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Guide to Pin and Sleeve Plugs, Receptacles, and Connectors

NEMA

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

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NEMA PR 3-1986

PR 3

GUIDE TO PIN AND SLEEVE PLUGS, RECEPTACLES, AND CONNECTORS

Published by

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(This Standards Publication approved as Authorized Engineering Information 11-20-1986.)

Foreword

This Standards Publication provides a synopsis of the safety and reliability facts about plugs, receptacles, and connectors of the pin and sleeve type intended for various applications. The continuing application requirements of the discriminating specifier and user provide an impetus for innovative designs, development, manufacture, and testing of the products of the pin and sleeve connector industry.

This publication supersedes NEMA Standards Publication PR 3-1980, and has been prepared by members of the Pin and Sleeve Plug, Receptacle, and Connection Section of the National Electrical Manufacturers Association. It will be reviewed periodically by the Section for any revisions necessary to keep it up to date with advancing technology. Proposed or recommended revisions should be submitted to:

Manager, Engineering Department
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Scope

The information in this publication applies to all plugs, receptacles, and connectors of the pin and sleeve type up to 600 volts alternating current, 250 volts direct current and all current ratings up to 400 amperes.

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GUIDE TO PIN AND SLEEVE PLUGS, RECEPTACLES, AND CONNECTORS

Section 1

PIN AND SLEEVE DEVICES

1.1 GENERAL

For many years, certain types of plugs and receptacles used to connect portable power equipment to a power source have been referred to as pin and sleeve devices. These devices differ from other systems by the types of contacts for joining the conductors. The pin and sleeve device uses a pin that is inserted into a sleeve. The pin and sleeve are made of highly conductive metal. Since the pin and contact tube are constructed and sized to develop and retain tension between each other, the resulting conductivity provides a highly reliable means of connection. The use of this type of connection is rooted in the original laboratories that developed our modern electrical power networks. (See Figure 1-1.)

1.2 TERMINOLOGY

The phrase "pin and sleeve devices" has now taken on a significance greater than just the description of the contact parts; and beyond that, construction of these parts can deviate significantly from the pure pin and sleeve design. (See Figure 1-2.)

Today, a pin and sleeve device is recognized as a highly reliable, safe, and versatile means of connecting a power system to its utilization equipment. Some of the many features available to the user of pin and sleeve devices include:

1. Amperage ratings far exceeding those of other systems.
2. Weathertight, watertight, explosion-proof, and dust-ignition-proof designs.
3. Design that will permit safe disconnect under full-load or locked-rotor conditions.
4. Mechanical or electrical interlock with circuit breakers or switches.

In all considerations, they retain their basic characteristics of reliability, safety, and flexibility.

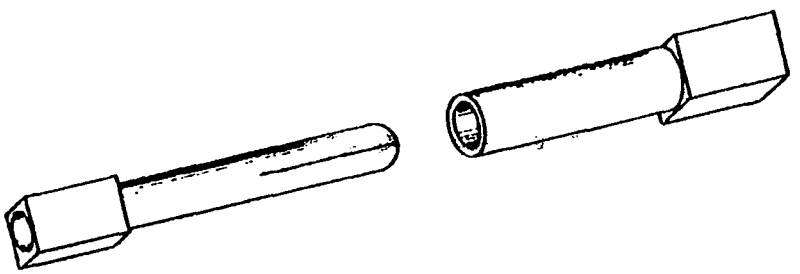

Figure 1-1

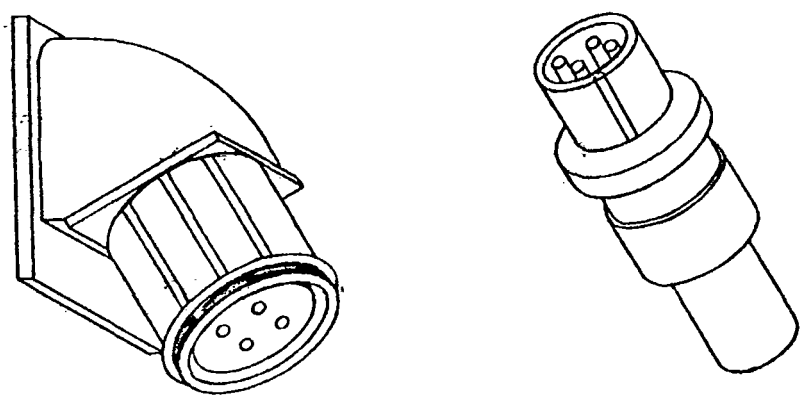

Figure 1-2

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Section 2
RELIABILITY

2.1 GENERAL

In the U.S. and internationally, the pin and sleeve type of construction is considered the norm for heavy-duty industrial applications. Above all, heavy-duty pin and sleeve devices are reliable, rugged, safe, and long-lasting.

2.2 ENDURANCE

The construction of these plugs, receptacles, and connectors is such that the abuses of normal heavy-duty use, including those of industrial environments, will not adversely affect their performance nor cause them to be unsafe over a long period of time.

2.3 SAFETY

Manufacturers' concerns for safety and reliability have resulted in the availability of the following pin and sleeve device features:

2.3.1 Noninterchangeability—contact orientation, polarization grooves and pins, and rotation options available permit compliance with Sections 210-7(f) and 410-56(g) of the National Electrical Code.*

2.3.2 Delayed action type units.

2.3.3 Nonlocking, locking, and self-locking.

2.3.4 Interlocked—to prevent either making or breaking the load on energized circuits by electrical or mechanical means.

2.3.5 Supplementary safeguards such as hinged lids and screw caps resist the entrance of moisture into the receptacles under adverse environmental conditions.

2.3.6 Arc-extinguishing—The arc formed by removing the plug under load is instantly snuffed in the deep, confined insulating arcing chamber while the plug contact is still a considerable distance inside. This provides for safe disconnection under full rated load without additional disconnecting devices.

2.4 LONG LIFE

The inherent total wiping action of the pin and sleeve contacts provides for long life where make and break under loads take place and particularly where inductive or direct-current loads are encountered.

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Section 3
MANUFACTURING AND EVALUATION

3.1 MATERIALS

The engineering plastics used in pin and sleeve devices, which simultaneously provide high-impact resistance, excellent dielectric characteristics, and resistance to tracking, support their classification for heavy-duty applications.

As with metals and elastomers, plastics of several different compounds or formulations may be found in a single device. For example, the arc chutes of a current-interrupting device may require a material having appropriate electrical properties, while housings and protective shrouds may require the use of nondeforming, high-impact materials.

Elastomers of a wide range may be used to provide seals against moisture and dirt or to form the entire housing of the device. Special resistance to oils, chemicals, sunlight, heat, and cold can be provided.

The metals used in the manufacturer of pin and sleeve devices are varied, and typically may include aluminum, copper, copper alloys, and steel alloys. Special platings or alloys to improve conductivity and inhibit corrosion are also employed.

3.2 WIRING TERMINATIONS

The proper selection of termination is dependent on factors relevant to end-user installation techniques and environmental conditions. Devices are provided by the manufacturer for direct field wiring to the device or with attached leads. Some representative wiring terminations are illustrated.

3.2.1 Pressure Lugs

The type of termination shown in Figure 3-1 can be used with devices in all current ratings. Either one or two screws capable of providing high unit forces may be used. The pressure plate type shown in Figure 3-2 serves to prevent galling of fine-strand conductors, distributes compression forces to the wire, and compensates for the effects of thermal cycling at the terminations.

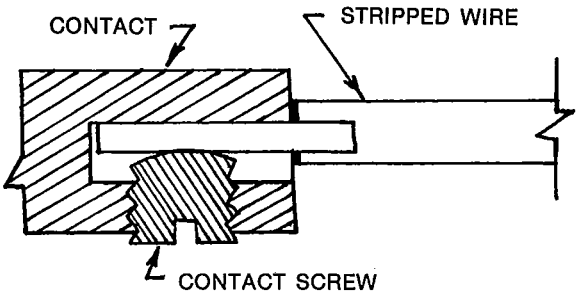

Figure 3-1

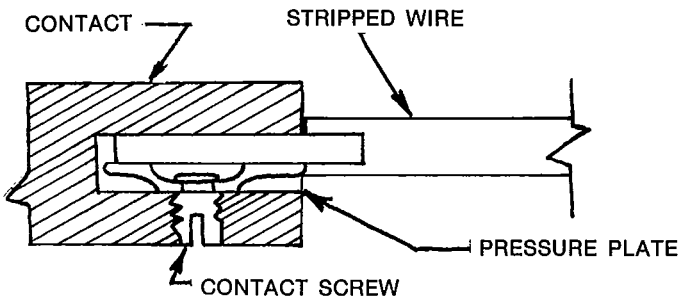

Figure 3-2

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3.2.2 Solder Pot

Solder connections (see Figure 3-3) are frequently used and are preferred by the military and wherever the wire conductors do not have to be easily removed. While this method achieves excellent electrical continuity of the termination, the installer should be knowledgeable in soldering techniques.

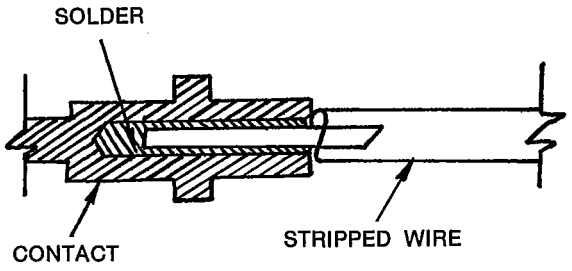

Figure 3-3

3.2.3 Crimp

Crimping (see Figure 3-4) is a popular termination construction among equipment manufacturers and original equipment manufacturers where very reliable and readily made connections are coupled with the need for resistance to corrosive atmospheres or high levels of mechanical vibration and shock, or both. Proper terminations are very easily attained with this method.

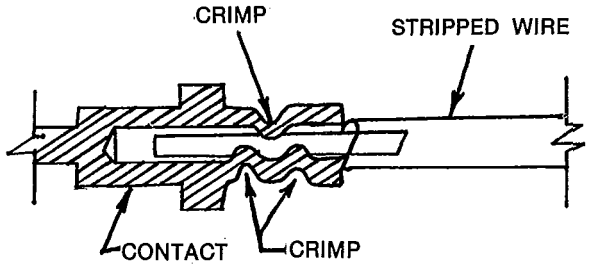

Figure 3-4

3.2.4 Combination Crimp and Solder

Crimp and solder connections are usually limited to termination of conductors or on attached leads furnished by the manufacturer of the device. This combination connection has an extremely high level of reliability.

3.2.5 Binding Head Screw

This general-use connection (see Figure 3-5) is commonly found on low-amperage (up to 30 amperes) pin and sleeve plugs, receptacles, and connectors. This type of termination requires limited skill by the installer. There should be adequate looping under the screw head and proper tightening torque to force the screw against the wire to assure a reliable contact.

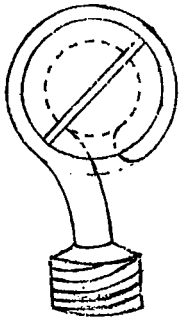

Figure 3-5

3.3 RECEPTACLE MOUNTING (See Figure 3-6)

3.3.1 Box

A common method is to mount the receptacles on a box which will accept conduit and provide adequate wiring space for conductors.

Boxes are available for mounting the receptacle either normally (90° to the mounting surface), or at some convenient angle, usually below the horizontal when mounted on a vertical surface. Some receptacles are designed for mounting on FS or FD boxes.

3.3.2 Sheet Metal Panels

Receptacles can also be mounted on sheet metal panels. The receptacle would normally be attached to the panel by bolts or clamping rings.

3.3.3 Concrete Slabs

Some receptacles are designed for mounting on a concrete slab. This type of construction utilizes a back box encased in concrete and a cover to which the receptacle is mounted. The cover also serves to conceal the opening between the concrete and the box.

3.3.4 Airport Aprons

Receptacles are available for installation in airport aprons. The cover for this installation protects the receptacle from damage by aircraft and service vehicles. The assembly is designed to withstand the adverse environments encountered on airport aprons.

3.3.5 Motor Base Plugs

For portable equipment there are motor base plugs with reverse service receptacle mounting. These permit the contacts to be mechanically protected and prevent accidental contact with live parts by personnel.

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3.4 TEST PERFORMANCE

Some performance characteristics are evaluated by the following tests:

3.4.1 Mechanical

1. Retention of plugs.
2. Strain relief.
3. Impact (drop test).
4. Special tests for hazardous location use.

3.4.2 Electrical

1. Continuity.
2. Potential drop.
3. Overload (electrical current).
4. Resistance to arching.
5. Dielectric.
6. Insulation resistance.
7. Temperature.
8. Full-load endurance.

These tests are intended to assist in the selection and application of pin and sleeve devices. For technical guidance, consult NEMA Standards Publication PR 4-1983, *Plugs, Receptacles, and Cable Connectors of the Pin and Sleeve type for Industrial Use* and FB 11-1983, *Plugs, Receptacles, and Connectors of the Pin and Sleeve Type for Hazardous Locations.**

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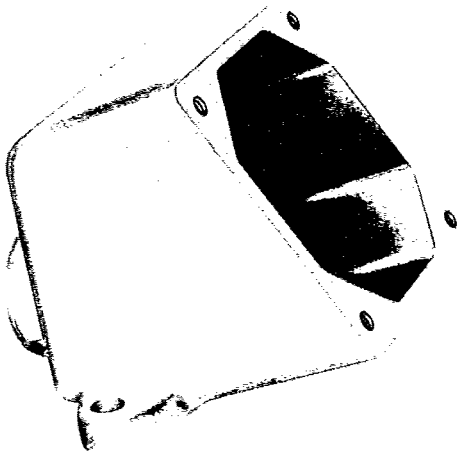
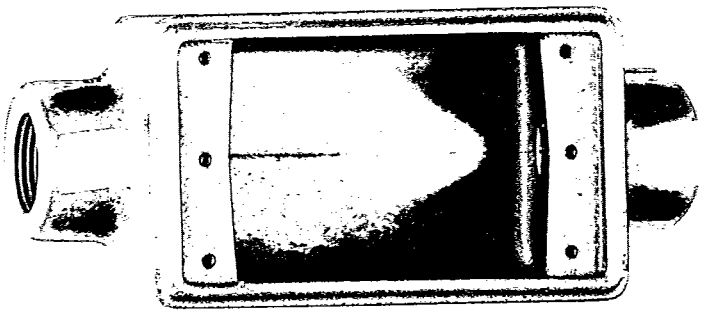
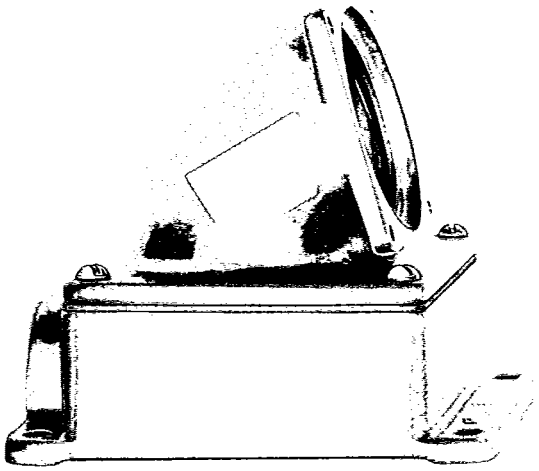


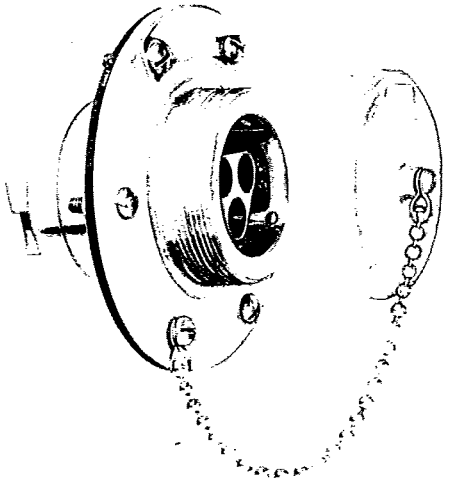
BACK BOX



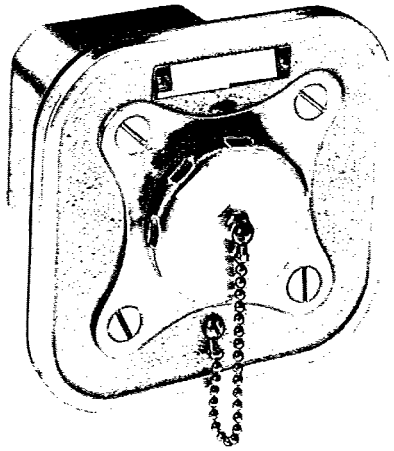
BOX FOR THROUGH FEED



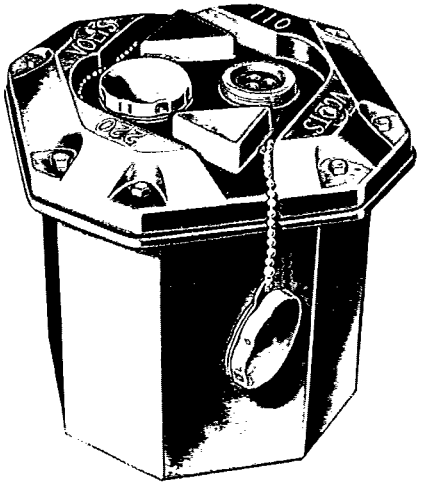
LARGE MOUNTING BOX



PANEL MOUNTING



CONCRETE SLAB MOUNTING



AIRPORT APRON MOUNTING

Figure 3-6
RECEPTACLE MOUNTING

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Section 4
CODE AND SAFETY REQUIREMENTS

4.1 CONFIGURATIONS

Individual manufacturers of pin and sleeve devices assign electrical ratings to their respective configurations in compliance with applicable portions of the *National Electrical Code*.*

The manufacturer so designs his contact configurations, utilizing polarization of indexing, or both, to prevent devices of one electrical rating from unsafe mating with any other device the manufacturer produces for a different electrical rating. Consequently, a user can choose from a wide variety of constructions available for his individual needs. As long as the user applies the selected configuration so it will be noninterchangeable on the same premises—that is, the same basic plug or connector not used for two different electrical ratings on the same premises—he is complying with the requirements of the *National Electrical Code*.* Conversely, one basic plug or connector may be used for different electrical ratings as long as each different rating is limited to a distinctly different premise.

IMPORTANT: Selection and application of the proper device should be done only by competent engineering personnel and should be backed up by a planned professional maintenance program.

4.2 ELECTRICAL RATINGS

4.2.1 Voltage

Most pin and sleeve devices are rated 0 to 600 volts, thereby allowing the user to apply them within that voltage range for any electrical system recognized by the *National Electrical Code*.* However, some devices are rated for a lower voltage such as a maximum of 110 or 250 volts on alternating-current circuits. Additionally, other pin and sleeve devices are rated up to 5000 volts for mining and series lighting applications.

4.2.2 Current

All of the devices have a specific amperage rating. Except for control circuit contacts which can be rated less than 10 amperes, current ratings are 10, 15, 20, 30, 60, 100, 200, and 400 amperes.

Many pin and sleeve devices are rated in horsepower to indicate the value of the locked-rotor current which they can safely interrupt.

4.2.3 Frequency

The common circuit frequency used in the U.S. is 60 hertz. In addition to that frequency, pin and sleeve devices are suitable for use on frequencies from 50 through 400 hertz.

4.2.4 Circuits

The number of contacts range from one to five plus ground. Selection of the plug and receptacle to be used should take into account the wiring system with which it is to be used. For example, a Wye system with the center grounded would require a 4-wire, 4-pole, or 4-wire, 5-pole device; depending upon whether or not a contact is to be used for a grounding path.

4.3 WIRE, POLE, AND POLARIZATION

4.3.1 Total Contacts

The number of poles indicates the total number of contacts in the device.

4.3.2 Current-Carrying Contacts

The number of wires denotes the specific number of current-carrying contacts of the device.

4.3.3 Field Wiring Terminals

Field wiring ground terminals are clearly identified by the mark "G" or "GR," or are green in color.

4.3.4 Polarization

Polarization permits assignment of electrical ratings by the manufacturer over a voltage range, and affords the user an opportunity to adapt if for the desired circuit voltage required.

4.4 CORD GRIPS AND STRAIN RELIEF

Cord grips are used to eliminate either placing a strain on the wire connections or damaging the cable. Devices rated 30 amperes or less are required to sustain a direct pull of 150 pounds for one minute; those rated above 30 amperes must withstand 300 pounds for the same length of time.

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Terminations at contacts are made with all strands of the conductor inserted to the full depth of the barrel and with the conductor insulation bearing against the shoulder of the barrel. Cable strain relief clamps are secured after forcing the cable into the wiring chamber to induce slack in the wires between the clamp and terminals. If bushings or cords are used to seal the cable, they are sized to maintain the integrity of the assembly.

Since the diameters and outer jacket materials on cables vary among cable manufacturers, specific information as to the cable type and size is needed by the device manufacturer to assure that the proper cord grip will be provided.

4.5 ARC QUENCHING

The arc chamber of pin and sleeve devices provides arc quenching deep inside the insulation which is not possible with conventional devices. Further, this arc quenching in combination with the wiping action of the contacts results in cooler operation and thus extended life and more compact designs.

4.6 PLUG SLEEVES

Sleeves are supplied on the plugs to promote safety by protecting the contact members and preventing exposure of the contacts during insertion.

4.7 CIRCUIT BREAKING

The circuit breaking ratings, amperes, voltages, horsepower, and power factor in alternating-current circuits conform with the applicable test provisions of standards of the Underwriters Laboratories, Inc.

4.8 POWER AND CONTROL CONTACTS

In addition to the normal connection functions of phase, neutral, and grounding contacts, pin and sleeve devices can be expanded to incorporate control circuits as well. Consistent with the basic safety concept of completing the grounding contact first and disengagement last, interlocking or monitoring circuit contacts can be timed to make last and break first. Devices for control applications only can incorporate almost any number of circuits as needed to meet a given requirement.

4.9 GROUNDING

The *National Electrical Code* and the Underwriters Laboratories, Inc. recognize the two safe methods used by the industry to terminate the grounding conductor from the portable device in pin and sleeve devices.

One method attaches the conductor in a lug on the plug handle. The ground pat is through the plug handle to the detent spring in the receptacle housing, and through the back housing of the receptacle to the equipment grounding conductor.

The other method terminates the grounding conductor in a contact which is bonded to the plug housing, if it is made of metal. When this latter approach is combined with the metal enclosure, a multiple grounding path results.

In many designs, the grounding contact is completed ahead of other of the circuit contact and is the last to be disconnected. However, since the interlock construction is virtually a dead-front device, it does not need to have a longer grounding contact member.

The pin and sleeve construction can also accommodate a ground continuity pilot circuit.

Section 5
ENVIRONMENT

5.1 SERVICE CONDITIONS

The manufacturer of pin and sleeve devices has limited or no control over environmental conditions to which a device may be subjected. However, the excellent service record of these devices is an indication of their inherent performance capability in a wide range of applications.

Environmental factors include ambient temperature, ambient pressure, dust, dirt, metal chips, moisture, rain, water, other liquids, sunlight, industrial chemicals, etc. Some designations reflecting environmental conditions include dripproof, dusttight, explosion proof, oiltight, rainproof, raintight, weather resistant, corrosion resistant, and dust-ignition-proof.

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Section 6
MAINTENANCE

6.1 GENERAL

All pin and sleeve devices used in industrial and other heavy-use environments should be inspected regularly and repaired, if necessary, to ensure proper function and safety. The responsibility for proper maintenance rests with the user.

6.2 INSPECTION SCHEDULE

Inspection of all fixed receptacles should be conducted at least once a year but more frequently if conditions warrant, as in severely corrosive atmospheres or where subject to intensive use. Plugs and cord connectors should be inspected more frequently than once a year, especially, if subjected to mechanical abuse such as being dropped on hard surfaces (i.e. concrete), or dragged on the ground. It is especially important to check the integrity of cord connector polarization.

6.3 STRAIN RELIEF

Cord/cable strain relief mechanism on plugs and cord connectors should be inspected to ensure that no external force can be transmitted through the cord or cable to conductor/wire terminations. Tighten clamp screws or other means of applying clamping force to values specified in the individual product instruction sheet. Make sure that the outer cord/cable jacket is completely within the clamping area and that there are no breaks, cracks, or cuts in the cord/cable jacket.

6.4 CONTACTS

Discoloration of contact/conductor terminations in plugs, receptacles and cord connectors is usually due to excessive heat, and is a clear indication of a problem that should be corrected before further use of the equipment. Loose conductor connection, equipment operated at greater than rated current, too high ambient temperature, repeated disconnection under load, poor pin to sleeve contact, and too small wire size are all possible contributors to circuit resistance and overheating. All "individual" wire strands should be contained in the termination area and the termination should be tight. Plugs should fit firmly when inserted into the mating connector or receptacle. Insufficient mating force of contacts can result in contact erosion/pitting caused by arcing of the contacts, accidental disengagement, or both.

Connectors and receptacles should be checked to ensure that adequate contact pressure is present. The complete interior (insulator and contacts) should be replaced if there is severe discoloration of the insulator or erosion of contacts such that their original shape has been altered.

6.5 ADDITIONAL CHECKS

Other checks which should be made during inspection and corrected before further use of the equipment are:

- Cracked or broken housing
- Cracked, broken, or dirty insulators
- Grounding conductor secureness
- Deteriorated or misplaced gaskets
- Loose or missing screws
- Insulation resistance of power contacts between themselves and to ground. Resistance value should never be less than 1 megohm.

6.6 CONTROL CONTACTS

Control contacts are occasionally used in conjunction with power poles. Inspect control contacts to ensure that they make last and break first.

6.7 PAINTING

Since the grounding circuit may include the external and interior surfaces of receptacles and cord connectors, and external surfaces of plug sleeves, these should not be painted beyond factor applied finishes. Also, to ensure correct usage and proper selection of replacement parts, nameplates should be kept clean and legible.

6.8 HAZARDOUS LOCATIONS

Equipment used in hazardous locations require additional inspections. All mechanically or electrically interlocked plugs and receptacles should be inspected for proper operation. Inspect for excessively worn or broken parts and replace as required. All parts and surfaces of these plugs and receptacles should be clean and free of foreign material, including corrosion. Flamepaths should be inspected to ensure that no excessive corrosion exists and that no scratches or gouges are on the ground joints. All screws holding receptacle to back boxes or adapters should be installed and torqued tight. Covers and threaded openings should be properly tightened. Plug and receptacle markings should agree with the Class, Group, and Division classification of the area where they are installed and used.

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6.9 ELECTRICAL PREVENTIVE MAINTENANCE PROGRAM

In addition to the required maintenance procedures outlined above, it is recommended that an Electrical Preventive Maintenance (EPM) program, as described in National Fire Protection Association Standard 70B-1983, *Recommended Practice for Electrical Equipment Maintenance**, to be followed.

EPM is the practice of conducting routine inspections, tests, and the servicing of electrical equipment to detect impending troubles and reduce their impact.

A well-administered EPM program can reduce accidents and injuries and minimize costly breakdowns and unplanned shutdowns of production equipment. Potential problems can be identified—and solutions applied—before they become major problems requiring more expensive, time-consuming solutions.

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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 similarly.

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Crouse-Hinds Electrical Construction Materials
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