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(Revision of
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IEEE Recommended Practices to Improve Electrical Maintenance and Safety in the Cement Industry

IEEE Industry Applications Society

Sponsored by the
Cement Industry Committee

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Abstract: These recommended practices are intended as a reference document for use by members of cement industry electrical maintenance departments. The procedures necessary for an efficient maintenance operation are summarized, and detailed information on maintenance procedures for many of the electrical devices more commonly found in the cement industry is provided.
Keywords: cement, control devices, electrostatic precipitator, equipment records, generators, grounding, instruments, lighting, maintenance, medium-voltage controllers, medium-voltage switchgear, motor control centers, motors, oil circuit breakers, power transformers, SCR controllers, secondary-unit substations, solid-state systems, spare parts, storage batteries

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Introduction

(This introduction is not a part of IEEE Std 625-2001, IEEE Recommended Practices to Improve Electrical Maintenance and Safety in the Cement Industry.)

Continuing efforts to improve safety and working conditions in the cement industry have made safety increasingly important to the management of every cement plant. Proliferating federal, state, and local laws have placed even greater stress on the need for a good maintenance and safety program. The Cement Industry Committee has analyzed many areas to which safety requirements pertain and, through the working groups, recommended practices have evolved for the industry.

Several years ago, the Safety Committee Working Group published its safety recommendations for the cement industry. At that time, no attempt was made to cover recommended maintenance practices in cement plants; the present recommended practices, however, combine both maintenance and safety practices. This approach was agreed on by the Environmental, Maintenance and Safety Working Group and is based on the belief that sound maintenance practices go, of necessity, hand-in-hand with safety. As in the previous recommended practices, IEEE Std 625-1979 and IEEE Std 625-1990, the recommendations contained here are advisory and should be considered in that light. The Environmental, Maintenance and Safety Working Group have agreed on these recommendations, but they recommend that they be revised in the future to suit specific plant conditions. In general, however, it is hoped that these practices can provide sound, basic guidelines for the industry at present.

For these recommendations to be of maximum use to the cement industry, the users' comments are required. Comments should be concerned with areas not covered in these recommended practices, as well as with those requiring greater coverage in subsequent reports.

This document was revised by the Environmental, Maintenance and Safety Working Group of the Cement Industry Committee. The members of the working group were as follows:

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Christopher C. Rayner, *Vice Chair*

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Ed Buehler	Larry D. McConnell	Diana L. Smith
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When the IEEE-SA Standards Board approved this standard on 14 March 2001, it had the following membership:

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IEEE Recommended Practices to Improve Electrical Maintenance and Safety in the Cement Industry

1. Overview

1.1 Scope

These recommendations apply to all electrical equipment such as substations, power transformers, motor controls, generators, distribution systems, instruments, and storage batteries commonly used in cement plants. They are intended to be used as a guide and may be supplemented where special needs exist. This document is a companion document to IEEE Std 277-1994, IEEE Recommended Practice for Cement Plant Power Distribution [B1] and IEEE Std 499-1997, IEEE Recommended Practice for Cement Plant Electric Drives and Related Equipment [B3][1].

1.2 Purpose

The purpose of these recommended practices are to define and recommend practices for improving electrical maintenance and safety in the cement industry in order to promote the following:

a) Safety to personnel and equipment
b) Maximum equipment reliability with minimum loss of production
c) Reduced unscheduled maintenance and increased equipment life
d) Clarification of needs and conditions to reduce special engineering and chance of error in specification
e) Overall economy

1.3 Objectives

It is urged that users and manufacturers cooperate with the working group to help formulate final recommendations that can ensure the use of proven equipment and methods. The ultimate objective is to establish recommendations to assist in improving electrical maintenance and safety.

[1]The numbers in brackets correspond to those of the bibliography in Annex A.

2. References

These recommended practices shall be used in conjunction with the following publications. When the following specifications are superseded by an approved revision, the revision shall apply:

30 CFR Part 56: Safety and Health Standards—Surface Metal and Nonmetal Mines.[2]

NFPA No. 70-2002, National Electrical Code.[3]

NFPA 70B-1998, Electrical Equipment Maintenance.

NUREG 1556 Vol. 4-1998, Consolidated Guidance About Materials Licenses: Program-Specific Guidance About Fixed Gauge Licenses Nuclear Regulatory Commission (NRC).[4]

3. Plant equipment numbers

In order to facilitate the maintenance procedures, spare-parts inventory, and the filing system of the manufacturer's information, it is important that each machine and piece of equipment be assigned a unique identification number. There are many numbering systems that can be used. A computer-compatible system is preferred to aid inventory and cost control. A simple system similar to many often used is described here. The equipment numbers consist of a department letter or number as a prefix and a three-digit number assigned according to the material flow and cost center. The motors and controllers for the same item usually carry the same basic number. The auxiliary equipment for the item, for example, an oil pump, can carry a suffix such as point one (.1), or can have a separate identification number. For example,

K-325 or 25-325	Kiln No. 3 Coal Mill
K-325.1 or 25-325.1	Kiln No. 3 Coal Mill Feeder

The numbers for the auxiliary devices (e.g., limit switches or pressure switches) could be the equipment numbers with a suffix such as LS or PS. For example,

K-326 LSO or Bucket gate open limit switch 25-325 LSO

Electrical equipment servicing more than one item in the same department (e.g., control centers, secondary-unit substations, or operator's panels) can be identified with an abbreviated description and the department letter. For example,

CC "KIA"	Kiln No. 1 "A" Control Center
LC "K1"	Kiln No. 1 Load Center
OP "KI"	Kiln No. 1 Operator's Panel

[2]CFR publications are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, USA (http://www.access.gpo.gor).
[3]NFPA publications are published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA (http://www.nfpa.org/).
[4]NUREG publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA (http://www.access.gpo.gov/).

Electrical equipment that is common to all departments (e.g., power transformers or main switchgear) can be identified with abbreviated descriptions such as 10 MVA transformer or main 5 kV switchgear.

4. Equipment manufacturer's data

It is necessary to acquire from each manufacturer a complete data file of the specific equipment used in the plant. This should include a list of recommended spare parts, a set of drawings, operating instructions, part numbers for reordering replacement parts, troubleshooting instructions, and suggested maintenance procedures. Practically all equipment manufacturers have this information available. This information is a prerequisite for a maintenance program. Hard copy and CD-ROM files of the drawings and data are normally available, and can be provided in a software format suitable for plant use.

The manufacturer's data should include the following:

a) Drawings
   1) Schematic and wiring diagrams
   2) Operating description
   3) Outline and installation drawings
   4) Bill of material

b) Instructions
   1) Handling and storage instructions
   2) Installation instructions
   3) Operating instructions
   4) Troubleshooting instructions
   5) Maintenance procedures
   6) Technical support phone number

c) Spare parts
   1) Part numbers
   2) Recommended spare parts
   3) Ordering information

This file should be set up for all electrical equipment, with every piece of information marked with the equipment identification numbers. This requirement is especially important if the equipment is old or not in good condition.

The equipment manufacturer's data files should be indexed, both according to the identification numbers and general category, for easy access. It is also recommended that the original documents be kept in the file room and that copies be made for outside use, as required.

5. Spare-parts inventory

Spare parts are an important part of any maintenance department. Good maintenance records help to determine what and how many parts are needed.

An accurate spare-parts inventory should be kept and made available for maintenance repairmen at all times. Adequate quantities of spare parts should be maintained, with minimum quantities established depending on the availability of each item. A sample of a good spare-parts list is shown in Table 1.

Table 1—Sample spare-parts list

Parts in use	Description	Quantity recommended	
		Maximum	Minimum
64	Scam panalarm division model 60-A1 plug-in relay, 120 V 60 Hz	4	2
6	Scam panalarm division model 50-Fl flasher, 120 V, 60 Hz	2	2

Spare parts with solid-state items should be stored according to the manufacturer's recommendation, as they may require a special environment. Warehoused items should be periodically inspected for condensation in large equipment. Large motors should be periodically rotated to avoid buckling of rotor shaft, etc.

6. Maintenance department

6.1 General

6.1.1 Maintenance department objectives

The basic objective of any maintenance department is to avoid unexpected production outages due to equipment breakdowns. The usual cause of breakdowns is neglect or prolonged periods of operation without preventive maintenance. The department interest should be focused on good preventive maintenance and the need for maximum utilization of time during normal shutdowns.

6.1.2 Maintenance department prime responsibilities

The prime responsibilities of any maintenance department are to

a) Maintain equipment in satisfactory condition for safe continuous operation.
b) Maintain equipment at peak operating efficiency at all times to avoid breakdowns.
c) Reduce the downtime associated with breakdowns to a minimum.
d) Control cost of maintenance.
e) Perform work in a safe and efficient manner.
f) Formulate and establish maintenance schedules based on equipment performance repair records and/or run time.
g) Recommend and control spare-parts inventory requirements.
h) Be a consultant to plant management when new equipment is being considered. Standardization of equipment, where possible, helps reduce spare-parts inventory requirements and simplifies maintenance work. After-sales support may be as important as technical specifications when selecting an equipment standard.
i) Meet regularly with management and other departments to review long-range maintenance requirements.
j) Continue to train and develop qualified maintenance electricians.
k) Provide state-of-the-art training for qualified maintenance electricians.
l) Maintain a computerized log of normal operating parameters and repair records for future reference.

m) For repeated failures or unanticipated frequent maintenance, examine the equipment for installation misapplication. A failure analysis should be performed for any failure.
n) Develop a close working relationship with equipment vendor/original equipment manufacturer (OEM). Establish a technical assistance contact. Identify reliable and reputable suppliers with good technical support. Careful planning and scheduling of manpower is an essential part of any maintenance department. Preventive maintenance requires many man hours with a minimum amount of downtime. Reliability is built into equipment, but requires maintenance to keep it there. Occasional proof testing is a necessary function.

6.1.3 Maintenance electrician's basic qualifications

The basic qualifications for a maintenance electrician are that he or she

a) Should be a certified electrician and physically and mentally fit to perform the job to which the maintenance electrician is assigned.
b) Should obey all company safety rules.
c) Should be able to read wiring diagrams and electrical equipment drawings.
d) Should have a good knowledge of the location of electrical equipment and of tools used for electrical work.
e) Should be able to install equipment and diagnose trouble on lighting, motors, motor controls, power circuits, and instrumentation.
f) Should be able to locate and repair or replace electrical equipment as the situation merits.
g) Should have hands-on experience troubleshooting programmable controllers, distributed control systems, drives, and digital and analog instrumentation.
h) Should be able to follow schedules as prepared by the maintenance department, and perform the work in an efficient and workmanlike manner. It is also essential that he recognize the tasks in which he should seek assistance.
i) Should cooperate with all employees, operators, and foremen at all times.
j) Should be able and willing to learn.
k) Should have a thorough working knowledge of the current National Electrical Codes, MSHA (Mine Safety and Health Administration) Standards, ANSI (American National Standards Institute), IEEE and NEMA (National Electrical Manufacturers Association) standards, and of local electrical codes where applicable.

6.2 Maintenance schedules

The most important part of any maintenance schedule is to display at all times what equipment is due for servicing. The maintenance schedule should be posted in front of all maintenance and production personnel at all times. In order to prepare a preventive maintenance schedule, a complete list of equipment, by departments, should be prepared.

Then, each unit of equipment should be analyzed to identify its characteristics of wear and its inherent weakness. It is very important that the maintenance schedules be coordinated between the maintenance department and management, to take advantage of all scheduled shutdowns. The servicing intervals may not necessarily agree with the manufacturer's recommendation. These intervals depend on the operating conditions and environment.

All electrical equipment should be serviced, including cables, motors, circuit breakers and starters, electronic control assemblies for adjustable speed drives, transformers, instruments, etc. In order to accomplish this, the entire plant should be on the maintenance schedule and these schedules should be updated weekly and monthly. Maintenance schedules should be closely followed to accomplish the maximum plant production.

6.3 Maintenance work orders

The work order should give the date, priority, name of originator, cost, equipment to be worked on, and details of work to be done. The work order is then given to the maintenance planner and scheduler, which is then given to the maintenance foreman. The maintenance foreman should review the work orders daily, and determine whether a shutdown is necessary. If a shutdown is needed, he should arrange it with production. He should also check the spare parts required and their availability. The work orders are then filed as

a) Ready to go
b) Awaiting shutdown
c) Awaiting parts

6.4 Maintenance inspection and repair records

Good inspection and repair records are essential to the success of any maintenance program. These records should indicate the nameplate data, purchase order data and number, and complete life history. The maintenance inspection and repair records should be either in duplicate, with each set filed in separate locations of the plant, or computerized with a backup record on tape or CD-ROM. A sample maintenance inspection and repair record is shown in Figure 1.

Inspection and Repair Record Card						
Item No.	Make	Purchase Order No. Part No.			Location	
Horsepower	RPM	Volts	Amperes	Type	Frame No.	Class
Phase	Form	Temperature	Hertz	Serial No.	Model No.	Enclosure
Brushes	Lubrication	Date Initial				
Quantity						
Size						
Catalog No.						
Bearings						
Non-Shaft End						
Shaft End						

Figure 1—Sample maintenance inspection and repair record card

6.5 Repair and maintenance cost records

The repair and maintenance costs for each piece of electrical equipment should be kept at all times and maintained indefinitely. These records can facilitate the decision as to whether to replace or repair the equipment after a number of years of service. These cost records also help when purchasing new equipment.

7. Equipment maintenance

7.1 Oil circuit breakers

7.1.1 Maintenance

Thorough maintenance of circuit breakers is very important and necessary to obtain the best service and performance.

7.1.2 Reports

Thorough reports with data on circuit breakers help the maintenance person determine when to plan a maintenance inspection.

7.1.3 Filing

A complete and accessible filing system should be maintained, accumulating all information pertinent to all types and sizes of circuit breakers. Also, instruction books, drawings, and spare-parts manuals supplied with the equipment should be kept on file and available for use. As the equipment ages, these books and drawings become more difficult to replace.

7.1.4 Organization and planning

The work to be done should be carefully planned, either by the supervisor or qualified assistants, and all potential hazards recognized and called to the work crew's attention.

7.1.5 Safety precautions

Safety devices should be examined before they are used to be sure they are in working condition. Nothing should be taken for granted.

7.1.6 Maintenance inspection determination

The following factors determine when a circuit breaker should be inspected:

a) Interval of time, since the last inspection (1 year maximum).
b) Number of switching and testing operations.
c) Number of fault operations.
d) Location and severity of faults.
e) Cleanliness of the environment surrounding the breaker.
f) Accumulated experience of the breaker characteristics and duty.

g) Preliminary external inspections.
h) Any unusual conditions such as noise, temperature, smoke, or friction. These conditions demand immediate inspection.

7.1.7 Parts and inventory

A supply of correct replacement parts should be available at all times.

7.1.8 De-energized equipment

For working on de-energized equipment, the following should pertain:

a) No work should be done on circuit breakers until clearance has been obtained and the appropriate switches locked out according to company published procedures.
b) When a circuit breaker is taken out of service, it should first be opened, discharged, and then isolated and grounded. For work on the circuit, the circuit should be disconnected by a visible disconnect means, locked out, and grounded.
c) Preparation. Before a breaker is taken out of service for a complete maintenance inspection, the following should be on hand:
   1) Adequate manpower to complete the job
   2) Manufacturer's specifications
   3) Necessary tools, including extension light, flashlight, wrenches, ladders, tarpaulins, and oil filtering and test equipment

7.1.9 After-maintenance check

Circuit breakers should be manually operated after an out-of-service maintenance inspection to ensure proper alignment of contacts, tightness of hardware, proper engagement of trigger and latch, etc.

7.1.10 Oil samples

Oil samples from all oil-type circuit breakers should be tested at the time of installation and retested annually. Deterioration of oil is caused by water, carbon, oxidation from excessive temperature, and contamination with foreign materials. Polychlorinated biphenyl (PCB) scans should be performed if the equipment has ever contained PCBs. It is possible for PCBs to leach out of contaminated internal surfaces.

7.1.11 Oil resistance level

Oil should be maintained at 37 kV/mm test or above at all times.

7.1.12 Trip mechanism

The trip mechanism and holding latch should be blocked with the breaker closed when breaker internal adjustments are being checked, so that it cannot trip open.

7.2 Power transformers

7.2.1 Energizing/de-energizing

It should not be assumed that a transformer is de-energized. Before work is started the breaker should be opened and it should be confirmed that the transformer is discharged. Before the breaker is closed again, it should be confirmed that the work is completed and that all is clear for energizing.

7.2.2 Checklist

Before work is started on any transformer, all tools should be counted (listed). This list should be checked after the end of work to make sure no tool has been left inside the transformer. It is good practice for each tool to be tied outside the transformer tank by means of a long string.

7.2.3 Tap-changer positioning

All tap-changer contacts should be on the same position. A tap-changer left between positions may cause a transformer failure. Experience has shown that manual tap-changer contacts can be a prime source of failure (arcing, burning, etc.), causing gas evolution and alarm or trip. For transformers equipped with off-load tap-changers, the transformer should be de-energized before the tap-changer is moved to another position. The transformer should always be de-energized and grounded before attempting repairs to the tap-changer mechanism.

7.2.4 Connections

All connections, both inside and outside the transformers, should be inspected every five years for tightness and discoloration, which would indicate "hot" connections (turns-ratio test), and tap-changer contacts (auto or manual).

7.2.5 Power transformers

All power transformers should be thoroughly checked for voltage ratio, impedance, and polarity before being installed.

7.2.6 Power transformer tanks

Power transformer tanks should be grounded to eliminate the possibility of personnel obtaining static shocks from them or being injured by the accidental grounding of the winding to the case. Bushings should be inspected and cleaned.

7.2.7 Oil specifications

Oil used with a transformer should either be the oil originally supplied, or an oil specifically approved by the equipment manufacturer. Insulating oil in all electrical equipment that has been in contact with, or has contained PCB compounds, is regulated by Federal Standards and possibly State and/or local standards as well. The obligation of the user or owner to identify such equipment and to comply with applicable rules and regulations is recommended. Oil should be checked every year for the presence of moisture. If moisture is present, as indicated by a dielectric test measurement below 37 kV/mm, the moisture should be removed from the oil in a suitable filter press or centrifuge.

It is important to realize that a minute quantity of water may spoil the insulating quality of transformer oil.

In addition to the dielectric test, dissolved gas analysis should be performed to determine the condition of the oil. This is an effective preventive tool in assessing the condition of the equipment.

7.2.8 Inspections

Yearly inspections are recommended for ground resistance, circulating current, plant connections, oil test, and "Megger" test of the windings, and for the functional operation of overtemperature switches and alarms. A chart recording the test values should be maintained from year to year.

7.2.9 Dry-type transformers

The elimination of cooling and insulating liquids in the ventilated dry-type transformer does away with the need for periodic testing and treatment of transformer oil. However, periodic load and temperature checks are still required.

7.2.9.1 Cleaning

It is important that care be used when cleaning dry-type transformers. Forced ventilation dry-type transformers circulate large quantities of air through their windings for cooling. If dirt is found on the windings, insulators, leads or terminal boards, it should be removed to permit free circulation of air and to guard against the possibility of insulation breakdown. Particular attention should be given to regular air filter replacement, cleaning top and bottom ends of winding assemblies, and to ventilation ducts. A vacuum cleaner is the preferred cleaning method, followed by the use of compressed air if necessary. The compressed air should be clean and dry and should be applied at pressures below 175 kPa. Dry nitrogen can be used instead of air, if precautions are taken to avoid the dangers of asphyxiation, but is not recommended. Lead supports, terminal boards, and other major insulating surfaces should be brushed or wiped with a dry cloth. Do not use liquid cleaners because of the possible deteriorating effect on the insulating materials.

7.3 Medium-voltage switchgear

7.3.1 General

Medium-voltage switchgear (5 kV and 15 kV) generally consists of air or vacuum circuit breakers, protective relays, storage batteries, and battery chargers. Storage batteries and chargers are covered in 7.4.

7.3.2 Medium-voltage air circuit breakers

7.3.2.1 Maintenance interval

Air circuit breakers are designed to be serviced at intervals in which no more than 2000 operations accumulate (1000 operations for circuit breakers with a rated short-circuit at maximum voltage of greater than 29 kA). Minimum time interval is 1 year.

7.3.2.2 Interrupters

Since they are not moving parts, the interrupters of a breaker normally require little or no maintenance, unless there is evidence of damage to the arc chute sides or contamination in the throat area.

7.3.2.3 Breaker contacts

The stationary contacts can be inspected only after the interrupter is removed. If the contacts are burned or pitted, they should be replaced or made smooth using the manufacturer's recommended repair procedures. Care should be exercised in dressing of contacts since it is possible to remove too much of the contact surface, which can reduce the current handling capacity of the contact, leading to premature failure. It is suggested that the contacts be replaced with new or refurbished units and the damaged contacts be rebuilt. Some contacts have metal coatings that require special repair techniques usually unavailable to maintenance organizations. This type of contact should be replaced. After inspection of the contacts is completed, their adjustment should be checked.

7.3.3 Medium-voltage vacuum circuit breakers and contactor controllers

7.3.3.1 General

Vacuum circuit breakers are power-interrupting devices applied to prevent damage to apparatus and to maintain continuity of electric power service. Circuit breakers are stored-energy or solenoid-operated devices. Vacuum contactors have limited power-interrupting capabilities, but are designed to be switched more frequently than circuit breakers. They are solenoid-operated devices designed to provide power to a load such as a motor or transformer.

7.3.3.2 Maintenance interval

While maintenance is greatly reduced with vacuum interrupting devices, in order to maintain a high degree of reliability, the breaker or contactor controller should be inspected and maintained at regular intervals. The recommended maintenance interval varies between manufacturers but, as a rule of thumb, it should be performed every 2000 operations for contactor controllers—or as indicated by a contact wear indicator if provided—or once a year, whichever comes first.

7.3.3.3 Vacuum breaker/contactor controller operating mechanism

A careful inspection should be made for rusting, deformation of parts, breakage of spring, abnormal wear, dirt or foreign matter in mechanism, and loosening of retaining devices. This inspection should be performed visually and by manually operating the breaker or contactor controller to observe smooth action.

7.3.3.4 Vacuum breaker/contactor controller electrical connections and wiring

The breaker or contactor controller should be visually checked for loose connections and dirt or foreign material. The connection points should be inspected for discoloration. Contact resistance should be measured.

7.3.3.5 Vacuum interrupters

Vacuum interrupters are highly reliable interrupting elements. The proper performance of these devices is primarily dependent upon the integrity of the vacuum in the chamber and internal dielectric strength. For an interrupter rating of 15 kV, these parameters can be checked by a 1-min 27-kV ac root mean square (rms) high-potential test; for contactor controllers or breakers rated at 1.5 kV or below, the interrupters can withstand 5.5 kV ac rms, 50 or 60 Hz test voltage for 1 min across a 2.3 mm contact gap. This test is performed with the breaker or contactor controller open and isolated from its electrical connections. The primary studs are connected together and to the high-potential machine lead. All bottom studs are connected together and ground along with the secondary contacts and the breaker frame. The test is started at zero potential and increased to 27 kV ac rms, 60 Hz, and maintained for 1 min. If there is a breakdown, then each contact should be tested separately to identify the defect and the defective contact should be replaced before placing the breaker back in service.

> **WARNING**
> Extreme caution should be exercised during high-potential testing because applying abnormal high voltage across a pair of contacts may produce x-radiation.

The radiation level encountered may increase or decrease depending upon contact spacing. It is, therefore, recommended that as a precautionary measure, all personnel stand at least 1 m away and in front of the breaker during testing. It is also recommended that because a dc tester may give erroneous readings of contact condition and may cause increased x-radiation, that an ac tester be used. The life of the contacts in a vacuum interrupter can be checked by measuring the contact wear gap indicator. The proper minimum measurement should be obtained from the manufacturer. Vacuum interrupters are normally closed contacts because of the atmospheric pressure pushing against the flexible bellows in the unmounted condition, and are made to be normally open contacts by the mechanical action of the operating mechanism. Due care is recommended for the inspection of the mechanical apparatus that operates the interrupter.

7.3.3.6 Mechanism

A careful inspection should be made to check for loose nuts and bolts, and for loose or damaged set screws and other devices.

7.3.3.7 Bushings and insulation

The surface of the bushings should be kept clean and unmarred to prevent moisture absorption. Damaged insulation surfaces should be sanded, cleaned, and refinished with either electrical varnish or clear resin. These surfaces should be allowed to dry smooth and hard before insulation is returned to operation. Silicon coatings are now available. Such coatings can be applied "live" with subsequent cleanings, a "water wash" up to 7 MPa. These coatings overcome the problems with "corn cleaning," which, after many "cleanings," can subsequently destroy the "glare" of the insulators, leaving them prone to moisture absorption.

7.3.3.8 Insulation test

When insulation has been repaired or replaced, or when the circuit breaker has been operating under adverse moisture conditions, it is recommended that the insulation be checked before the breaker is put back into service. A standard 60 Hz high-potential test is 14.25 kV rms for 1 min, which normally indicates whether the 5 kV breaker is satisfactory for service. With the breaker contacts in the fully open position, the test potential should be applied to each terminal individually, with all other terminals and the frame grounded. After high-potential tests are made on organic insulating materials, these materials should be inspected for visible leakage current paths, and necessary action should be taken to repair or replace insulation that may have been affected by moisture absorption.

7.3.3.9 Protective relays

The purpose of a protective relay is to detect destructive or abnormally operating power system components, such as generators, motors, transformers, bus sections, distribution feeders, or transmission lines, and initiate circuit opening and isolation of these components. Annual inspection and testing are recommended to help ensure that all protective relays perform properly.

Technical assistance in the setting, inspection, testing, and maintenance of the protective relays can be obtained from the manufacturer and/or a reliable testing facility.

7.4 Storage batteries

7.4.1 General

The purpose of a storage battery is to provide a reliable source of electrical power for controlling electrically operated components and systems in the cement industry. A storage battery, in combination with a charger, is the fundamental element associated with a system that provides power for such vital activities as opening and closing ac power distribution circuit breakers. Usually only the vital equipment required for safety shutdown of the plant following an emergency or loss of ac power is connected to the battery/charger dc power system. The charging system provides continuous charging of the batteries (known as float charging) and allows the battery to maintain full capacity for delivering maximum output power to its connected circuitry, in the event the loss of ac power occurs. The charger also supports continuous dc loads during normal operation. Batteries that are properly maintained can remain operational for many years. Conversely, neglected or inadequately maintained batteries are prone to failure and may not function when called upon to operate in emergency situations.

WARNING
Batteries generate explosive gases during normal charging and discharging operations; therefore, specific safety precautions are required during normal use.

7.4.2 Types of storage battery

7.4.2.1 Vented lead–acid batteries

Also known as "flooded" or "wet," vented lead–acid batteries are typically of the pasted plate construction, in which the active materials are pasted onto a lead alloy grid. Typical grid alloys include lead–calcium, lead–antimony, and lead–selenium. The choice of alloy influences the operating characteristics of the battery.

7.4.2.1.1 Lead–calcium batteries

With stable charge characteristics and a low level of water consumption throughout life, lead–calcium batteries are well suited to float operation. The number of charge–discharge cycles is limited, so they are less suitable for applications involving frequent discharges.

7.4.2.1.2 Lead–antimony batteries

These batteries give predictable service lives and operate well in duties requiring frequent discharges. In float service, however, antimony migration causes the rate of water consumption to accelerate throughout life, causing a considerable increase in maintenance requirements.

7.4.2.1.3 Lead–selenium batteries

Also known as "low antimony," these batteries have characteristics similar to those of lead–antimony, with the exception that they exhibit stable charging and maintenance requirements throughout life.

7.4.2.2 Valve-regulated lead–acid (VRLA) batteries

Valve-regulated lead–acid batteries (VRLA) share the same chemistry with their vented counterparts, but provide a means for recombining charge gas, thus limiting hydrogen evolution and water consumption. Their compact size has made them popular in many applications. While the lack of water additions has led them, incorrectly, to be called "maintenance-free," they have additional failure modes and actually require some additional surveillance to ensure reliable operation.

7.4.2.3 Nickel–cadmium (Ni–Cd) batteries

The traditional construction for Ni–Cd batteries is the pocket plate type. More recently, fiber plate batteries and hybrid sintered/plastic bonded plate batteries have been used in stationary applications. These types share an alkaline electrolyte and a plate structure that does not deteriorate with age. Nickel–Cadmium batteries in float service have long lives, good charge–discharge cycling capability, and are less affected by high temperature than their lead–acid counterparts.

7.4.3 Recommended storage battery maintenance

7.4.3.1 Watering

Approved or distilled water should be added as required to keep the electrolyte level between the high-level and the low-level lines on the container.

7.4.3.2 Cleaning

The outside of the cells should be kept clean and dry by wiping with a water-damp cloth as required. Any acid on the covers or connectors should be neutralized with a cloth moistened with a solution of baking soda and water; then traces of soda should be wiped off. Solvents, cleaning compounds, oils, waxes, or polishes should never be used on plastic containers or covers, since such materials may attack the plastic and cause it to craze or crack.

7.4.3.3 Connectors

Visible corrosion should be removed from connectors. Corroded or pitted connectors should be replaced as they may render the battery ineffective when it is needed. Battery connections should be checked for tightness on a periodic basis. It is also recommended that the resistance of the connections be measured periodically. Refer to the appropriate IEEE procedure for guidelines pertaining to these measurements.

7.4.3.4 Periodic testing

Testing of batteries has been shown to be the only accepted method to ensure that a battery functions when needed. IEEE Std 450-1995 [B2], IEEE Std 1106-1995 [B4], and IEEE Std 1188-1996 [B5] call for batteries to be tested according to a specific schedule and method depending upon the type of battery that is installed. The basic tests recommended in the IEEE recommended practices are

a) Lead–acid vented cells: A performance test within the first 2 years and then every 5 years until degradation is indicated.
b) Valve-regulated cells: A performance test every year until degradation is indicated.
c) Nickel–cadmium cells: A performance test within the first 2 years and then every 5 years until degradation is indicated.

Other tests are described based on the importance of the application and there are also alternative test methods that may be applicable to the application.

7.4.3.5 Equalizing charges

Some battery types, including lead–calcium, lead–antimony and nickel–cadmium, may require equalizing charges at regular intervals if the normal circuit voltage is below the battery's full charge voltage. The manufacturer's recommendations should be followed for this procedure.

7.4.4 Important safety rules

The following important safety rules apply to the use and maintenance of batteries:

a) Batteries generate explosive gases during charging and discharging; therefore, it is extremely important to avoid any open flames, personnel smoking, and/or any electrical arcing/sparking (including static discharge) in the vicinity of the battery. Refer to NFPA No. 70-2002[5] or 30 CFR Part 56[6].
b) Personnel equipment must be worn when working on batteries (eye goggles, acid-resistant gloves, apron).
c) Portable or stationary water facilities must be available for rinsing eyes and skin.
d) An approved fire extinguisher should be available.
e) A vented cover should be installed over the battery terminals to prevent contact with personnel or tools. Use insulated tools when working on batteries. Never place tools on top of battery.
f) Lift the batteries by means of mechanical equipment, such as a hoist, crane, or lift truck. Move the batteries horizontally by means of power trucks, conveyers, or rollers.
g) Restrict the battery area to authorized personnel.
h) Make certain that the battery-charging area is adequately ventilated. Air should be ventilated away from possible ignition sources, preferably through an outside wall.

7.4.5 Periodic inspections

7.4.5.1 Battery inspections

IEEE Std 450-1995 [B2], IEEE Std 1106-1995 [B4], and IEEE Std 1188-1996 [B5] recommend periodic inspections and measurements. The following is a summary of the recommendations for vented lead–acid batteries:

a) **Monthly**—Record the charger output current and voltage, along with pilot cell voltage, specific gravity, and temperature.
b) **Quarterly**—Record the individual cell float voltages, and specific gravity and temperature readings on 10% of the cells.
c) **Annually**—Record the float voltage and specific gravity of all cells and temperature of 10% of cells. Record intercell connection resistance values. Perform a detailed visual inspection of all cells, noting jar and plate condition, visible signs of corrosion, etc. Inspect the battery rack, as applicable, for loose connections and signs of corrosion.

Specific gravity measurements cannot be made on VRLA cells. To monitor the state of health of VRLA batteries, it is recommended that internal ohmic measurements be made on a quarterly basis. Examples of internal ohmic measurements are ac impedance, ac conductance, and dc resistance. Specific gravity measurements are not required for Ni–Cd cells.

[5] For information on references, see Clause 2.
[6] Throughout the rest of this recommended practice, CFR numbers will be referred to by the abbreviation 30CFR56.

7.4.5.2 Battery chargers

Battery chargers are essentially maintenance free and require only periodic dust removal from the top of the screen-type cover and interior. Ventilation is of prime importance. The area around the charger should be checked, and it should be made certain that nothing interferes with the free flow of air. Checks should be made for dust deposits. Dust on the heat-radiating surfaces and contacts of the charger can greatly reduce heat dissipation. Dust and other accumulations should be removed regularly. The area around the charger should be kept dry. On occasion, condensation may form, especially when the unit is idle; this should be cleaned to prevent fungus growth.

Connections at the terminals should be clean and tight. The heating of terminals is a definite indication of corroded or loose terminal connections. Fuse clips are particularly subject to overheating and corroding. They should be checked regularly for proper tension and cleanliness of the contact area.

Float and equalize voltage should be checked on a regular schedule and readjusted if necessary.

When possible, the current-limit operation should be checked. If current limit occurs when the load current is too high, overloads may damage the unit. An over-current indication can be used to initiate an alarm in the central control room.

NOTE—Analog voltmeters fitted to battery chargers are of low accuracy and are for general indication only. All battery voltage measurements should be made with a calibrated digital voltmeter.

7.4.5.3 General maintenance of uninterruptible power supplies

Emergency power sources should be on a regular preventive maintenance schedule. The batteries should be load tested on an annual basis or at routine plant shutdowns. The manufacturer of the equipment should be scheduled to come to the plant and thoroughly check and inspect for faulty circuits and/or electrical components.

7.5 Secondary-unit substations

7.5.1 General

A secondary-unit substation consists of the following:

a) Primary air-interrupter switch
b) Transformer
c) Low-voltage distribution section

These three sections should receive an inspection annually.

7.5.2 Medium-voltage switch

The medium-voltage air-interrupter switch requires very little maintenance. Annual inspections should determine what maintenance is required.

7.5.3 Transformer section

See 7.2.

7.5.4 Low-voltage distribution section

7.5.4.1 Switchgear

An annual inspection should be scheduled for the switchgear.

7.5.4.2 Air circuit breakers

Air circuit breaker maintenance should include the following activities:

a) Each breaker should be operated several times while in the "TEST" position and all functions checked. This is particularly important for breakers that normally remain in either the same open or closed position for long periods of time.
b) The breaker should be removed from its compartment to a clean maintenance area for complete cleaning and inspection.
c) A complete contact inspection, including contact wipe and pressure should be made. Arcing contacts and arc quencher barriers should be replaced when they are eroded to half their original thickness.
d) Mechanical bearing points and sliding surfaces should be lubricated with a thin film of manufacturer's approved grease. Hardened grease and dirt may be removed with kerosene. All excess lubricant should be removed to help avoid accumulation of dirt or dust.
e) Trip units for low-voltage switchgear should be set or adjusted only after a system study has been made. This system study should be updated as required, for example, if the fault capacity of the utility supply increases due to expansion of the electrical supply system.
f) The trip-free mechanism should be checked to ensure that the breaker cannot be installed in the closed position.

7.6 Medium-voltage motor controllers

7.6.1 Protective relays

Protective relays for medium-voltage controllers may be set using the manufacturer's instructions.

7.6.2 Calibration

These units should be calibrated by someone who performs this work frequently and has the special equipment required. This work is best left to professionals, such as service shops.

7.6.3 Inspection

Medium-voltage motor controllers should be scheduled for inspection and maintenance every 6 months, as outlined in 7.6.4. Experience can show if this inspection should be made at more or less frequent intervals.

7.6.4 Controller mechanism

The controller mechanism should be checked as follows:

a) Place the controller in the disconnect position.
b) Check for loosened screws, nuts, bolts, clamps, and electrical interlocks.
c) Blow out the contactor to remove dirt.
d) Examine the arc chutes.
e) Check the contacts for wear.

f) Clean the insulators.
g) Check and adjust the power stabs. A force gauge should be used for this purpose.
h) Check the dimensions of the isolating mechanism and mechanical interlocks in accordance with the manufacturer's instructions.
i) Thoroughly clean the mechanism before returning it to service.

7.6.5 Adjustable speed controllers

Annual maintenance should be scheduled for adjustable speed controllers. An infrared (thermographic) scan of all connections, while the equipment is in operation, is useful and beneficial for identifying problem areas. Annual maintenance should include

a) Complete de-energization of the equipment, according to the manufacturer's recommendations, and installation of a ground chain.
b) Cleaning of all compartments and heat sinks by brushing and vacuuming.
c) Maintenance of medium-voltage switches, starters, and transformers, where included, as outlined in 7.3.
d) Tightening of the power and control connections. Connections showing indications of local heating (thermographic inspection) should be cleaned and repaired.
e) Replacement of failed or obviously distressed components and insulation. The replaced items should meet the manufacturer's specifications.
f) Checking of regulator card connections and cleaning and repair of loose connections, following manufacturer's recommendations for electronic and solid-state devices. Care should be taken not to change regulator adjustments that have been preset for proper operation.
g) Inspection of all moving parts for wear, corrosion, freedom of movement, and contact pressure. This includes wires exposed to the cooling fan airflow, since the air can cause wires to rub against grounded objects causing a short and, possibly, a plant shutdown.
h) Inspection of the cooling fans and fan housing, tightening of electrical connections, and cleaning or replacing the filter material.
i) Motor maintenance as outlined in 7.8.
j) Verification that all space heating functions operate properly.
k) Verification that the enclosure has maintained its design integrity.
l) Remove the ground chain, energize, and perform trial run of drive. Check cooling fans for proper operation. Operation, stability, and speed range should be observed and adjustments made in accordance with the manufacturer's recommendations.

NOTE—The speed range may be specified by the manufacturer's process considerations for the driven equipment.

7.7 Motor control centers

Annual or semi-annual maintenance should be scheduled for motor control centers. An infrared (thermographic) scan of all connections, while the equipment is in operation, is useful and beneficial for identifying areas of local overheating prior to the scheduled maintenance. Scheduled maintenance should include

a) Complete de-energization of the equipment and lockouts and tags utilized. It is recommended that special care be taken to isolate all sources of energy, as there may be voltage present from external sources.
b) Cleaning of all compartments by brushing and vacuuming.
c) Contact and thermal overload resistance check. Testing the overload trip mechanism. Electrical and mechanical performance of the breaker can be tested with a circuit-breaker tester.

d) Tightening of the power and control connections. Connections showing indications of local heating, or where local overheating was detected by thermographic inspection should be cleaned and repaired. Fuse clips should be cleaned and tightened where indicated.
e) Replacement of failed or obviously distressed components and insulation.
f) Removal of draw-out units and check of stabs and unit wiring.
g) Inspection of all moving parts for wear, corrosion, freedom of movement, and contact pressure. Contacts that are beaded or worn to the extent that failure is anticipated before the next scheduled maintenance should be replaced. Contact resistance should be measured.
h) Checking of interlocks for alignment, overtravel, and wear.
i) Replacement of failed light bulbs, and broken or sticking indicating meters and pilot devices.
j) Careful replacement of failed fuses and components. Replacements should meet the original design specifications. It is especially important that current-limiting fuses or air circuit breakers have adequate interrupting capacity.
k) Observe the following "do's" and "don'ts":
    1) *Do* keep a supply of spare parts for immediate replacement, including fuses, circuit breakers, overload relays, heaters, coils, pilot devices, interlocks, terminal blocks, and complete draw-out assemblies in each size.
    2) *Do* check starter for proper fuses, overload device, circuit breaker, and exercise circuit breaker or disconnect switch.
    3) *Do* replace or check fuses, overloads, and circuit breakers for operation after each fault. Circuit breakers and overloads should be checked for tripping with a test current source to meet manufacturer's recommendations. A circuit-breaker tester is recommended.
    4) *Don't* use lubricants on control devices.
    5) *Don't* use emery paper or sandpaper to clean contact devices.
    6) *Do* remove ground chain and close doors before energizing motor control center.

7.8 Motors and generators

7.8.1 General

Any unusual sounds, vibrations, smoking, smells, heating, and obvious distress should be investigated immediately and repaired. Motor manufacturer's recommendations should be followed. Replacement parts should meet the original equipment manufacturer's specifications. Spare rotors and armatures should be handled and stored, preferably indoors, and supported by the shaft to minimize damage in handling.

This recommended practice is not intended as a repair manual. The many types of motors, motor voltages, and enclosures necessitate that the treatment here be only general and in the line of preventive maintenance.

7.8.2 AC motors

Motors should be inspected and preventive maintenance scheduled annually. Such inspection and maintenance should be in accordance with 7.8.2.1, 7.8.2.2, 7.8.2.3, 7.8.2.4, 7.8.2.5, 7.8.2.6, 7.8.2.7, and 7.8.2.8.

7.8.2.1 Lockout

All sources of energy to the motor should be disconnected and locked out. It is not safe practice to lock out control circuits only (even though some electrical safety codes may only require a local lockout "stop" push button), in lieu of main power circuits, for motor starters. For example, only locking out a local "start–stop" push button near the motor for maintenance and inspection of the drive or driven equipment without also locking out the power supply to the main motor, means that several kinds of control wire failure or mis-operation of the starter contactor could result in the motor being energized inadvertently.

7.8.2.2 Cleaning

AC motor cleaning should include the following activities:

a) The environment should be examined for unusual water or dust and their sources should be eliminated.
b) Motors with stator shift should have their stators shifted and cleaned inside and out.
c) Totally enclosed fan-cooled (TEFC) motors should have their exteriors cleaned, ventilation passages opened, and fans examined and cleaned.
d) Open drip-proof and splash-proof motors should not be blown out. Use a vacuum cleaner after major dirt accumulations have been removed manually. Do not use liquid cleaners.
e) Forced-air cooled motors, either ac or dc, should have their exteriors cleaned, ventilation passages opened, blower fans examined and cleaned. If filters are used with the forced-air blowers, they should be cleaned or replaced.

7.8.2.3 Examination

Motors should be examined for signs of damage such as loose or abraded windings, broken bars or end rings, loose or broken fans, scorched insulation or bearings and housings, air-gap clearances, loose wedges, and areas of obvious distress. The motor conduit box should be examined for proper gasketed sealing. All electrical connections should be checked for integrity and should be tightened, if necessary, including the motor ground. For motors over 3.7 kw any "wire nut" connectors should be replaced with approved devices, such as crimp-type ring connectors.

7.8.2.4 Checking insulation resistance

A rule of thumb is a minimum of 1 MΩ/1000 V rating plus 1 MΩ, that is, 1.5 MΩ for 480 V machines and 5 MΩ for 4160 V machines. Surge protective devices should be disconnected, as capacitor discharge resistors can cause a low reading. A time history record of important machines should indicate any significant trend and is a better prediction of failure than actual spot readings. Low-reading machines should be dried with moisture-free heat and varnished. Where feasible, baking is desirable.

A nondestructive test instrument should be used to do the testing. A 500 V, dc megger or limited-circuit hipot for testing is suggested for 460 V motors and a 5000 V, dc source for 4000 V motors. Readings should be observed after stabilizing or after 1 min. As with any voltage, care should be exercised when testing, as shock hazards exist.

7.8.2.5 Lubrication

Much damage can be done by overgreasing as by undergreasing. Bearings that are greased should be purged and regreased with recommended grease. (Severe duty may require greasing on a 30–180 day schedule depending on the manufacturer's recommendations.) Oil-lubricated motor bearings should be drained, flushed, and relubricated with recommended oil. Motors may be equipped with oil slingers.

7.8.2.6 Reassembly

After the motor is checked in accordance to 7.8.2.2, 7.8.2.3, and 7.8.2.4, the disassembled motor should be reassembled, housing covers replaced, and the motor rotated, while still uncoupled, by hand, to test for freedom of rotation.

7.8.2.7 Alignment check

Axial, angular, and vertical alignment should be checked. The most accurate method of checking and adjusting alignment is using a laser alignment instrument. Proper alignment between motors and attached equipment can help extend the life of the motor and related components. Also, sleeve-bearing motors should be checked for conditions preventing operation within end float limits. Generally, coupled loads should not exert axial loads on drive motors. Belted drives should be adjusted to the correct tension.

7.8.2.8 Dry run

Once the motor is ready to run, a final dry run is recommended while it is uncoupled to check for vibration, direction of rotation, bearing heating, oil ring turning, operation on magnetic center, and unusual sounds. Observations should be within acceptable limits for the motor. Vibration should be checked again after the motor has been coupled to the driven device.

7.8.3 DC motors and generators

7.8.3.1 General

The procedures outlined in 7.8.2 for ac motors also apply to dc machines. In addition, some special precautions are recommended for dc machines.

7.8.3.2 Care

Special care of brush length, brush tension and clearances, indications of brush chatter and arcing, and insulator conditions on dc motors and generators is urged. Commutator condition should be observed for color, grooves, mica height, and concentricity. Where noted, out-of-tolerance conditions indicate future trouble and should be repaired in accordance with the manufacturer's recommendations.

7.8.3.3 Start-up

In start-up, commutation sparking and brush operation should be observed. Unusual, unexplained poor commutation is an indicator of impending failure and should be investigated to remove the cause.

7.8.3.4 Environment

Proper airflow and humidity needs to be maintained in order to achieve optimum brush life and desired filming of the commutator. The manufacturer should be consulted to determine proper airflow and humidity. Air filters should be cleaned or replaced as necessary.

7.9 Control devices

7.9.1 General

Control devices are subjected to repeated operation, and preventive maintenance can only be ignored at the expense of unplanned outages. A replacement part should be stocked for each different device and at least one spare for up to 10 devices, two for 10–50 devices, and three spares for 50–100 devices.

7.9.2 Inspection and preventive maintenance

Detailed logs should be kept on all equipment and should record the date of all checks made, the condition of the equipment, and any repairs that were performed. Thermographic inspection using an infrared scan is a beneficial preventive maintenance that can be used while units are still in service. In addition, semi-annual de-energized inspection and preventive maintenance is recommended. Inspection should include the following activities:

a) Cleaning and critical inspection for corrosion, damage, freedom of movement, and visual operation. Loose connections should be tightened.
b) Operation while energized on the test bench to check for contact continuity, noise, alignment, and freedom of movement. Circuits and devices should be inspected for evidence of localized heating.
c) A calibration check, where feasible, on the test bench, over the required operating range.
d) Reinstallation, taking special care to replace damaged gaskets, and remake connections.

7.9.3 Level detectors

On–off level devices are checked as outlined in 7.9.2. Special care is required for electronic devices in which a visual bench check does not simulate actual operation. A comparison check against a new or replacement device can help evaluate proper performance.

7.9.4 Temperature, pressure, and flow switches

On–off temperature, pressure, and flow switches are also checked as outlined in 7.9.2. A calibration check for operation within desired limits is recommended, as these safety devices are relied on to protect machinery. The use of controlled temperature, pressure, and flow test setups is recommended to enable calibration of these devices and to help ensure proper operation.

7.10 Instruments

7.10.1 General

Proper operation of process instrumentation is mandatory for the control of cement plant processes. An out-of-calibration or improperly operating instrument can be worse than no instrument at all, as misleading information can be catastrophic.

Past experiences indicate that a semi-annual inspection and calibration check with unspecified intermediate checks within the six-month period are to be recommended or in keeping with specific recommendations by the manufacturer. Any suspected malfunction should be checked immediately. Thermocouples and radiation pyrometers, depending on severity of service, need checking more often, as they usually operate in a hostile environment.

7.10.2 Nuclear gauges

Purchase and use of nuclear gauges is licensed and regulated by the Nuclear Regulatory Commission and state regulatory agencies, and strict inventory and operational documentation is required. It should also be noted that while anyone can close and lock out the device shutter, only the designated Radiation Safety Officer has the authority to open the shutter. Improper use of these devices could result in severe federal penalties. Only technicians who have completed an approved training course should service these instruments. Instruments should have their shutters closed before repair is commenced. Wipe tests should be performed at minimum intervals specified by the license.

WARNING
Only personnel with proper training in the handling and safe operation of these devices should be allowed to service them.

7.10.3 Instrument maintenance and calibration

Sophisticated analog and digital instrumentation requires sophisticated maintenance personnel and test equipment. Safe and efficient operation of the plant depends on the accuracy of the plant instrumentation. Calibration of instruments traceable to National Institute of Standards and Technology (NIST) standards is recommended.

7.10.4 Test equipment and supplies

Where available, test equipment especially built to test and calibrate a specified manufacturer's equipment is recommended. In addition to the regular instrument maintenance tools, the following devices are recommended to enhance the instrument maintenance function:

a) Test equipment, which should include:
   1) Digital voltmeter or multimeters
   2) Digital frequency counter
   3) Dual-beam oscilloscope
   4) Volt-ohm milliammeters, both low impedance ($\leq 2000\,\Omega/V$) and high impedance ($\geq 20000\,\Omega/V$) (A high-impedance meter is used to check high-impedance circuits where the instrument itself can load and affect circuit operation.)
   5) Precision milliammeter
   6) Portable potentiometer
   7) Current calibrator
   8) Thermometers of trusted integrity
   9) Portable optical pyrometer with calibration facilities
   10) Portable manometers
   11) Precision timer.
b) Backup replacement instruments for each different instrument and 5% spares for multiple-instruments.
c) A complete set of manufacturer's data and instructions on the instrumentation used.

7.10.5 Sensors

7.10.5.1 Thermocouples and pyrometers

7.10.5.1.1 Daily inspection

Inspect thermocouples and pyrometers daily as follows:

a) Visually check all thermocouples and pyrometer heads for mechanical alignment and loose or broken connections. Note and advise the supervisor of their condition.
b) Remove radiation pyrometers from the support fitting for external-lens-surface cleaning. Advise the control room operator before proceeding.
c) Inspect the kiln thermocouple's pantograph pickup (carbon collector brushes) for chipping or excessive wear. Check the spring tension to ensure proper tracking of the pantograph guide wheels. Check the surface of the collector rings for mechanical continuity, alignment, and any evidence of oxide film formation. Note any unusual condition and advise the supervisor that repairs should be scheduled.

7.10.5.1.2 Monthly inspection and calibration

Check the calibration of the thermocouples and radiation pyrometers as follows:

a) Alert the control room operator to the scheduled calibration. Remove the radiation pyrometer from the support fitting. Using the portable optical pyrometer, sight through the sighting tube at the target area observed by the permanent radiation pyrometer. Take a minimum of three sightings and note the readings. For example, they should be within ± 5°C of each other at the temperature range of 1450°C–1500°C. The noted reading should be within ± 10°C of the prior temperature recorded at the central panel. If there is any discrepancy, remove the permanent pyrometer and clean all lens surfaces. If a temperature variation greater than ± 10°C persists, proceed with the calibration of system components in accordance with the manufacturer's instructions.

b) Advise the central control operator before commencing any thermocouple checks. Utilizing the portable potentiometer, check each thermocouple calibration right at the connection block in the thermocouple head. Note any deviations, advise the supervisor, and replace the defective thermocouple.
c) Inspect the pantograph collector brushes for wear. If they are uneven or chipped, dress with a file. Remove any film deposit appearing on the connector rings with sandpaper. Cleaning solvents leave residues that negatively affect conductivity.

7.10.5.1.3 Yearly inspection and calibration

Check the thermocouple protection tubes and optical pyrometer for physical damage as follows:

a) Remove the thermocouple protective wall from its support fitting and check the surface for abrasion, wear, and thermal fatigue cracks. Replace if insufficient metal remains to last through the next production cycle.
b) Inspect the thermocouple assembly.
    1) Fabricated assemblies consisting of wire and ceramic beads—examine the junction and beads. Replace any broken or cracked beads.
    2) Swaged ceramic types—check the mechanical condition of the tip and sheath. Check for wire-to sheath grounding; replace if required.

7.10.5.2 Pressure Elements

7.10.5.2.1 Weekly inspection

Visually check the impulse tubing, manifold assemblies, and associated piping for leaks, plugging, or mechanical damage. If any defect is observed, note the condition and notify the central control operator and maintenance supervisor.

7.10.5.2.2 Quarterly inspection

Notify the central control operator before removing any process-sensing tap from service. When the process element system is removed, close the blocking valves at the associated transmitter and rod, or blow down the tubing and piping from pipe cross to pipe cross. When the cleaning process is completed, replace any pipe plugs, tighten all connections, close the equalizing valve, and open the transmitter blocking valves.

7.10.5.2.3 Yearly inspection

With the process element system shut down, close the blocking valves and open the equalizing valve at the transmitter. Rod or blow down all piping or tubing. Remove the primary sensor and inspect for wear or damage in the following manner:

a) In the orifice plate, check the leading edge for scouring or radii formation. Replace if either condition is noted.
b) In the pressure taps, check for wear or build-up at the probe tip. Replace if necessary.

7.10.6 Controllers

7.10.6.1 General

Subclause 7.10.6 describes the routine maintenance requirements for temperature transmitters, pressure transmitters, stand-alone process controllers, process recorders, process alarms, and gas analyzers.

7.10.6.2 Temperature transmitters

Temperature transmitters accept millivoltage input and produce milliamperage output, such as 1–5 mA, 4–20 mA or 10–50 mA.

7.10.6.2.1 Quarterly inspection and calibration

Quarterly inspection of temperature transmitters should include the following:

a) External enclosure
    1) Visually check the enclosure and its components for dust build-up. If they are dusty, clean them.
    2) Check the terminal screws and wire lugs for broken or loose wires and frayed or burned insulation.

b) Internal chassis
    1) Before proceeding with any electrical checks, notify the central control operator.
    2) Look for visual indications of leaky capacitors, discolored or broken resistors or diodes, and any evidence of overheated components.
    3) Mechanically check for loose component leads at the point of insertion through the printed circuit boards and on resistors, capacitors, and diodes.

c) Calibration
    1) Before proceeding with calibration, notify the central control operator.
    2) Apply proper signals to the transmitter input by using a portable potentiometer and precision milliammeter. Set the portable potentiometer output to the millivoltage corresponding to 0% of scale. Adjust transmitter zero adjustment until the milliammeter on the output shows the milliamperage corresponding to 0% of scale. Next, set the potentiometer output to the millivoltage corresponding to 100% scale. Adjust the span adjustment until the milliammeter shows the milliamperage corresponding to 100% of scale. Then repeat the zero and span adjustments until satisfactory results are obtained.

7.10.6.3 Pressure transmitters

7.10.6.3.1 Monthly inspection

Monthly inspection of pressure transmitters should include the following:

a) For differential pressure transmitters, close the high- and low-process pressure valves and open the equalizing valve to the manifold assembly.
b) For static pressure transmitters, close the transmitter shut-off valve and break open the pressure connection at the transmitter case.
c) The milliammeter should show milliamperage corresponding to zero. If there is any variation, adjust the zero screw on the front of the transmitter.
d) Always open valves slowly and at the same time when placing the transmitter in service.

7.10.6.3.2 Quarterly inspection and calibration

Check the transmitter calibration. Utilizing an adjustable bellows, manometer, and milliammeter on the output, adjust the bellow pressure input to the transmitter to read 100% of scale range on the manometer. If the transmitter output displayed on the milliammeter is not the value corresponding to 100% of scale, adjust the transmitter output. Next, set the bellow pressure input to the transmitter to 0% scale range, as displayed on the manometer. Adjust the transmitter for zero until the milliammeter reading corresponds to 0% of scale. Next, adjust the bellow pressure input to the transmitter to read 100% of scale range on the manometer, and adjust the transmitter for span until the milliammeter reading corresponds to 100% of scale. Repeat the zero and span adjustments until the required accuracy is obtained.

7.10.6.4 Stand-alone process controllers

7.10.6.4.1 Monthly calibration

Using the controller manual bypass unit, disconnect the controller from the process. Check the process variable and controller output electrically by means of a current calibrator. Reinstall the controllers.

7.10.6.4.2 Twice yearly controller tuning[7]

Record all settings before any changes are made. Check the operation of the process controller by introducing a 10% set-point change and observing the control action correction. It is preferable to have the central control operator make the set-point changes. If the response is too fast or slow, cycling should be noted on the input. Should fine tuning of the controller become necessary, reduce the proportional band settings to 50% of the previous value. Leave the adjustment setting long enough to observe the control action. Continue the reduction of the proportional band settings until cycling is barely evident; then increase slightly, eliminating cycling. Decrease the setting of the reset rate dial until cycling is evident, then remove cycling through a slight increase of the reset rate time. If the controller contains the third control mode (derivative), set the reset time dial at maximum and the derivative time dial at minimum. With the proportional band adjustment completed as described, increase the setting of the derivative time dial until cycling stops. Reduce the proportional dial setting slightly and increase the derivative setting until cycling stops. Continue increasing the derivative time until cycling resumes; then remove cycling by increasing the proportional band setting. Set the reset time dial to the same value noted on the derivative dial. If cycling results, increase the reset time setting in small increments until cycling stops. Should this procedure fail to stabilize the control action, notify the supervisor before removing the control amplifier module.

7.10.6.4.3 Yearly inspection and calibration

Remove the controller from service and bench test in accordance with the manufacturer's instructions.

7.10.6.5 Process recorders

7.10.6.5.1 Daily inspection

Daily inspection of chart recorders should include the following:

a) Check the chart and ink supply and replace them if necessary. Observe the inking for proper pen tension. If the chart line displays a break in continuity, increase the pressure of the tension clip.
b) Check the pen lifter (if not hinged) to be certain it is not sprung out of shape. If it is, the chart should show signs of snagging.

7.10.6.5.2 Yearly inspection and calibration

Yearly inspection of chart recorders should include the following:

a) Check pen overtravel, and if necessary, adjust the stop setting so that overtravel is equal at both ends. Utilizing the current calibrator, check the recorder zero, span, and linearity.
b) Check the recorder chart drive and its mechanical components.

[7]More frequent checks are recommended if incorrect operation is suspected.

7.10.6.6 Process Alarms

7.10.6.6.1 Quarterly inspection

Check the process alarm trip points. Have the central control operator increase or decrease the set-point signal and observe the indicator for the alarm trip point. If any variation is noted, advise the supervisor so that recalibration may be scheduled.

a) To adjust the set-point on the high alarm
   1) Apply input of the same value below the set-point value desired.
   2) Increase the input until the alarm just triggers. Note the input value.
   3) Adjust the set-point until the alarm just triggers at the input value desired.
b) To adjust the set-point of the low alarm
   1) Apply input of the same value above the set-point value desired.
   2) Decrease the input until the alarm just triggers. Note the input value.
   3) Adjust set-point until alarm just triggers at input value desired.

7.10.6.7 Analyzing system

The gas analyzer system consists of gas sampling and gas analyzing. Gas analyzers are used for process control and as continuous emissions monitoring systems (CEMS) for environmental emissions monitoring. General maintenance requirements described in this section are required for both types of units. Analyzers required for emissions monitoring may be subject to specific regulations covering calibration, reporting and availability. Knowledge of, and compliance with, the specific regulatory requirements for each instrument is required.

7.10.6.7.1 Gas sampling

Gas sampling requires periodic inspections in accordance with 7.10.6.7.1.1, 7.10.6.7.1.2, and 7.10.6.7.1.3.

7.10.6.7.1.1 Daily inspection

The following checks should be made daily:

a) Check tubing and piping visually for leaks or plugs.
b) Check the sample-probe cooling water-supply pressure at gage. Observe the sight-funnel discharge drain-water flow. Check the drain water for evidence of hot temperature. If the water is hot, increase the flow rate.
c) Observe the sample gas flow.
d) Check for clarity of trap and trap water.
e) Check makeup and wash-water flow rate.
f) Check the sample gas flows. Observe the flowmeters controlling the gas sample flow into oxygen, combustibles, and carbon dioxide analyzers. The flow rate should equal the design rate. If the flow rate requires adjustment, notify the central control operator and proceed with the adjustment of the sample gas flow rate.

7.10.6.7.1.2 Monthly inspection

Clean the components of the sample assembly as follows:

a) Flush the water-cooling jacket of the probe with high pressure water. Clean the interior of the probe.
b) Clean scale and deposits from the sample system. Clean and check the mechanical components for proper operation.

7.10.6.7.1.3 Yearly inspection

Take down the complete system, check, and remove any evidence of mineral deposits. Check sample gas temperatures and moistures when starting up. The sample gas should be clean and free of moisture at a temperature not exceeding 40°C.

7.10.6.7.2 Gas analyzers

Stack gas monitors required for emissions control normally have automatic calibration systems that check calibration automatically on a regular schedule. Automatic calibration may also be installed on process gas analyzers. Where automatic calibration is not provided, monthly calibration is recommended.

7.10.6.7.2.1 Monthly inspection

Check the calibration of oxygen, combustible and carbon dioxide analyzers as follows:

a) Zero the adjustment to one analyzer at a time. Shut off the sample gas flowmeter, allowing zero gas only to flow through the analyzer. Turn the analyzer zero adjustment to obtain a reading of zero on the meter. Re-establish the correct sample flow after the zero adjustment is made.
b) Span the adjustment to one analyzer at a time. Admit a calibration gas at the proper flow rate. When the meter has reached its final value, turn the span adjustment, if necessary, to cause the indicator to agree with the known concentration in the calibration gas.

7.10.7 Actuators

7.10.7.1 General

Actuators consist of a position modulator and a drive unit and linkages, which require periodic inspections, as described in 7.10.7.2 and 7.10.7.3.

7.10.7.2 Position modulator or control amplifier

7.10.7.2.1 Monthly inspection

Remove the cover and check for loose wires, loose terminal screws, or evidence of burned circuit components. Have the operator apply 10% step change to ensure proper operation. If electromechanical relays are used, check the relay sequencing for any overlap indicated by arcing relay contacts. If adjustment is necessary, readjust according to the manufacturer's instructions.

7.10.7.2.2 Yearly inspection and calibration

Utilizing the current calibrator and precision milliammeter, connect the equipment in series to the input terminals of the control amplifier (position modulator) and proceed with the minimum and maximum actuator position adjustment, using the proper input signals corresponding to the 0% and 100% position, respectively. This calibration should be done in accordance with the manufacturer's instructions and recommendations.

7.10.7.3 Drive unit and linkages

The drive unit and linkages require periodic inspection in accordance with 7.10.7.3.1.

7.10.7.3.1 Quarterly inspection

Quarterly inspections should include the following checks on the motor, bearings, frame and linkages:

a) Motor
   1) Check for excessive heating.
   2) Check to see if the motor is clean and properly ventilated, and that there is no excessive vibration. If there is excessive vibration, note and check with the supervisor so that maintenance may be scheduled.
   3) Check the position feedback slide wire for wear and cleanliness. Adjust the wiper tension.

b) Bearings
   1) If possible, check the lubrication of the motor. See that the grease fittings or oil cups, if used, are in place and in good condition.
   2) Check the bearings for excessive heating and also for any unusual sounds.

c) Frame
   1) Check for any missing or broken parts.
   2) Check for cracks.
   3) See that all the bolts are tight.
   4) Check the ground connections and see that they are tight.
   5) Check flexible conduit and see that the connectors are tight.
   6) Check the gearbox lubrication and renew in accordance with the manufacturer's instructions.

d) Linkages
   1) Check for any evidence of binding and relieve.
   2) Clean the swivel toggles and check for sufficient lubrication.
   3) Clean accumulated dust buildup.

7.11 Grounding system

7.11.1 General

The plant grounding system provides equipment grounds for personnel safety and system electrical neutral grounds, which are essential for the safe operation of surge suppressors and protective relays for equipment protection. For these two important reasons, the grounding system should be maintained and tested annually. The yearly inspection and testing should be in accordance with 7.11.2 and 7.11.3.

7.11.2 Visual inspection

Visual inspection should include the following checks:

a) Check for broken and loose cables. Any broken or loose ground cables should be repaired as soon as possible. Especially check the ground terminations on vibrating equipment such as motors and switchgear.
b) Check for corroded cables. The corroded cables and their environment should be carefully checked, so that the cause of the corrosion can be identified. Corroded cables should be replaced and the cause of the corrosion should be corrected.
c) Check the system grounding resistor for physical damage and rated resistance.

7.11.3 Testing

Ground resistance of the test ground rods should be checked and recorded at least once a year by means of acceptable earth-resistance measuring equipment and procedures. Corrective action should be taken if a significant increase in resistance is observed, or if the resistance exceeds the generally recommended range ($0.5\,\Omega$–$2\,\Omega$). Specific additional tests are required by MSHA-30CFR56 where there is no ground fault detection system in place for motor controls. Independent testing companies are also available for periodic ground-resistance tests where appropriate plant resources are lacking. Insulated grounding connections for electronic data processing (EDP) should be checked separately.

7.12 Lighting system

Proper maintenance of the lighting system is essential for preventive maintenance and personnel safety. All fixtures and receptacles should be inspected annually and damaged fixtures, receptacles, and burned wiring should be replaced. The annual inspection should include the lighting of panel boards and transformers.

Emergency lighting systems should be checked for proper operation, and the batteries inspected and replaced where indicated. Ground fault protection devices on receptacles and circuit breakers should be tested once a month.

7.12.1 Lighting "Do's"

The following is a list of good practices for maintenance of lighting systems:

a) Include safety practices for cleaning of lighting, for re-lamping, and repair as a prominent part of the training program.
b) De-energize and lock out the lighting circuits to be worked on.
c) Check and adjust the lighting circuits for the correct nominal voltage. Light sources are designed to operate most economically when supplied with rated voltage. Voltage that is either too high or too low will affect the life, efficiency, and economy of the lamps. Use proper ballast taps for nominal voltage.
d) Select the appropriate access equipment to provide safe, quick, easy access to lighting equipment.
e) Have the route electrician replace failed lamps each day while making his rounds. The system is economical in cement plants where luminaries are readily accessible.
f) Instruct the foremen to report outages as they occur. Night watchmen should report yard lighting outages.
g) Replace flashing fluorescent lamps as soon as feasible. Continuous flashing can destroy the starter and may damage the ballasts.
h) Use a ground replacement plan in storage and high-bay areas.
i) Replace burned-out lamps with lamps of the same wattage and voltage called for by the design.
j) Replace blackened or discolored lamps even though they may still be burning. Severe blackening usually indicates that burnout is imminent.
k) Replace all damaged reflectors, broken sockets, and faulty circuit breakers and switches.
l) Clean when periodic light-meter foot candle readings show a 15%–20% drop in light intensity from the reading taken just after the initial cleaning. Lumen output from mercury vapor lamps decreases over time, and they should be replaced every four years.
m) Lighting equipment should be washed, not just wiped off with a dry cloth. Tests have proved that thorough washing reclaims 10%–15% more light than dry wiping. Also, dry wiping causes grit to scratch the lens.
n) Provide emergency lighting that can operate in the event of a power failure for control rooms, electrical rooms, stairways, and exit routes.

7.13 Special systems

7.13.1 Fire alarm system and extinguishers

7.13.1.1 Fire alarm system

The fire alarm system consists of fire alarm pull stations, the master control panel, and audible alarm devices to warn people in case of fire. The fire alarm system requires annual inspection by certified personnel as follows:

a) Check the emergency circuits including the circuit breakers feeding the system.
b) Check every pull station for operation.
c) Check and clean the fire alarm control panel. Fire drills may also be required for keeping personnel alert.

7.13.1.2 Fire detection and extinguishing system

The fire detection and extinguishing system consists of smoke and heat detectors, agent storage containers (for such agents as halogens or carbon dioxide), discharge nozzles, master control unit, batteries, charger, etc.

The maintenance of the preceding items should be carried out in accordance with the manufacturer's recommendations and NFPA 70B-1998.

The monthly and annual inspection and maintenance procedures, as described in 7.13.1.2.1 and 7.13.1.2.2, should also be performed following any event that may impair the reliability of the system.

7.13.1.2.1 Monthly inspection

Monthly inspection of fire extinguishers should include the following checks:

a) Fire extinguishers should be checked monthly or at more frequent intervals as necessary.
b) The extinguisher should be in its designated place.
c) Access to, or visibility of, the extinguisher should not be obstructed.
d) The operating instructions on the extinguisher nameplate should be legible and face outward.
e) Extinguishers with seals or tamper indicators that are broken or missing should be recorded.
f) For water types without gauges, the fullness should be determined by "lifting."
g) Any obvious physical damage, corrosion, leakage, or clogged nozzles should be recorded.
h) Extinguishers with pressure gauges reading outside the operable range should be recorded.
i) When an inspection reveals that tampering has occurred, or that the extinguisher is damaged, impaired, leaking, under- or over-charged or has obvious corrosion, the extinguisher should be repaired or replaced.
j) Those personnel making inspections should record any corrective actions taken on extinguishers.
k) Fire pumps should be tested annually.

7.13.1.2.2 Annual inspection

Extinguishers and extinguishing systems should be subjected to annual maintenance unless otherwise indicated by monthly inspections. The annual inspection should conform to NFPA 70B-1998.

7.13.2 TV systems

The closed-circuit TV systems consist of TV cameras and TV monitors. They require periodic inspections in accordance with 7.13.2.1 and 7.13.2.2.

7.13.2.1 Daily inspection

Daily inspection of TV systems should include the following checks:

a) Check the kiln hood viewing for dust buildup or dust film on the window. Clean if necessary.
b) Check the camera for overheated condition or excessive vibration.
c) Check the camera cooling system.

7.13.2.2 Monthly inspection

a) Check the camera settings for brightness, target current, linearity, etc. Adjust as necessary.
b) Check the monitor and clean the picture-tube face mask. Adjust brightness, contrast, horizontal linearity, vertical linearity, height, etc.

7.13.2.3 Annual inspection

Clean the interiors of the cameras and monitors.

7.13.3 Telephone system

It is very important that the plant telephone system be operative at all times and especially when needed in emergencies. Therefore, whenever it fails, it should be repaired immediately. The plant telephone equipment consists of the main telephone equipment, backup batteries (if used), a rectifier, telephone sets, etc. The preventive maintenance of the telephone equipment should be semi-annual and consist of cleaning and inspection, servicing or replacing batteries, and the testing of the system in accordance with the manufacturer's dry run test.

7.14 Electrostatic precipitator

7.14.1 Checking

Well-scheduled checking of the unit for condition of components and operation is essential for both performance and safety.

7.14.2 Operating Records

Complete records on daily operating data—such as opacity, current and voltage meter readings—will often help identify impending problems. This information should be used to schedule maintenance before operations are affected. It is recommended that major inspections be conducted biannually.

7.14.3 Filing

A complete and accessible filing system should be maintained and readily available to maintenance personnel. Basic to this system is recommended maintenance procedures issued by the original equipment supplier. Because electrostatic precipitators have features unique to each manufacturer, it is essential that a set of operating and maintenance manuals be at hand. All personnel responsible for maintenance of the unit should be very familiar with the manual and adhere to manufacturer's instructions.

It is also recommended that the original equipment supplier conduct an on-site training session on operation and maintenance before the unit first becomes operational. Equipment suppliers should update maintenance manuals with technical bulletins when significant changes on practices are developed and issued to the end user.

7.14.4 Working schedule

Work should be carefully planned and supervised by experienced and properly trained personnel. Ongoing training sessions relating to general safety practices, as well as specific safety items for precipitators, should be standard policy.

> **WARNING**
> It should be remembered, at all times, that a precipitator uses extremely dangerous high voltage.

7.14.5 Safety devices

All safety devices should be examined and, if necessary, tested to insure that they are in good condition. Nothing should be taken for granted.

7.14.6 Inspection and maintenance

The following points should serve as guidelines for inspection and maintenance.

7.14.6.1 Interlocks

Interlocks provide good protection against contact with energized parts of the high-voltage system. This means of protection should not be considered as supplanting established safety measures for industrial electrical equipment. A key interlock system is a group of individual locking units that is designated to permit entry into the precipitator only after the unit is shut off.

7.14.6.2 High-voltage parts

All high-voltage parts of the precipitator and electrical equipment should be physically ground-connected after shutdown and before entering the unit, the insulator compartments, or bus ducts. Safety grounding devices should be provided for this purpose.

7.14.6.3 Hopper access doors

Hopper access doors should be opened very carefully. Accumulated hot dust can build up around these doors exposing personnel to a serious burn potential. Hopper doors should be part of the key interlock system.

7.14.6.4 Insulation compartments

During shutdowns, the insulation compartments should be inspected and cleaned as necessary. Care should be taken not to damage the insulators. After cleaning, nothing should be applied to the cleaned surface. Check insulator heating equipment.

7.15 Solid-state systems

Since industrial solid-state systems were designed for the industrial environment, they require a very minimal amount of maintenance. Just as important as the routine maintenance is the requirement that the environment that the system is installed in meets the guidelines set forth by the manufacturer (temperature, humidity, power, electrical noise, and grounding). Meeting these guidelines should minimize maintenance and extend equipment life.

7.15.1 Programmable controllers

The following recommendations apply to the maintenance of programmable controllers:

a) Current copies of the Programmable Controller (PLC) program should be maintained at all times. If the PLC can be backed up on tape or disk, multiple dated copies should be maintained. Offsite storage of one backup copy is recommended. Printed copies of the ladder listing should be maintained as a backup to the tapes. These can also be used as a troubleshooting aid. PLC circuit design should incorporate safety devices (e.g., a conveyor safety pull cord as a ‘‘hardwired’’ component in the control circuit).
b) Programmable controllers maintain their program in nonvolatile memory. This can be either programmable read-only memory (PROM) or battery backed random-access memory (RAM). If your unit is of the battery type, the battery should be changed as recommended by the manufacturer or sooner, depending on your maintenance intervals.
c) Spare input/output (I/O) modules and circuit cards should be kept (for quantities and recommended maintenance equipment, see 7.9.1).
d) A visual inspection and cleaning should be done on a monthly basis. Visually check for all proper operating lights and indications. Cleaning should consist of the removal and cleaning of all filters. Complete cleaning and inspection of the controller and its circuit boards and I/O equipment should be done during your major plant maintenance interval.
e) All ground connections should be checked on a monthly basis.

7.15.2 Digital process control systems

The following recommendations apply to the maintenance of digital process control systems:

a) Process control systems maintain their programs (configuration) on disk or tape. Multiple copies should be maintained at all times. Offsite storage of one backup copy is recommended. A printed copy of the system configuration should be maintained as a backup to the disk or tape.
b) A digital process control system is to be the major part of a control system and a complete set of spare circuit boards and parts should be maintained (for quantities and recommended maintenance equipment, see 7.9.1).
c) A visual inspection should be done on a monthly basis. The equipment should be kept clean and dust-free at all times. This allows for proper heat dissipation. If the equipment is redundant, the redundant half may be shut off to facilitate cleaning while the system is in operation.
d) All system-power-supply voltage levels should be checked on a monthly basis and adjustments made to keep them within the specified tolerance. Ground system integrity should also be checked at this time.

e) Instrument loop tuning should be checked twice per year, or when the control loop appears unstable. The tuning procedure is outlined in 7.10.6.4.2.
f) The control system signal conditioning equipment should be calibrated at the same time the field devices are calibrated. At this time, the cathode-ray tube (CRT) display should also be checked to verify that the instrument loop being calibrated is also providing correct information for the operator.

8. Safety precautions and procedures

8.1 Personal protective equipment

The following personal protective equipment is minimal and is strongly recommended:

a) Nonconductive hard hats, safety shoes, and safety glasses for all workers.
b) Eye protection and face shields for workmen engaged in grinding; chiseling; cutting metals, concrete stone, or brick; or welding.
c) Rubber gloves, as approved by MSHA-30CFR56-2000 when moving trail cable in excess of 600 V. Rubber gloves should be worn inside leather shells to protect the insulating material. Rubber gloves should be tested monthly and blankets quarterly. In addition, they should be both carefully inspected before each use, and discarded when found to be in an unsafe condition.
d) Safety belts of suitable material and construction, and scaffolding equipment with toeboards and railing are recommended when working in elevated locations. Safety belts and lanyards should be inspected before each use and maintained in good condition. Safety straps should be properly fastened and lanyards securely attached and properly anchored.
e) Ear protection equipment is recommended in areas where the established noise level exceeds 85 dBA.

8.2 Electrical fires

The following guidelines apply to the control and prevention of electrical fires:

a) Follow company procedures when discovering fires. Summon help before attempting to control any fire. Do not put your own safety at risk. All but small fires should be left to trained firefighters.
b) Disconnect the power source first and shut down ventilation systems in the area affected.
c) Control or extinguish the electrical fires only with a fire extinguisher rated for Class C fires. Care should be taken when using these types of fire extinguishers because they displace available oxygen from the air and could cause suffocation of personnel.
d) Dry chemical fire extinguishers work, but should be avoided due to the corrosive properties of some of the chemicals used and cost of cleanup. When using a CO_2 extinguisher, the cone may become frosted and conduct electricity.
e) When a selenium rectifier burnout occurs, fumes of selenium dioxide are liberated, which has an overpowering stench. These fumes are poisonous and should not be inhaled. Damaged rectifiers should be allowed to cool before handling, since a skin burn could result in the selenium compound being absorbed.
f) General cleanliness is essential in the area of electrical apparatus for the prevention of electrical fires. Electrical arcs can ignite oil, grease, and carbon dust. Electrical and electronic equipment should be kept clean and free of such deposits. Keep exits and passage ways in transformer vaults or electrical equipment rooms unobstructed. Do not use vaults or equipment rooms for storage. Make sure alternate exits are usable. Maintain a safe position while operating switchgear to prevent harm, should a fault blow a compartment door open or off.

8.3 Safety precautions

Company safety rules and precautions should be obeyed and safety procedures followed at all times. All injuries and first-aid treatment should be reported.

The precautions listed below do not preclude the use of new technologies or alternative arrangements, provided that the level of protection is equivalent and is acceptable to the authority having jurisdiction:

a) Safety devices should be examined before they are used to ensure they are in working condition.
b) All circuits should be de-energized during maintenance except when trouble shooting or testing.
c) Close-fitting, comfortable cotton clothing with sleeves down and buttoned, and suitable eye protection should be worn.
d) All rings and metallic jewelry, metal headgear, bracelets, watch bands, etc., should be removed from hands, arms, neck and head.
e) Employees should be familiar with the location and operation of fire-fighting equipment.
f) Cleaning of electrical equipment should be done with a nonflammable, nontoxic solvent. Adequate ventilation should be maintained when using solvents of any nature.
g) Electrical equipment should be de-energized and grounded before cleaning.
h) Electrical equipment should be de-energized and grounded when working in wet areas.
i) Adequately sized breakers or switches ahead of fuses should be opened before changing fuses. Replacement fuses should be of the same type, rating, and current versus time ratio.
j) The use of goggles and respirators is imperative when using compressed air to clean electrical apparatus.
k) Metal rulers or steel tapes should never be used in the area of live electrical equipment or circuits.
l) Portable electrical tools should be grounded at all times when in use, unless approved by a testing laboratory as "double-insulated."
m) All tools should be maintained in good condition, inspected before each use, and properly selected for the job.
n) All wire rope and slings should be visually inspected before lifting electrical equipment. Wire rope should not be used for rigging except for tag lines. Only slings that are not damaged and have a manufacturer's tag indicating maximum capacities should be put in service. Approved rigging charts showing strengths of ropes, slings, and load capacities should be posted at all overhead cranes.
o) Portable ladders should be nonconductive and of a length suitable for the job to be performed. Metal ladders should not be used.
p) Ladders should be inspected for cracked or broken rungs or side rails before each use. Defective ladders should be discarded.
q) Only ladders equipped with safety feet should be used.
r) The base of the ladder should be placed one-quarter of its length from the vertical to secure a safe working angle.
s) Do not use ladders in a strong wind or over operating machinery.
t) Label all disconnect devices with a description of the circuit the device controls, including an equipment number if applicable.

8.4 Working procedures on equipment

The following guidelines are suggestions for general safety information. Each company should have written safety procedures, including a requirement for safety training to comply with MSHA requirements (MSHA-30CFR56-2000). All employees should know and observe company rules and procedures.

a) No work should be done on lines or equipment until clearances have been obtained and the appropriate switches locked out and tagged.

b) A sufficient number of qualified personnel should be present to do the work safely.
c) The work to be done should be carefully planned and all potential hazards identified.
d) Whenever it becomes necessary to replace a worker, the replacement should be fully informed of existing hazards and conditions.
e) All circuits should be considered live until proven otherwise.
f) Only voltmeters or testers of the proper rating for the voltage or circuits being worked on should be used.
g) When working within reach of exposed live electrical equipment, suitable barriers should be installed to prevent accidental contact.
h) Whenever possible, circuits should be de-energized and grounded, and the breaker or disconnect device padlocked in the open position. Locked or padlocked devices, circuits, or switches should be tagged with a warning sign signed by the person opening the switch. No other person should be authorized to remove such locks or warning signs except the person installing such devices.
i) Before re-energizing a circuit on which work has been performed, it must be confirmed that everyone involved is not endangered by the re-energization.
j) Lockouts at push-button stations (i.e. control power) should not be considered adequate safety devices. Power circuits should be locked out.
k) The secondary terminals of a current transformer should always be short-circuited before the circuit to the instrument is broken.
l) First-aid treatment should be obtained for all injuries no matter how minor. Minor injuries left unattended often have serious consequences.
m) All persons engaged in electrical work of any nature should be thoroughly familiar with the approved methods of artificial resuscitation. In the event of electrical shock, quick action is of the utmost importance. Artificial resuscitation should be started immediately and emergency help summoned.
n) All accidents, no matter how trivial, should be reported.

Annex A

(informative)

Bibliography

[B1] IEEE Std 277-1994, IEEE Recommended Practice for Cement Plant Power Distribution.

[B2] IEEE Std 450-1995, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead–Acid Batteries for Stationary Applications.

[B3] IEEE Std 499-1997, IEEE Recommended Practice for Cement Plant Electric Drives and Related Equipment.

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[B5] IEEE Std 1188-1996, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead–Acid (VRLA) Batteries for Stationary Applications.