessibility to such voltages. For input voltages above 120 volts nominal, control transformers should be used to limit the control voltages to no more than 120 volts nominal.

Voltages exceeding 42.4 volts peak are considered to be dangerous, and necessary precautions should be taken.

Authorized Engineering Information 9-17-1981.

5.9 TRANSFORMER CONSTRUCTION

Where a transformer is chosen as the primary means of minimizing ac shock hazards, the following points shall be considered:

1. The transformer shall be a two-winding design with the primary winding electrically isolated from its secondary winding and shall be varnish impregnated and baked to exclude moisture. Each class of insulation shall operate within its design temperature limits as indicated in Table 6-1.

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. 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. For primary conductor of 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 39mm (.010 inch) or more.

b. Coil winding methods which provide physical separation between input and output circuits.

3. The insulating materials used within the transformer at the points described below shall have a dielectric strength rating equal to or greater than 5 000 volts.

a. Between the primary windings and the core.

b. Between the secondary windings and the core.

c. At cross over points between high and low potential windings.

d. At the interface between the shield and adjacent coils.

4. The insulation on leads or taps shall be rated for the voltage applied.

NEMA Standard 9-17-1981.

5.10 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.

NEMA Standard 9-17-1981.

5.11 INPUT AND OUTPUT TERMINALS

Alternating-current input terminals shall be of a size and design to accommodate the power wiring specified for the rated input current in the 1981 *National Electrical Code.*

Direct-current output terminals shall be of a size and design to accommodate the power wiring specified in the 1981 *National Electrical Code* for the highest rated root mean square output currents.

Terminals intended for use by the equipment user (that is, remote controls, etc.) shall be of a size and design to accommodate the wiring specified for the intended purpose by the 1981 *National Electrical Code.*

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

NEMA Standard 9-17-1981.

5.12 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 non-current-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 ground 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.

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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

5.12.1 Class I

For above ground installation, the requirements in Table 5-3 shall apply.

5.12.2 Class II

For below ground installation where the ac input power conductors are No. 6 AWG or larger, the required ac input grounding conductor shall have a cross-sectional area of one-half that of one power conductor. Where the ac input power conductors are smaller than No. 6 AWG, the required ac input grounding conductor shall have a cross-sectional area equal to that of one power conductor.

NEMA Standard 9-17-1981.

5.13 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 to accommodate the required strain relief. If the charger is supplied with ac input cable, a strain relief shall be included.

NEMA Standard 9-17-1981.

5.14 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.

NEMA Standard 9-17-1981.

5.15 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-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.

NEMA Standard 9-17-1981.

5.16 CHARGING CONNECTOR AND BATTERY TRAY GROUNDING (CLASS II ENCLOSURE)

A separate, clearly identified grounding terminal(s) shall be provided for the charging connector and battery tray grounding. The grounding terminal(s) shall be bonded to the inside of the charger enclosure (frame) near the dc output cable exit(s).

Grounding terminals and grounding studs used in conjunction with the grounding terminals shall have a current carrying capacity not less than that of the required grounding conductors. Grounding terminals shall be sized to accommodate the required grounding conductors.

NEMA Standard 9-17-1981.

5.17 DIRECT—CURRENT OUTPUT CABLES

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 a 40 °C (104 °F) ambient.

On Class II chargers, a grounding cable(s) shall be provided for each set of battery charger output cables to connect the charging connector housings and the charging connector grounding pin(s) when grounding-type charging connector(s) are supplied to the grounding terminals specified in 5.16. The grounding cable(s) shall be of the same conductor material as the dc output cables.

Where the dc output conductors are No. 6 AWG or larger, each grounding conductor shall have a cross-sectional area of at least one-half that of one dc output conductor. Where the dc output conductors are smaller than No. 6 AWG, each grounding conductor shall have a cross-sectional area equal to that of one dc output conductor.

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When single conductor dc output cables are supplied, each set of dc output and grounding cables shall be securely bound together at intervals of not more than 24 inches (610 mm), or each set of dc output and grounding cables shall be entirely contained within those conduits which have been listed as flame resistant by the Mine Safety and Health Administration.

NEMA Standard 9-17-1981.

5.18 SERVICE GROUND CHECK CIRCUIT (CLASS II ENCLOSURES)

An insulated terminal shall be provided for connection of the service ground check conductor. The terminal shall be sized to accommodate a conductor of not less than No. 8 AWG.

A grounding screw (terminal) shall be bonded to the enclosure and shall be separate from the service ground terminal. The purpose of this terminal is to ground one side of the emergency pushbutton.

NEMA Standard 9-17-1981.

5.19 EMERGENCY STOP PUSHBUTTON (CLASS II ENCLOSURES)

A maintained type, red emergency stop pushbutton with two electrically isolated normally closed contacts shall be provided to deenergize the charger in an emergency situation. This pushbutton shall be wired in such a way as to interrupt the continuity between the insulated ground check terminal and the separately bonded grounding screw terminal specified above.

The pushbutton shall also de-energize the main ac charger contactor to shut down the charger if the user's ac input is not equipped with a service ground check circuit. Pulling out the pushbutton shall permit the restart sequence.

NEMA Standard 9-17-1981.

Section 6
TEST METHODS

6.1 GENERAL

Section 6 shall 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: design tests, safety tests, and production tests.

NEMA Standard 9-17-1981.

6.2 INSTRUMENTATION

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

NEMA Standard 9-17-1981.

6.3 DESIGN TESTS

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

Design tests shall include the following:

1. Dielectric test (see 6.4.1)
2. Fire hazard test (see 6.4.2)
3. Mechanical integrity test (see 6.4.4)
4. Charging curve test (see 6.3.2)
5. Charger efficiency test (see 6.3.3)
6. Power factor test (see 6.3.4)
7. Operational temperature rise test (see 6.3.1)

6.3.1 Operational Temperature Rise Test

The battery charger shall be operated over the complete 8-hour charge curve to establish the peak temperature rise. The charger shall operate over the input voltage range specified in Table 4-1.

The total temperature of insulating materials used in battery chargers shall not exceed the values specified in Table 6-1.

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

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Table 6-1
INSULATING MATERIALS

Class of Insulating Material	Limit of Hottest-Spot Temperature Rise, Degrees C[1]	Limit of Hottest-Spot Total Temperature, Degrees C[1]
90	50	90
105	65	105
130	90	130
155	115	155
180	140	180
220	180	220

NEMA Standard 9-17-1981.

[1]These temperature limits for insulating materials may not apply to insulation in curcuit breakers or other devices. For temperature limitation on devices, refer to the appropriate device standards. Authorized Engineering Information 9-17-1981.

6.3.2 Charging Curve Test

In determining the charging curve, the average direct voltage and current, as distinguished from the root mean square 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 ampere-hour capacity to a final average cell voltage of 1.70 volts per cell at 25 °C (77 °F). The actual ampere-hour 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 ampere-hour curve and characteristic curve shall be plotted.

The battery shall be discharged in accordance with paragraph 1.02 of NEMA Standards Publication No. IB 2-1974 (R 1980) *Capacity Determination of Lead-acid Industrial Storage Batteries for Motive Power Service,* to determine the ampere-hours returned to the battery. The ampere-hours discharged shall be at least 100 percent of the battery's established ampere-hour 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.

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[1]		
Copper-to-copper connecting joints	30	70
Silver-surfaced or equivalent connecting joints	35	80
Enclosures	35	75

[1]Higher connection temperatures corresponding to the temperature rating of the cable shall be applicable where cables with higher temperature insulation are used. (Total temperatures shall be 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.

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

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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:

$$\text{Percent Charger Efficiency} = \frac{\text{Average d-c voltampere output}}{\text{input watts}} \times 100$$

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 shall be measured with a wattmeter, and the volt-amperes shall be calculated, using root mean square (rms) responding meters, from measurements of the true rms input voltage and true rms input current. 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:

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

6.4 SAFETY TESTS

Safety tests shall be made once on a representative sample of every battery charger model(s) and shall be repeated whenever a change is made that affects the safety characteristics of the charger. Design safety tests shall include the following:

1. Dielectric test (see 6.4.1)
2. Fire hazard test (see 6.4.2)
3. Mechanical integrity test (see 6.4.3)
4. Audible sound level limit test (see 6.4.4)

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 is reached in normal use. As an alternative, 120 percent of the specified test voltage shall be applied for 1 second.

The charger shall be tested by means of a suitable transformer having a 500 volt-ampere or larger capacity and having an output voltage that is essentially sinusoidal and can be varied.

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

1. Alternating-current input terminals to dead-metal parts.
2. Alternating-current input terminals to direct-current output terminals.
3. 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.

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 these 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)

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

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For all fire hazard tests, the battery charger shall be operated from a source of supply adjusted to the upper limit on 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 material 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

NEMA Standard 9-17-1981.

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.

Authorized Engineering Information 9-17-1981.

6.4.2.1 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.

6.4.2.2 MISCONNECTION

A battery charger intended for operation from two or more supply voltage levels or variations in number of battery cells or a combination thereof shall be connected in such a way as to produce the worst case 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.

6.4.2.3 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, that is, maximum rated input voltage supplied to the charger.

6.4.2.4 INTERNAL SHORT OR MALFUNCTION (FAILURE 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.

6.4.2.5 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 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.

6.4.2.6 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 circuity inoperable on some types of chargers.[2] 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.

([2]This sentence approved as Authorized Engineering Information).

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

The drop test shall consist of the following two parts:

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1. The package shall be placed on a 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.

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

6.4.4 Audible Sound Level Limit

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 ANSI S1.4-1971 (R 1976) Specification for Sound Level Meters.[3]

No acoustic vibrations greater than 85 decibels (A-weighting) shall be produced at any point 5 feet distant from any vertical surface of the charger.

NEMA Standard 9-17-1981.

6.5 PRODUCTION TESTS

Production tests shall be made on all production units for the purpose of maintaining 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 (see 6.5.1)
3. Circuit operation test (see 6.5.2)
4. Emergency stop pushbutton test (see 6.5.3)

6.5.1 Cabinet Ground Integrity Test

The resistance of the ground connections in the charger cabinet shall be checked with a volt-ohm-meter (VOM) (on the R x 1 scale). One lead from the VOM shall be connected to the cabinet grounding terminal and the other lead shall be used to probe the cabinet grounding terminals and exposed dead-metal parts.

All test points shall indicate essentially zero ohms.

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.

6.5.3 Emergency Stop Pushbutton Test

Continuity between the input ground and ground monitor terminals shall be checked without power to the charger and using a volt-ohm-meter (VOM) (on the R x 1 scale), and with the emergency stop button pulled out. Pushing in the emergency stop button shall eliminate continuity. The button shall stay in until again pulled out to restore continuity.

With power to the charger, pushing in the emergency stop button shall cause the contactor to be de-energized, thus shutting down the charger.

NEMA Standard 9-17-1981.

[3]American National Standards Institute, 1430 Broadway, New York, NY 10018.

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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.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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INDUSTRIAL BATTERY AND CHARGER SECTION
OF THE
NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

MEMBER COMPANIES

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Winston-Salem, NC 27107

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