NEMA SG 4

ALTERNATING-CURRENT HIGH-VOLTAGE CIRCUIT BREAKERS

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

NEMA Standards Publication SG 4-2000

Alternating-Current High-Voltage Circuit Breakers

Published by

National Electrical Manufacturers Association
1300 N. 17th Street
Rosslyn, Virginia 22209

© Copyright 2000 by the National Electrical Manufacturers Association. All rights including translation into other languages, reserved under the Universal Copyright Convention, the Berne Convention for the Protection of Literary and Artistic Works, and the International and Pan American Copyright Conventions.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table of Contents

Foreword ... iii
Section 1 GENERAL ... 1
1.1 SCOPE ... 1
1.2 REFERENCES ... 1
1.3 DEFINITIONS ... 3
1.3.1 Applicable American National Standards ... 3
Section 2 RATING STANDARDS ... 7
2.1 APPLICABLE AMERICAN NATIONAL STANDARDS ... 7
Section 3 FUNCTIONAL COMPONENTS AND REQUIREMENTS ... 9
3.1 APPLICABLE AMERICAN NATIONAL STANDARDS ... 9
3.2 OPERATING MECHANISMS FOR OUTDOOR CIRCUIT BREAKERS ... 9
3.2.1 All Operating Mechanisms ... 9
3.2.2 For Pneumatic Mechanisms Only ... 9
3.2.3 For Spring Charge Mechanisms ... 9
3.2.4 For Hydraulic Mechanisms ... 9
3.3 REQUIREMENTS FOR TERMINALS AND CONNECTIONS ... 10
3.3.1 Threaded Terminals ... 10
3.3.2 Flat Terminals ... 10
3.3.3 Ground Terminals ... 10
3.4 INSTRUMENT CURRENT TRANSFORMERS ... 10
3.4.1 Ratings ... 12
3.4.1.1 Ratings Applicable to all Types of Current Transformers ... 12
3.4.1.2 Preferred Current Ratings for Multi-Ratio Bushing-Type Current Transformers ... 14
3.4.1.3 Ratings for Free-Standing Current Transformers ... 14
3.4.2 Characteristics ... 16
3.4.2.1 Polarity and Lead Marking ... 16
3.4.2.2 Secondary Leads and Terminations ... 16
3.4.2.3 Primary Terminal Connection Mechanical Loading ... 16
3.4.2.4 Typical Connection for Secondary Burdens ... 20
3.4.3 Test Procedures ... 20
3.4.3.1 Design Tests ... 20
3.5 UNDERVOLTAGE TRIP DEVICE ... 20
3.6 SECONDARY AND CONTROL WIRING (SMALL WIRING) ... 21
Section 4 TESTING STANDARDS ... 23
4.1 APPLICABLE AMERICAN NATIONAL STANDARDS ... 23
4.2 RADIO INFLUENCE VOLTAGE TESTS AS APPLICABLE (DESIGN TEST) ... 23
4.3 NOISE REQUIREMENTS ... 25
4.3.1 Terminology and Definitions ... 25
4.3.2 Noise Exposure Conditions ... 25
4.3.3 Noise Level ... 25
4.3.4 Noise Measurement Equipment ... 26
4.3.5 Design Tests ... 27
Section 5 SPECIAL APPLICATION ... 29
5.1 REPETITIVE DUTY CIRCUIT BREAKERS FOR ARC FURNACE SWITCHING ... 29
5.1.1 Servicing ... 29
5.1.2 Circuit Conditions ... 29

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

5.1.3 Operating Conditions 29
5.1.4 Conditions of the Circuit Breaker 29
5.1.5 Minimum Operations Under Fault Conditions 29
5.1.5.1 Schedule 1 30
5.1.5.2 Schedule 2 30
5.1.5.3 Schedule 3 30
5.1.5.4 Schedule 4 30
5.1.5.5 Schedule 5 30
Section 6 RECOMMENDED INSTALLATION, OPERATION, AND MAINTENANCE PROCEDURES 31
6.1 GENERAL 31
6.2 SHIPMENT 31
6.3 STORAGE 31
6.4 UNPACKING 32
6.5 HANDLING 32
6.6 SELECTION OF LOCATION FOR INSTALLATION 32
6.7 MOUNTINGS 32
6.7.1 Mounting in Cells 32
6.7.2 Mounting on Structure 33
6.7.3 Floor Mounted 33
6.7.4 Bushings 33
6.7.5 Operating Mechanism 33
6.7.6 Contacts 34
6.7.7 Power Operated Circuit Breakers 34
6.8 INSULATING FLUID 34
6.8.1 Oil Testing 34
6.8.2 Oil Drying 34
6.8.3 Filling Tanks With Oil 35
6.8.4 Filling and Handling De-energized SF_6 Circuit Breakers 35
6.8.4.1 Management of SF_6 Gas in High-Voltage Circuit Breakers 35
6.9 CONNECTIONS 36
6.9.1 Secondary and Control Wiring 37
6.9.2 Ground Connections 37
6.10 AUXILIARIES 37
6.10.1 Tank Lifters 37
6.10.2 Other Lifters 37
6.10.3 Undervoltage Trip Device 37
6.10.4 Auxiliary Switches 38
6.11 FINAL INSTALLATION INSPECTION 38
6.12 POWER OPERATED CIRCUIT BREAKERS 38
6.13 MAINTENANCE 39
6.14 SPARE PARTS 40
Appendix A BUSHING POTENTIAL DEVICES FOR TANK-TYPE OUTDOOR OIL CIRCUIT BREAKERS 41
A.1 General 41
A.2 Characteristics 41
A.3 Class and Ratings 42
A.4 Performance Characteristics 43
A.5 Adjustment 43
A.6 Polarity 44
A.7 Nameplates 44
A.8 BUSHING POTENTIAL DEVICE TEST (PRODUCTION TEST) 44
A.9 Oil Sampling 44
A.10 Preferred Mounting Flange Dimensions for Bushings to be Used with Oil- Filled Apparatus 45
Appendix B 47

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

FOREWORD

This is one of a series of NEMA standards publications covering the range of low- to high-voltage switchgear products. Such products are generally applied to utility and industrial uses with a portion going to commercial applications. User and general interest input played a significant part in the development of the product requirements carried by this publication. It, as well as other NEMA standards publications, is not intended to stand alone for, without exception:

a. It adopts by reference the appropriate American National Standards (approved by American National Standards Committee C37) as the main body of this NEMA publication.
b. It offers a vehicle for getting into print the proposed NEMA revisions of the pertinent C37 standards, until such time as those revisions can be evaluated, approved, and published as a revision of the particular American National Standard.
c. It covers additional information about a product of specific interest to the manufacturing community, which the American National Standards Committee does not include in its scope.

Within this NEMA publication, therefore, the main focus is on American National Standards and the consensus method of standards approval used by ANSI.

Switchgear standards are, for the most part, developed through the combined and separate efforts of IEEE and NEMA. Accredited Standards Committee C37 serves as the administrator through which all switchgear proposals intended for eventual publication as American National Standards are channeled. It is within these organizations that the principal manufacturer-user exchange is accomplished. This exposes product requirements to those people having the direct responsibility for the use, design, application, maintenance, and acceptance of the products and thus assures a most objective and critical review within the voluntary standards program.

This standard is a revision of NEMA SG-4-1990 and contains both substantive and editorial changes.

Approximate metric conversion of US dimensions have been included for reference.

Section 1 – The references have been updated and expanded to include pertinent international standards references. The definitions have been updated to include modern circuit breakers. The definitions list has been alphabetized for easy reference.

Section 2 – With the adoption of ratings in C37.06 for circuit breakers used in gas-insulated substations, these tables (Table 2-1 and Table 2-2) are removed and the section simplified to recognize C37.04 and C37.06 as the ratings standards.

Section 3 – The information regarding functional components has been updated to reflect modern technology. Requirements for terminals and connections have been expanded to include flat terminals and ground connections.

Requirements for bushing potential devices for tank-type outdoor oil circuit breakers and dimensions of oil-filled bushings have been moved to the appendix for reference as useful information for installed equipment.

The figures for connection of secondary burdens of current transformers have been moved to the appendix as useful reference information.

Section 4 – The bushing potential device test has been moved to the appendix as useful reference material.

Section 5 – Information on use of circuit breakers for motor starting applications has been eliminated as it is now part of C37.010. Information on multiple single phase circuit breakers was removed for lack of

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

applicability to modern power systems. The requirements for repetitive duty circuit breakers for arc furnace switching have been updated and clarified.

Section 6 – The recommended installation, operation, and maintenance procedures were modified to include present practice. Extensive information regarding SF_6 gas was included.

These standards are periodically reviewed by the High-Voltage Power Circuit Breaker Voting Classification of the Switchgear Section of NEMA for any revisions necessary to keep them up-to-date with advancing technology. Proposed or recommended revisions shall be submitted to:

Vice President, Engineering
National Electrical Manufacturers Association
1300 North 17th Street
Rosslyn, VA 22209

This standards publication was developed by the High-Voltage Power Circuit Breaker Voting Classification of the Switchgear Section of NEMA. Section approval of the standard does not necessarily imply that all members voted for its approval or participated in its development. At the time it was approved, the voting classification was composed of the following members:

T. Olsen, Siemens Power Transmission & Distribution, Inc. – Chair

R. Barna, Mitsubishi Electric Power Products, Inc.
J. Carroll, Square D Company
N. Davies, Cutler-Hammer, Inc.
P. Dwyer, General Electric Company
R. Garzon, Square D Company
G. Jones, Square D Company
R. Long, Cutler-Hammer, Inc.
G. Montillet, Alstom-USA, Inc.
A. Paulin, General Electric Company
R. Reed, Square D Company
G. Sakats, Powercon Corp.
S. Slattery, Siemens Energy & Automation, Inc.
M. Smith, Siemens Power Transmission & Distribution, Inc.
D. Stone, Cooper Power Systems
T. Tobin, S&C Electric Company
J. Wiseman, Square D Company
R. York, ABB Power T&D Company, Inc.

DISCLAIMER

The standards or guidelines presented in a NEMA Standards Publication are considered technically sound at the time they are approved for publication. They are not a substitute for a product seller's or user's own judgment with respect to the particular product referenced in the standard or guideline, and NEMA does not undertake to guaranty the performance of any individual manufacturer's products by virtue of this standard or guide. Thus, NEMA expressly disclaims any responsibility for damages arising from the use, application, or reliance by others on the information contained in these standards or guidelines.

--`,,`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Section 1
GENERAL

1.1 SCOPE

This standards publication encompasses:

a. All ratings for outdoor circuit breakers above 1000 volts for alternating-current service. (Automatic circuit reclosers are excluded.) Circuit breakers for service in metal-clad enclosures are included in NEMA Standard SG 5.

b. Attachments for these circuit breakers, such as bushing current transformers, bushing potential devices, interlocks, undervoltage trip devices, shunt trips, overcurrent trips, and auxiliaries sold with the circuit breakers such as closing relays and structural steel supports.

c. Renewal, modernizing, and spare parts for these circuit breakers and attachments.

d. Recommended installation, operation, and maintenance procedures.

1.2 REFERENCES

The following publications are adopted in whole and in part as indicated herein as referenced in this standards publication:

American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036

4-1978	*Techniques for High-Voltage Testing*

Note—The 1978 revision is specified because the 1995 revision does not include critical test techniques needed for circuit breaker testing. When the 1995 version of IEEE 4 is suitably revised, it will be officially recognized and will become part of this revision of SG 4.

C2-1997	*National Electrical Safety Code*
C37.04-1999	*Rating Structure for AC High-Voltage Circuit Breakers*
C37.06-2000	*Preferred Ratings and Related Required Capabilities for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*
C37.06.1-2000	*High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis Designated "Definite Purpose for Fast Transient Recovery Voltage Rise Times"*
C37.082-1982 (R 1988)	*Methods for the Measurement of Sound Pressure Levels of AC Power Circuit Breakers*
C37.09-1999	*Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*
C37.11-1997	*Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

C37.12-1991	*AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Specifications Guide*
C37.010-1999	*Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*
C37.011-1979 (R 1989)	*Application Guide for Transient Recovery Voltage for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*
C37.012-1979 (R 1999)	*Application Guide for Capacitance Current Switching AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*
C37.015-1993 (R1999)	*Application Guide for Shunt Reactor Current Switching*
C37.85-1989 (R 1995)	*Safety Requirements for X-Radiation Limits for AC High-Voltage Power Vacuum Interrupters*
C37.100-1992	*Definitions for Power Switchgear*
C50.10-1990	*General Requirements for Synchronous Machines*
C57.13-1993	*Requirements for Instrument Transformers*
C57.19.00-1991	*General Requirements and Test Procedures for Outdoor Power Apparatus Bushings*
C57.19.01-1992	*Performance Characteristics and Dimensions for Outdoor Apparatus Bushings*
C84.1-1995	*Voltage Ratings for Electric Power Systems and Equipment (60 Hz)*
S1.1-1994	*Acoustical Terminology (Including Mechanical Shock and Vibration)*
S1.4-1983	*Specification for Sound Level Meters (including Supplement S1.4a-1985)*
S1.13-1971 (R 1986)	*Methods for the Measurement of Sound Pressure Levels*

Note—The latest NEMA approved revision for the referenced ANSI and IEEE standards will be in effect.

National Fire Protection Association
1 Batterymarch Park, Box 9101
Quincy, MA 02269-9101

70B-1998	*Electrical Equipment Maintenance*
70E-2000	*Electrical Safety Requirements for Employee Workplaces*

American Society for Mechanical Engineers (ASME)
Order Department
22 Law Drive, Box 2300
Fairfield, NJ 07007-2300

Material Specifications

BPVC Section 8-1998	*Boiler and Pressure Vessel Code, Section 8, Pressure Vessels*

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

American Society for Testing and Materials (ASTM)
100 Barr Harbor Drive
West Conshohocken, PA 19428

F855-96 *Standard Specifications for Temporary Protective Grounds to be used on De-energized Electric Power Lines and Equipment*

IEC Central Office Customer Service Center
3, rue de Varembe
P.O. Box 131, 1211 Geneva 20
Switzerland

IEC publications are available for ordering either from IEC directly or from ANSI.

Note—Refer to the listing of ANSI standards

IEC 61634 *High-Voltage Switchgear and Controlgear – Use and Handling of Sulfur Hexafluoride (SF_6) in High-Voltage Switchgear and Controlgear*

Institute of Electrical and Electronics Engineers, Inc. (IEEE)
445 Hoes Lane, P.O. Box 1331
Piscataway, NJ 08855-1331

3-1982 *Recommended Practice in the Selection of Reference Ambient Conditions for Test Measurement of Electrical Apparatus*

80-1996 (R1991) *Guide for Safety in AC Substation Grounding*

693-1997 *Recommended Practices for Seismic Design of Substations*

1291-1993 *Guide for Partial Discharge Measurements in Power Switchgear*

B1.1-1989 *Unified Inch Screw Threads*

National Electrical Manufacturers Association (NEMA)
Standards Publications Office
1300 North 17th Street
Rosslyn, VA 22209

CC 1-1993 *Electric Power Connectors for Substations*

107-1988 (R1993) *Methods of Measurement of Radio Influence Voltage (RIV) of High-Voltage Apparatus*

Note—The latest NEMA approved revision for the referenced ANSI and IEEE standards will be in effect.

1.3 DEFINITIONS

1.3.1 Applicable American National Standards

ANSI/IEEE C37.100 has been approved by NEMA and, with the following additions, constitutes Section 1 of this publication.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

accumulator: A device in which potential energy is prestored by compressed and completely confined gas and is transmitted through the medium of a liquid, usually oil.

air control valve: A valve that is responsive to an applied signal for releasing air to or from an operating cylinder.

air line: Tubing or piping used for moving compressed air from one point to another in any closed air system.

air receiver: A tank or other closed vessel for storing air under pressure.

air system for operating mechanism: An assembly of parts and devices which provide compressed air for the operation of a circuit breaker or circuit breaker operating mechanism. It shall be permitted to include equipment external to the circuit breaker, equipment, or both, that is an integral part of the circuit breaker or circuit breaker mechanism.

alarm pressure switch: A switch that initiates a signal when the operating pressure is above or below the desired range.

blade tip: The contact-making end of a blade-shaped contact member.

burden regulation: The deviation in ratio and phase angle of the secondary voltage as a function of burden variation over a specified range with a constant rated primary line-to-ground voltage.

check valve: A valve which prevents flow in one direction.

continuous noise: The noise produced by vibrations, fans and blowers.

control system for compressed-gas circuit breakers: A combination of pneumatic and electrical control equipment by which sequential operation of the circuit breaker parts is obtained.

cross bar (blade): That current-carrying part to which the lift rod of a circuit breaker is attached.

downstream: The same direction as that of the natural flow of any medium away from a reference point.

dump valve: A valve arranged for rapidly releasing compressed air from a confined space.

electrical control valve: A valve with operation that is initiated electromagnetically as by a solenoid.

electropneumatic control valve: A valve with operation that is initiated electromagnetically and controlled, timed, and completed pneumatically.

emergency closing device: A device for providing the equivalent of full operating energy by other than the normal means for a power operated circuit breaker. It permits closing the circuit breaker on an energized circuit under fault conditions, in an emergency, and when the normal power source is unavailable.

exhaust header: A receiver for gases exhausted from the arc chute or interrupter head. It is common to one or more pole units and collects and momentarily delays the exhaust of these gases to atmosphere.

exhaust ports: The openings through which compressed air is released from a confined space.

eye-type current transformer: A current transformer that has a fixed primary winding physically separated from multiple-secondary coils of the bushing-current-transformer type. The primary and

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

secondary windings are assembled as an integral structure. The secondary windings have a conductive shield to provide protection against high-voltage.

fixed gap: A gap resulting from contact motion over a fixed distance for the purpose of obtaining arc length control.

free standing current transformer: A current transformer having a primary winding consisting of one or more turns mechanically encircling the core(s). The primary winding(s) and secondary winding(s) are insulated from each other and from the core(s) and are permanently assembled as an integral structure independent of the circuit breaker.

hand trip valve: A manually operated pneumatic device to open the circuit breaker or a pole of the circuit breaker when the electrical control is inoperative.

header: A main pipe connection from which compressed air is drawn at various points to supply several circuit breakers or the several poles of one circuit breaker.

hydraulic control valve: A valve that is responsive to an applied signal for controlling hydraulic fluid.

hydraulic system for hydraulically operated mechanisms: An assembly of parts and devices that provides for the control of hydraulic energy for the operation of a circuit breaker or circuit breaker operating mechanism.

impulse noise: The noise produced by a closing, opening, or combination of closing and opening operations

inhibited oil: Mineral insulating oil to which a synthetic oxidation inhibitor has been added.

intermittent noise: The noise produced by periodic operation (occurring one or more times per week) of such devices as compressors, hydraulic pumps, compressor unloader exhausts, air regulator valves, and air drains.

interrupter for compressed air-blast circuit breakers: An assembly of pneumatic and mechanical parts operable to obtain interruption of current flow.

interrupter column: A movable or stationary insulating column that contains the interrupter element and the connecting pneumatic or mechanical devices necessary for the operation of the interrupter by the circuit breaker mechanism.

interrupter head: The interrupter element within the interrupter column or pole unit where current interruption occurs.

interrupter resistor and/or capacitor: A device used in conjunction with the interrupter to reduce short-circuit current or the rate of rise of recovery voltage across separable contacts at interruption, or both, or to equalize voltages across two or more separable contacts in series at and after interruption or to assist in controlling voltage surges on closing.

isolating switch: A sequence switch that is designed to hold rated voltage across its contacts.

lift or push rods: Insulating rods to which the moving contacts of a circuit breaker are attached and through which they are operated.

lockout pressure switch: A switch that prevents the electrical operation of a circuit breaker if the operating pressure is below a predetermined value.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

low-pressure interlock: A device that operates to prevent automatic circuit breaker operation when the available pressure falls below a predetermined value.

motor control pressure switch: A switch that governs the operation of a motor in order to maintain the desired operating pressure.

muffler: A device located with respect to the interrupter to reduce the exhaust noise level.

pneumatic control valve: A valve with operation that is initiated by compressed air.

pressure switch: A switch that closes or opens an electrical circuit in response to a predetermined value of pressure.

reclosing duty (duty cycle): A requirement of service that demands that a circuit breaker close a number of times in succession to restore power to a faulted circuit (or system) with a time interval between successive closings before the circuit breaker locks out in its open position.

resistor probe: A metallic member that is used in conjunction with the interrupter to provide for arc transfer or the insertion of a resistor as contacts separate, or both, or close during circuit breaker operation.

rotating column: An insulating column structure that can rotate on its base and to which are affixed interrupter heads or sequence switch contacts made operable by rotation of the column.

sequence switch: A switch that is connected in series with an interrupter and interlocked with the interrupter so that it will not open until after the operation of the interrupter.

sequence switch interlock: A pneumatic or electrical device that prevents the opening of the sequence switch until after the operation of the interrupter.

strainer: A screen or filter in the system to prevent the passage of foreign particles.

stroke: The distance covered by the moving contacts between the fully closed and fully opened (at rest) position. For circuit breakers with pivoted contact blades, the stroke is the distance covered by the moving contact blade tip between the fully closed and fully opened positions.

sulfur hexafluoride (SF_6): A gaseous compound that is utilized as an insulating medium, an interrupting medium, or both in circuit breakers.

temperature compensated pressure switch: A component to monitor gas density in electrical equipment.

uninhibited oil: Mineral insulating oil to which no synthetic oxidation inhibitor has been added.

upstream: The direction opposite to the natural flow of any medium away from a reference point.

voltage regulation: The deviation in ratio and phase angle of the secondary voltage as a function of primary line-to-ground voltage variation over a specified range with a constant linear impedance burden.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Section 2
RATING STANDARDS

2.1 APPLICABLE AMERICAN NATIONAL STANDARDS

ANSI/IEEE C37.04, ANSI C37.06, and ANSI C37.06.1 have been approved by NEMA and constitute Section 2 of this publication.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

--```-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Section 3
FUNCTIONAL COMPONENTS AND REQUIREMENTS

3.1 APPLICABLE AMERICAN NATIONAL STANDARDS

ANSI/IEEE C37.04, ANSI C37.06, ANSI C37.06.1, ANSI/IEEE C37.09, ANSI/IEEE C37.11, ANSI/IEEE C57.13, and ANSI/IEEE C57.19.00 have been approved by NEMA and, with the following additions, constitute Section 3 of this publication.

3.2 OPERATING MECHANISMS FOR OUTDOOR CIRCUIT BREAKERS

3.2.1 All Operating Mechanisms

The types of operating mechanisms used differ in the means used for obtaining the power required to operate a circuit breaker. The following general features apply to all types.

a. The mechanism shall be trip-free as described in clause 6.9 of C37.04 under operating mechanism requirements.
b. Electrical control shall meet the requirements of C37.11.
c. The control voltages and their ranges for closing and tripping shall be in accordance with C37.06 and shall apply to all electrically operated devices involved in the operation of the mechanisms. Specified operating times are obtained with rated control voltage on the devices.
d. The operating mechanism shall be mounted and enclosed in weatherproof housing with doors so arranged as to make accessible parts of the mechanism usually requiring inspection or maintenance. Each housing shall have a removable conduit plate or sufficient conduit knockouts for bringing in conduit.
e. The wiring for all control devices shall be included and shall terminate on readily accessible terminal blocks adjacent to incoming conduit.
f. To reduce condensation, each housing shall have a continuously operating heater, 120 or 240 volts alternating current.
g. If required for maintenance of the circuit breaker, a means of manual operation during maintenance shall be provided.
h. Means shall be provided to prevent automatic operation of the mechanism when maintenance work is being done.

3.2.2 For Pneumatic Mechanisms Only

The air tank shall conform to the ASME *Boiler and Pressure Vessel Code*, Section 8. A manually operated valve shall provide for draining the air-condensed moisture and oil from the lowest point of the air system. The air tank shall be equipped with a safety relief valve set at approximately 20 percent above the normal operating pressure. Pressure switches shall (1) give alarm indication when the pressure drops to a value approximately 10 percent above the minimum operating pressure of the mechanism and (2) prevent the mechanism from attempting a closing operation when the pressure is too low to complete an operation by opening up the closing control circuit. These features can be combined into one device.

3.2.3 For Spring Charge Mechanisms

For specific requirements for motor-operated spring-charged mechanisms, refer to C37.04.

3.2.4 For Hydraulic Mechanisms

For hydraulic mechanisms, the mechanism, if specified, shall be so arranged that manual charging and manual release for maintenance closing is possible.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

The manual closing function shall not be used if the circuit breaker is energized, unless the stored energy indicator shows that minimum operating pressure for operation is available.

The hydraulic system shall be equipped with a safety relief valve set at approximately 20 percent above the normal hydraulic operating pressure.

An alarm pressure switch shall close when the hydraulic pressure drops to a value approximately 10 percent above the minimum operating pressure of the mechanism. A lockout pressure switch shall prevent the mechanism from attempting a closing operation when the hydraulic pressure is too low to complete the operation. (These functions shall be permitted to be combined into one device.)

One manually operated valve shall provide for closing the circuit breaker hydraulically from the mechanism housing.

3.3 REQUIREMENTS FOR TERMINALS AND CONNECTIONS

3.3.1 Threaded Terminals

The thread dimensions for threaded terminal studs for circuit breakers shall be in accordance with Table 3-1.

Table 3-1
THREAD DIMENSIONS FOR THREADED TERMINAL STUDS

Stud diameter inches	Number of threads per inch	Thread class	Minimum length			
			Length of stud inches(mm)		Usable thread inches (mm)	
3/4	16	UNF-2A	2	(50)	1-1/2	(38)
1-1/8	12	UNF-2A	2-1/2	(63)	2-1/8	(53)
1-1/4	12	UNF-2A	2-1/2	(63)	2-1/8	(53)
1-1/2	12	UNF-2A	2-1/2	(63)	2-1/8	(53)
1-3/4	12	UN-2A	2-1/2	(63)	2-1/8	(53)
2	12	UN-2A	3	(76)	2-1/2	(63)
2-1/2	12	UN-2A	3	(76)	2-1/2	(63)

3.3.2 Flat Terminals

The flat terminal requirements shall be in accordance with Figures 3-1 to 3-5. Bolt holes are 9/16 inch (14 mm) in diameter. Refer to NEMA CC1 for detailed requirement.

3.3.3 Ground Terminals

The circuit breaker ground terminals shall be unpainted, copper faced steel or stainless steel pad, 2 inches by 3.5 inches (51 mm by 89 mm) minimum area for terminal connection. The terminal area shall be provided with two holes spaced on 1.75 inch (45 mm) centers. The holes shall either be 9/16 inch (14 mm) diameter through-holes, or, alternatively, shall be drilled and tapped for a 1/2 inch-13NC thread in accordance with ANSI B1.1-1989, and shall have a thread depth of 0.5 inch (13 mm). If through-holes are provided, the pad shall be at least 3/8 inch (9.5 mm) thick.

3.4 INSTRUMENT CURRENT TRANSFORMERS

This standard is a supplement to ANSI C57.13 to cover those requirements peculiar to current transformers used on or with circuit breakers.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

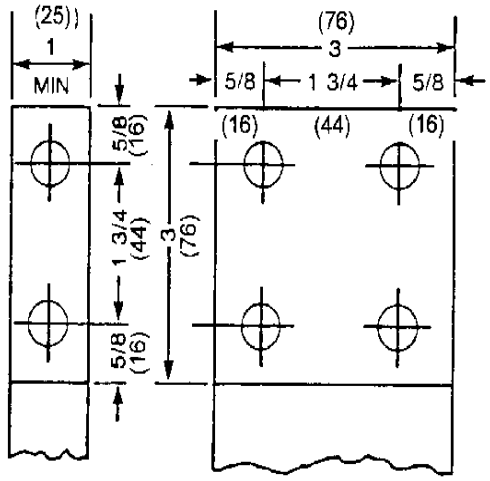

Figure 3-1
BOLT HOLES FOR TERMINAL CONNECTORS

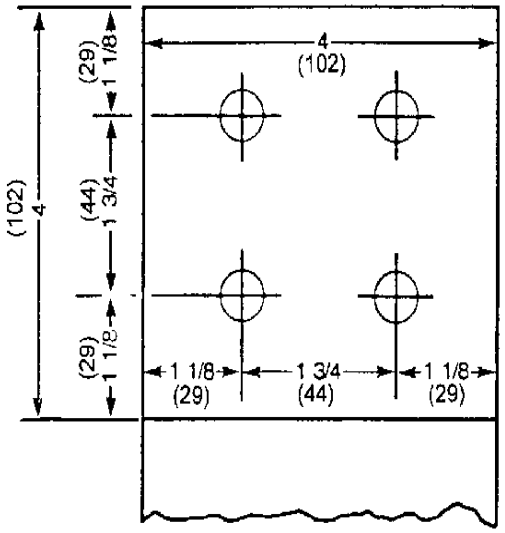

Figure 3-2
BOLT HOLES FOR TERMINAL CONNECTORS

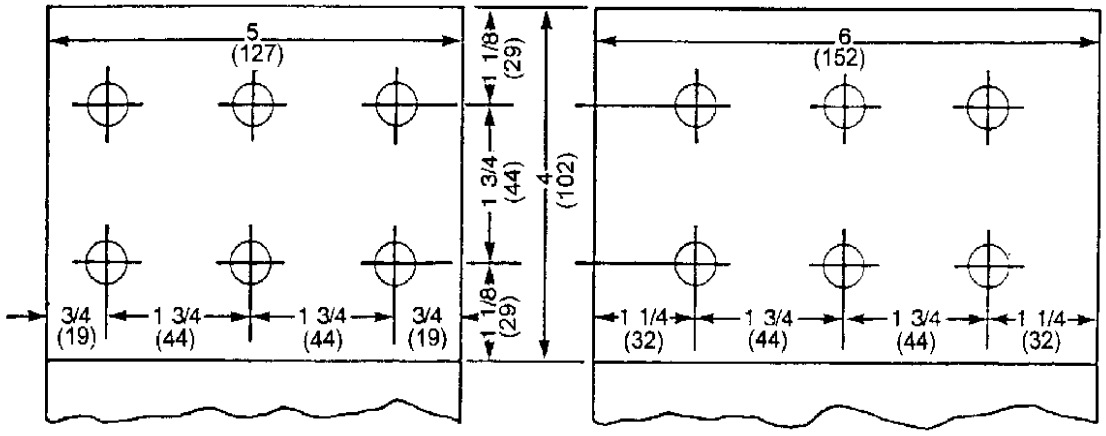

Figure 3-3
BOLT HOLES FOR TERMINAL CONNECTORS

Figure 3-4
BOLT HOLES FOR TERMINAL CONNECTORS

Figure 3-5
BOLT HOLES FOR TERMINAL CONNECTORS

Notes
1 All dimensions are in inches (mm for reference only).
2 Holes in Figures 3-1 through 3-5 are 9/16 inch (14 mm).
3 Material is from NEMA CC1.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

3.4.1 Ratings

The ratings of a current transformer used for AC high-voltage circuit breakers shall include those terms used in C57.13 and the following additional terms:

a. Maximum voltage
b. Dielectric withstand
c. Thermal short-time current capability

3.4.1.1 Ratings Applicable to all Types of Current Transformers

3.4.1.1.1 Continuous Thermal Current Capability

The continuous thermal current capability of a current transformer shall be equal to the rated continuous current of the circuit breaker with which it is used when connected on a ratio having a primary current rating equal to or greater than the continuous current rating of the circuit breaker.

Note—If connection is made on a lower ratio, the circuit breaker can carry a current equal to the primary current of that ratio including the thermal factor without causing overheating of the current transformer.

3.4.1.1.2 Mechanical Short-time Current Capability

The mechanical short-time current capability of any tap of a single-ratio or multiratio current transformer shall be the lesser symmetrical current value of either (1) 120 times the rated primary current of the tap under consideration or (2) the closing and latching capability of the circuit breaker as defined in C37.06.

Note—Where item (1) is the lower value, the effects of the power system parameters, secondary burden, and thermal short-time current capability shall be considered in the application of current transformers.

3.4.1.1.3 Thermal Short-time Current Capability

The thermal short-time current capability of a single ratio transformer or any tap of a multiratio current transformer shall be the lesser symmetrical current value of either (1) 60 times the rated primary current of the tap under consideration for 1 second, (2) 42.5 times the rated primary current of the tap under consideration for 2 seconds, or (3) the short-time current-carrying capability of the circuit breaker as defined in C37.06.

3.4.1.1.4 Accuracy Class Ratings

The accuracy class ratings of current transformers at standard burdens shall be as shown in Table 3-2.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 3-2
ACCURACY CLASS RATINGS FOR CURRENT TRANSFORMERS
FOR OUTDOOR CIRCUIT BREAKERS

Circuit breaker ratings		Accuracy class ratings[1]			
		Relaying service		Metering service	
Maximum voltage, kV, rms	Continuous current 60 Hz, amperes, rms	Multiratio current transformers[2]	Accuracy voltages, class[3]	Single-ratio current transformers[4]	Accuracy class[5]
15.5 through 48.3	600 800 1200 2000 3000 4000 5000	600:5 1200:5 2000:5 3000:5 4000:5 5000:5	100 200 400 800	300:5 600:5 800:5 1200:5 1500:5 2000:5 3000:5	0.6B--0.5 0.6B--0.5 0.6B--0.5 0.3B--0.5 0.3B--0.5 0.3B--0.5 0.3B--0.5
72.5	1200 2000	1200:5 2000:5 3000:5	400 800		
123 and above	1200 1600 2000 3000 4000	1200:5 2000:5 3000:5 4000:5 5000:5	800		

1. These values apply only when current transformers are used on 60 Hz circuits.
2. These current transformers normally have a primary current rating that corresponds to the continuous current rating of the circuit breaker, except that circuit breakers rated 800 and 1600 amperes use current transformers rated 1200 and 2000 amperes, respectively.
3. These secondary terminal voltage values for C or T classifications apply to the full winding as specified in C57.13 for 10 percent error.
4. Minimum ratios shall not be less than 50 percent of the continuous current rating of the circuit breaker.
5. These values apply only to those secondary windings specified for metering service.

3.4.1.1.5 Nameplates

Bushing-type current transformers shall have nameplates which meet the requirements in C37.04.

Current transformer nameplates shall be provided that contain the following data, as applicable. The requirements of C57.13 are included in these data.

a. Manufacturer's name
b. Manufacturer's type designation
c. Manufacturer's serial number
d. Year of manufacture
e. Rated frequency
f. Rated maximum voltage
g. Rated impulse withstand voltage
h. Rated power-frequency withstand voltage
i. Rated switching-impulse withstand voltage
j. Rated primary current
k. Rated secondary current
l. Rated continuous-thermal-current factor
m. Rated thermal short-time current

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

n. Rated mechanical short-time current
o. Weight of complete current transformer
p. Gallons of oil or weight of gas per current transformer
q. Instruction book number
r. A connection diagram showing:

1. The primary terminal markings
2. The position of each secondary core
3. The terminal designation of each core
4. The polarity markings of the primary and each core
5. The turns ratio between each terminal
6. The full winding ratio expressed, for example, as 3000:5 MR
7. The accuracy class of each core and the ratio for which the accuracy is expressed

3.4.1.1.6 Excitation Characteristics

The manufacturer shall be consulted for typical excitation characteristics.

3.4.1.2 Preferred Current Ratings for Multi-Ratio Bushing-Type Current Transformers

The preferred primary and secondary current ratings and the preferred secondary tap connections for multi-ratio bushing-type current transformers shall be as shown in Table 3-3.

3.4.1.3 Ratings for Free-Standing Current Transformers

3.4.1.3.1 Rated Dielectric Withstand

Insulation classes and dielectric tests shall be as shown in C57.13.

Note—If these current transformers are to be installed with circuit breakers, the manufacturer shall be consulted because the dielectric tests and test procedures are different.

Wet dielectric voltage tests and creepage distances shall be as shown in C57.13. Switching-impulse withstand voltage tests for voltage ratings of 362 kV and above shall be as shown in C37.06.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 3-3
PREFERRED CURRENT RATINGS AND SECONDARY TAP CONNECTIONS FOR MULTI-RATIO CURRENT TRANSFORMERS

Current ratings, amperes	Turns ratios	Secondary taps	Current ratings, amperes	Turns ratios	Secondary taps
600:5			**3000:5**		
50:5	10:1	X2-X3	300:5	60:1	X3-X4
100:5	20:1	X1-X2	500:5	100:1	X4-X5
150:5	30:1	X1-X3	800:5	160:1	X3-X5
200:5	40:1	X4-X5	1000:5	200:1	X1-X2
250:5	50:1	X3-X4	1200:5	240:1	X2-X3
300:5	60:1	X2-X4	1500:5	300:1	X2-X4
400:5	80:1	X1-X4	2000:5	400:1	X2-X5
450:5	90:1	X3-X5	2200:5	440:1	X1-X3
500:5	100:1	X2-X5	2500:5	500:1	X1-X4
600:5	120:1	X1-X5	3000:5	600:1	X1-X5
1200:5			**4000:5**		
100:5	20:1	X2-X3	500:5	100:1	X1-X2
200:5	40:1	X1-X2	1000:5	200:1	X3-X4
300:5	60:1	X1-X3	1500:5	300:1	X2-X3
400:5	80:1	X4-X5	2000:5	400:1	X1-X3
500:5	100:1	X3-X4	2500:5	500:1	X2-X4
600:5	120:1	X2-X4	3000:5	600:1	X1-X4
800:5	160:1	X1-X4	3500:5	700:1	X2-X5
900:5	180:1	X3-X5	4000:5	800:1	X1-X5
1000:5	200:1	X2-X5			
1200:5	240:1	X1-X5			
2000:5			**5000:5**		
300:5	60:1	X3-X4	500:5	100:1	X2-X3
400:5	80:1	X1-X2	1000:5	200:1	X4-X5
500:5	100:1	X4-X5	1500:5	300:1	X1-X2
800:5	160:1	X2-X3	2000:5	400:1	X3-X4
1100:5	220:1	X2-X4	2500:5	500:1	X2-X4
1200:5	240:1	X1-X3	3000:5	600:1	X3-X5
1500:5	300:1	X1-X4	3500:5	700:1	X2-X5
1600:5	320:1	X2-X5	4000:5	800:1	X1-X4
2000:5	400:1	X1-X5	5000:5	1000:1	X1-X5

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

3.4.1.3.2 Rated Primary and Secondary Current

The maximum rated primary current of a wound-type current transformer shall be at least equal to the rated continuous current and the load current carrying capability of the circuit breaker with which the current transformer is to be used. Current ratings for multi-ratio wound-type current transformers for relaying service shall be as shown in Table 3-3. The current ratings for single-ratio current transformers for metering service shall be 300:5, 600:5, 800:5, 1200:5, 1500:5, 2000:5, and 3000:5.

3.4.2 Characteristics

3.4.2.1 Polarity and Lead Marking

Polarity and lead marking shall be as shown in C57.13 and in accordance with the following additional requirements.

3.4.2.1.1 Bushing-Type Current Transformers

Polarity and lead marking for bushing-type current transformers shall be as shown in Figures 3-6 and 3-7. The two leads for single-ratio current transformers such as those used for metering service shall be marked X1 and X2.

3.4.2.1.2 Free-standing Current Transformers

Polarity and lead markings for multi-ratio and single-ratio secondaries for current transformers shall be as shown in Figure 3-8. Single-ratio secondaries with two leads shall be marked with suitable prefix letters and suffix numbers. A fourth secondary with a single-ratio secondary for metering service shall use secondary terminal markings W1 and W2. If this fourth secondary is a multi-ratio secondary for relaying service, it shall use secondary terminal markings W1, W2, and W3.

As shown in Figure 3-8, H1 shall be the marked primary terminal. This terminal shall be electrically and mechanically connected to the upper structure of the current transformer. The H2 terminal shall be electrically insulated from the upper structure and from H1, and it shall connect to the circuit breaker.

3.4.2.2 Secondary Leads and Terminations

Secondary leads shall be brought out to accessible terminal boards with polarity, phase, and lead designations shown on suitable connection diagrams. Terminal boards shall be equipped with means for short circuiting individual secondaries. Where applicable, secondary leads shall be brought out through suitable oil- and gas-tight seals.

3.4.2.3 Primary Terminal Connection Mechanical Loading

The maximum mechanical loading which may be applied to the primary terminal connection of a current transformer shall equal that required for a circuit breaker terminal connection as shown in C37.04.

--`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

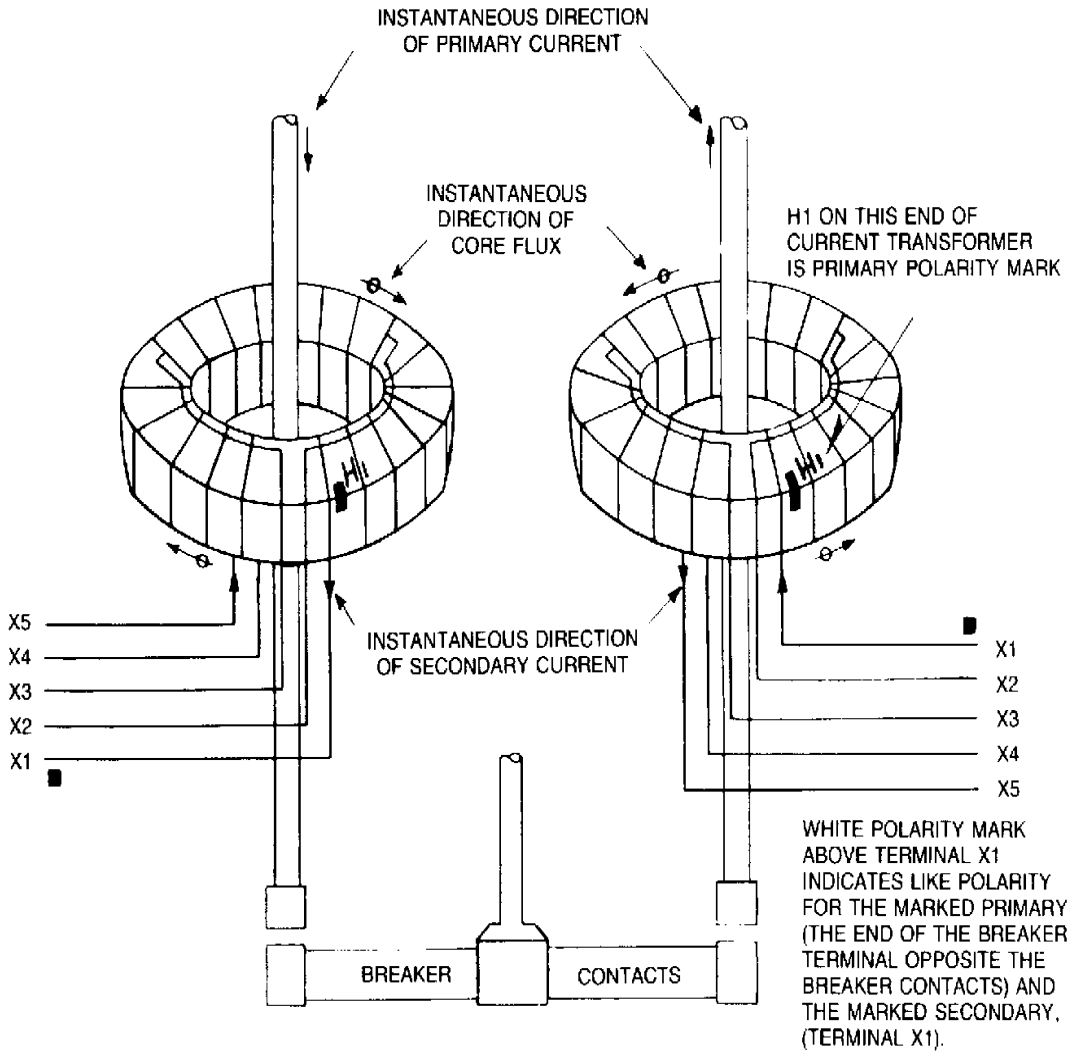

Figure 3-6
TYPICAL ARRANGEMENT OF TWO BUSHING-TYPE CURRENT TRANSFORMERS ON ONE POLE OF DEAD-TANK-TYPE CIRCUIT BREAKERS, SHOWING TAPS AND NUMBERING SYSTEMS ON CONNECTION BOARD

NOTE—When intermediate taps are used, the tap numerically nearest X1 has the same polarity as X1.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

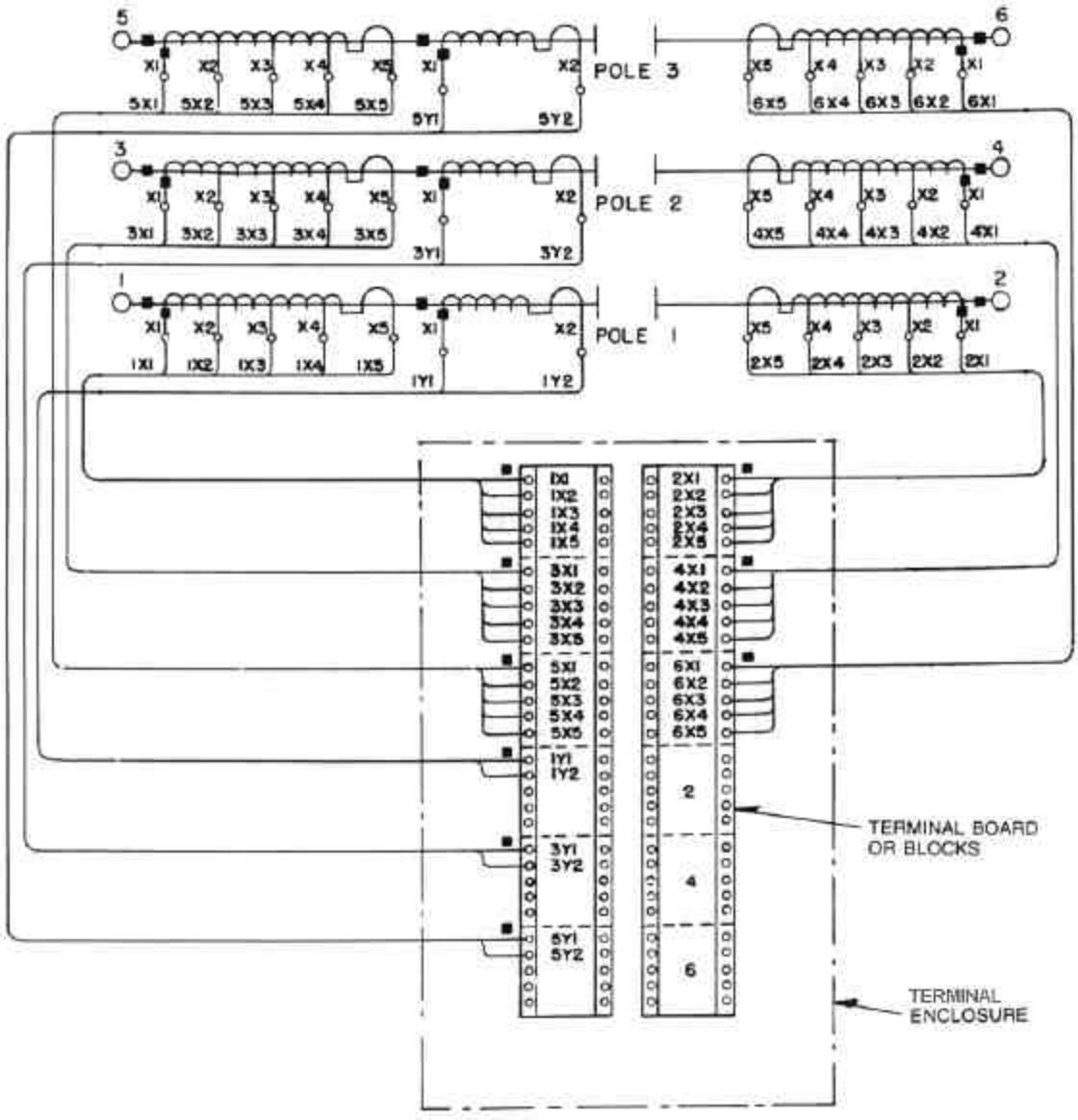

Figure 3-7
CURRENT TRANSFORMER AND LEAD IDENTIFICATION OF BUSHING-TYPE CURRENT TRANSFORMERS FOR DEAD-TANK-TYPE CIRCUIT BREAKERS

Exact location of current transformers, leads, polarity marks, and terminal blocks shall be determined from the manufacturer's connection diagram or instructions.

When one current transformer per pole is used, current transformers are located on primary terminals 1-3-5 unless otherwise specified.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

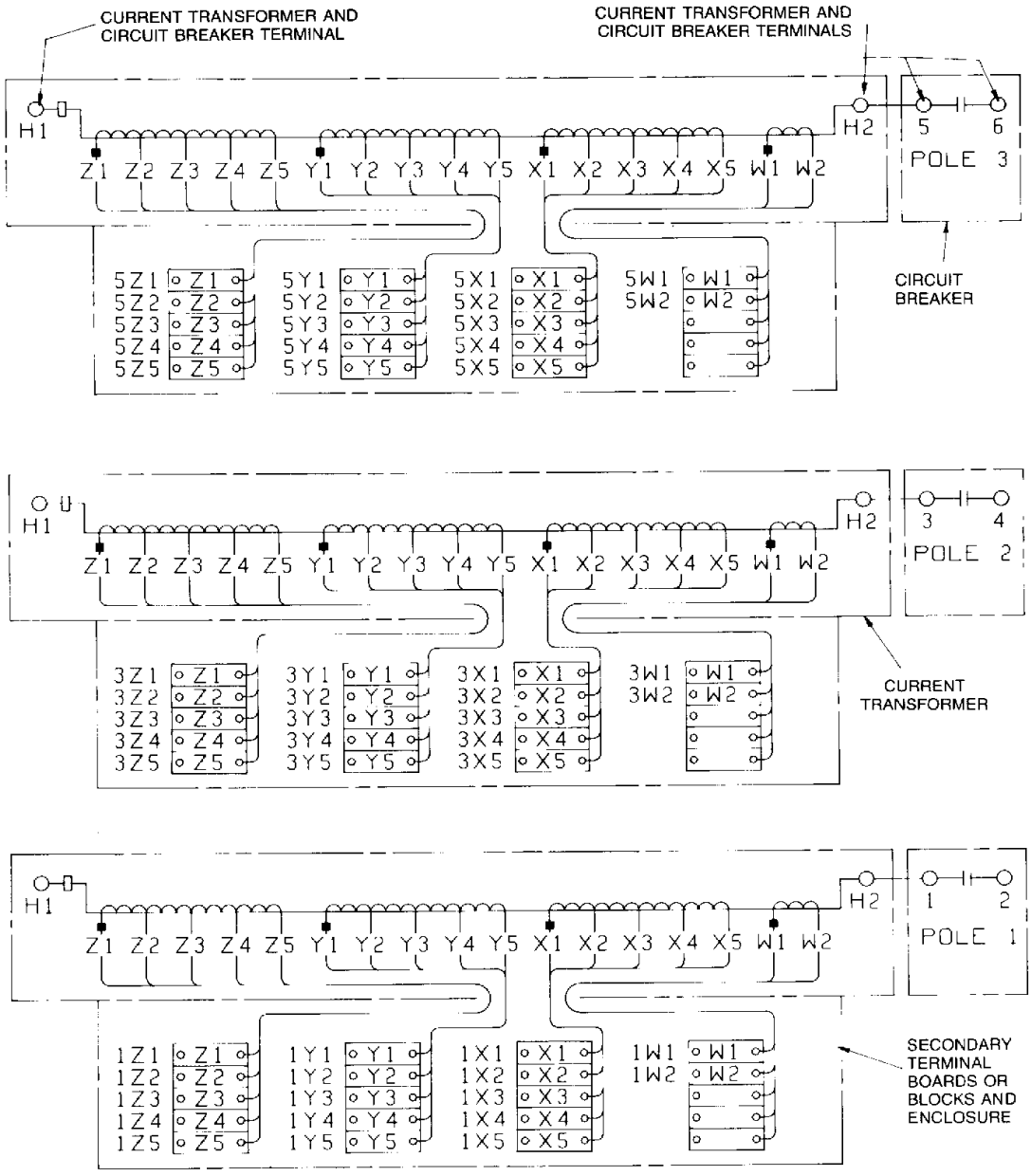

Figure 3-8
CURRENT TRANSFORMER AND LEAD IDENTIFICATION OF CURRENT TRANSFORMERS FOR LIVE-TANK-TYPE CIRCUIT BREAKERS

Exact location of current transformers, leads, polarity marks, and terminal blocks shall be determined from the manufacturer's connection diagram or instructions.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

3.4.2.4 Typical Connection for Secondary Burdens

Typical connection for secondary burdens to bushing-type current transformers shall be as shown in Figures B-1 through B-4 in Appendix B. Similar connections shall be made for the various secondaries of free standing current transformers, except that all four secondaries shall be on the same side of the circuit breaker.

3.4.3 Test Procedures

The following design and production tests shall be made on instrument current transformers for use on or with circuit breakers.

3.4.3.1 Design Tests

The design test requirements and procedures shall be as specified in C57.13 and in accordance with the following additional requirements.

3.4.3.1.1 When rated dielectric strength is not demonstrated in accordance with C57.13, the test requirements and procedures as specified in C37.06 and C37.09 shall be used.

3.4.3.1.2 Wet dielectric tests shall be made with values in accordance with C37.06 and C37.09. When the current transformer is part of the circuit breaker structure, the wet tests on the circuit breaker shall include the current transformer. When the current transformer is not part of the circuit breaker or when it can be set apart from the circuit breaker, the current transformer shall be tested separately.

3.4.3.1.3 Dielectric tests shall be made in accordance with C37.09. Where current transformers are closely associated with the circuit breaker, that is mounted on the circuit breaker-supporting structure or on separate pedestals at the end of the pole units, the dielectric tests shall be made on the combined circuit breaker and current transformer, unless it can be established otherwise that there is no reduction of insulation withstand strength because of the adjacent apparatus.

3.4.3.1.4 Switching surge withstand voltage tests shall be made in accordance with C37.06 and C37.09.

3.4.3.1.5 Production Tests

Accuracy tests on bushing-type current transformers shall be made in accordance with C57.13. All other tests shall be made in accordance with C37.09.

Accuracy tests on free-standing current transformers shall be made in accordance with C57.13. All other tests shall be made in accordance with C37.09.

Free-standing current transformers shall be tested to meet the power-frequency withstand voltage test values required by C37.06.

3.5 UNDERVOLTAGE TRIP DEVICE

The dropout voltage range of an undervoltage trip device shall be 30 to 60 percent of its voltage rating for both DC and AC applications.

An electrically-reset undervoltage trip device shall pick up, and a mechanically-reset undervoltage trip device shall seal in, at 85 percent or less of its rated voltage.

Note—An undervoltage device trip is a device in which the coil is energized without an auxiliary switch. The armature may be released for tripping at any point in the closing stroke of the circuit breaker.

--`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

3.6 SECONDARY AND CONTROL WIRING (SMALL WIRING)

Wire for instrument current transformer secondary leads shall not be smaller than 14 AWG. Wire for instrument potential transformer secondary leads and for control wiring shall be electrically coordinated with the inherent current requirements and voltage drop limitations of the circuit, and mechanically coordinated and designed for its intended application in the circuit breaker. Splices, when required, shall be brazed or made by permanently fitted pressure-type connectors.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

--`,,`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Section 4
TESTING STANDARDS

4.1 APPLICABLE AMERICAN NATIONAL STANDARDS

ANSI C37.09 has been approved by NEMA and, with the following additions, constitutes Section 4 of this publication.

4.2 RADIO INFLUENCE VOLTAGE TESTS AS APPLICABLE (DESIGN TEST)

4.2.1 The equipment and general method used in making radio influence voltage tests shall be in accordance with the recommendations given in NEMA 107.

4.2.2 Tests at one selected radio frequency shall be made with the circuit breaker both in the closed and open position.

4.2.3 In the case of multipole circuit breakers, one pole or terminal or groups of the same shall be permitted to be used at a time.

4.2.4 The tanks of the circuit breakers shall be filled with the prescribed amount or pressure of insulating fluid.

4.2.5 The case, tank, frame, and other normally grounded parts shall be connected to ground.

4.2.6 When a test is made with the circuit breaker in the open position, the pole or group of poles not under the test shall be grounded and ungrounded, and the radio influence voltage shall be determined for each condition.

4.2.7 No other grounded or ungrounded object or structure (except mounting structure when required) shall be nearer any part of the circuit breaker or its terminals under test than three times the longest overall dimension of the test piece, with a minimum allowable spacing of 3 feet (0.9 m).

4.2.8 Where space requirements under test conditions do not permit the foregoing clearances to be maintained, the test will be considered satisfactory if the limits of radio influence voltage obtained are equal to or less than those specified in Table 4-1. In such cases, a record shall be made of the object, structures, and their distances from the device under test.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 4-1
LIMITS OF RADIO INFLUENCE VOLTAGE

Circuit breaker rated maximum voltage, kV	Test voltage, kV	Limit of radio influence voltage, microvolts at 1000 kHz
15.5	9.4	500
25.8	15.7	650
38.0	23	650
48.3	29	1250
72.5	44	1250
123	73	2500
145	88	2500
170	103	2500
245	147	2500
362	219	2500
550	335	2500
800	485	2500

a. Measurements shall be made with circuit breakers in the noncurrent-carrying or nonoperating condition.

b. In the case of circuit breakers having voltage ratings not covered by this table, the test voltage shall be 10 percent above the line-to-neutral voltage corresponding to the maximum voltage of Range B as given in Table 1 of C84.1.

c. Circuit breakers having two voltage ratings shall be tested at the higher voltage rating.

4.2.9 Tests may be made under the conditions prevailing at the time and place of test. However, it is recommended that tests be avoided when the radio influence voltage of test equipment (including the influence voltage of irrelevant electrical devices) with the circuit breaker under test disconnected from the test equipment exceeds 25 percent of the radio influence voltage of the circuit breaker to be tested.

4.2.10 The frequency of the supply voltage shall be within 5 percent of the rated frequency of the circuit breaker.

4.2.11 Tests shall be conducted under the atmospheric conditions prevailing at the time and place of test.

It is recommended that tests be avoided when the vapor pressure is below 0.2 in (5 mm) or exceeds 0.6 in (15 mm) of mercury. Since the effects of humidity and air density upon radio influence voltage are not definitely known, no correction factors are recommended for either at the present time. However, it is recommended that barometric pressure and dry-bulb and wet-bulb thermometer readings be recorded so that suitable correction factors, if determined, can be applied to previous measurements.

4.2.12 It shall be permissible to connect conductors of the largest size intended for use with the test piece to each terminal. The length of the conductors, when used, shall be equal to or greater than the longest overall dimension of the test piece, except that the length need not exceed 6 feet (1.8 m). The free end of such conductors shall terminate in a sphere having a diameter of twice the diameter of the conductor, plus or minus 10 percent, or shall be shielded in some other suitable manner to eliminate the effect of the end of the conductor as a source of radio influence voltage.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

4.2.13 The test shall be made without removing any component part, and the test voltage shall be determined by the lowest rated voltage of any component part. The limiting radio influence voltage shall be identical with the highest value fixed for any of the component parts that determine the test voltage.

4.2.14 The following precautions shall be observed when making radio influence tests.

4.2.14.1 The circuit breaker shall be at approximately the same temperature as the room in which the test is made.

4.2.14.2 The circuit breaker shall be dry and clean.

4.2.14.3 The circuit breaker shall not be subjected to dielectric tests within 2 hours prior to the radio influence voltage test.

4.2.14.4 If the radio influence voltage falls off rapidly after the supply voltage has been applied for a short time, the circuit breaker may be pre-excited at normal operating voltage for a period not exceeding 5 minutes before proceeding with the tests.

4.3 NOISE REQUIREMENTS

The purpose of this standard is to establish guidelines to provide protection against excessive environmental disturbance from outdoor switchyard circuit breakers. This standard does not apply to circuit breakers used in gas-insulated substations and metal-enclosed equipment.

Circuit breakers shall be designed to comply with the noise regulations that set forth measurements and practices with regard to noise levels that are deemed acceptable in occupational environments without personal protective equipment to reduce the noise level.

4.3.1 Terminology and Definitions

All terms and definitions not modified by this standard shall be in accordance with S1.1 and S1.13.

4.3.2 Noise Exposure Conditions

Noise exposure conditions cover the exposure under the following circumstances:

a. Personnel at, or very close to, the circuit breaker during installation, maintenance, or inspection periods.
b. Personnel at control stations.
c. Persons in the proximity of the equipment as permitted by limiting boundaries.

4.3.3 Noise Level

The noise level shall not exceed those values given in Table 4-2 for the different equipment and noise classifications. Where intermittent noise recurs several times daily, with each noise level persisting for 1 second or as long as several hours per day, the accumulated intermittent noise shall be calculated as follows, using the permissible sound levels and times given in Table 4-3.

When the daily noise exposure is composed of two or more periods of exposure to different sound levels, their combined effect shall be considered, rather than the individual effect of each. If the sum of the following fractions: C1/T1 + C2/T2 ... Cn/Tn exceeds unity, then the mixed exposure shall be considered to exceed the limit value. Cn indicates the total time of exposure at a specified sound level, and Tn indicates the total time of exposure permitted at that level. If the period between repeating (intermittent) noise is less than 1 second, the noise is considered to be continuous. Exposure to impulsive or impact noise shall not exceed 140 dB peak sound pressure level.

--`,,`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

4.3.4 Noise Measurement Equipment

Noise measurements shall be made with a sound-level meter meeting the requirements of S1.4. The reference pressure for all measurements shall be 0.0002 microbars. S1.13 shall apply unless otherwise modified by this standard. Impulse noise limits shall be specified as peak values without weighting. The peak sound pressure level shall be measured with a sound-level meter in combination with either an impact noise analyzer or an octaveband noise analyzer using the all-pass range.

Continuous and intermittent noise measurements shall be made with a sound level meter giving an rms response, using the A scale and a "slow" meter speed.

Table 4-2
SOUND LEVEL LIMITS

	Impulse noise limit		Intermittent noise limit		Continuous noise limit	
Equipment classification kV range	**Maximum sound pressure level dB***	**Horizontal distance to measurement point, feet (m)**	**Maximum sound pressure level dB***	**Horizontal distance to measurement point, feet (m)**	**Maximum sound pressure level dB***	**Horizontal distance to measurement point, feet (m)**
General-purpose Outdoor Equipment						
362 kV and Below	140	3† (1)	**	50† (15)	90	50† (15)
Above 326 kV	140	3† (1) 2‡ (0.7)	**	100† (30)	90	100† (30)
Definite-purpose outdoor equipment (The following limits are in addition to those required for general-purpose equipment.)						
362 kV and Below	105 95	150† (50) 500† (150)	90 80	150† (50) 500† (150)	85 75	150† (50) 500† (150)
Above 362 kV	105 95	300† (100) 1000† (300)	90 80	300† (100) 1000† (300)	85 75	300† (100) 1000† (300)

* The sound level limits are based on no-load operation since personnel are not expected to stand adjacent to the circuit breaker when it is opening under fault conditions. Measurement shall be made 5 feet (1.5 m) above ground level.
† Measured from perimeter of circuit breaker with cabinet doors closed.
‡ Measured at location of the control switch of the circuit breaker with the cabinet doors open.
**See 4.3.3 for maximum allowable sound level.

Note—It is considered that the routine operation of the switching station will not submit a person to continuous or intermittent exposure unless he/she is at least at or within the specified minimum distance from the noise, depending on the circuit breaker voltage rating.

--`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 4-3
PERMISSIBLE NOISE EXPOSURE

Duration per day, hours (T_i)	Sound level, dBA
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
1/2	110
1/4 or less	115

Care shall be taken so that measurements will not be influenced by noise reflection, focus, or amplification from walls, buildings, or other surfaces.

4.3.5 Design Tests

Design tests to determine the levels of impulse, continuous, and intermittent noise shall be made in accordance with C37.082 under no-load conditions on a completely assembled circuit breaker.

If a complete three-phase circuit breaker is not assembled at the place of manufacture, the tests shall be made at the installation site.

Factors over which the manufacturer does not have control shall be considered when making noise measurements at installations. The tests shall be carried out at maximum rated operating conditions and corresponding operating speeds. If the circuit breaker is operated for test purposes without its normal interrupting fluid, the design tests shall be performed under this condition.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

--`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Section 5
SPECIAL APPLICATION

5.1 REPETITIVE DUTY CIRCUIT BREAKERS FOR ARC FURNACE SWITCHING

Power operated circuit breakers particularly designed for arc furnace switching, when operating under usual service conditions, shall be capable of operating at least the required number of times given in Table 5-1. The operating conditions and the permissible effect upon the circuit breakers are given in the following paragraphs. For each column, all paragraphs listed shall be considered.

5.1.1 Servicing

Servicing shall consist of adjusting, cleaning, lubricating, and tightening, as recommended by the manufacturer. The operations listed are on the basis of servicing at intervals of 6 months or less.

5.1.2 Circuit Conditions

Each operation referred to in Table 5-1 consists of closing and opening of the circuit breaker under the specified load conditions.

5.1.3 Operating Conditions

The frequency of operation shall not exceed twenty in 10 minutes or thirty in 1 hour. Rectifiers, air systems, or other auxiliary devices may further limit the frequency of operations.

Servicing shall be applied at intervals no greater than those shown in the third column of Table 5-1.

5.1.4 Conditions of the Circuit Breaker

After the operations shown in Table 5-1, the following shall have taken place:

a. No parts shall have been replaced.
b. The circuit breaker shall meet all of its current, voltage, and short-circuit current ratings.

Table 5-1
OPERATING CAPABILITIES

Circuit breaker rating		Maximum number of operations	Number of operations	
Rated maximum voltage, kV	Rated continuous current, amperes	Between servicing	No-load mechanical	Switching and interrupting
4.76 through 38	1200, 2000, 3000	250	20,000	See Schedule 1 through 5

5.1.5 Minimum Operations Under Fault Conditions

If a fault operation above 9,000 amperes occurs before the completion of the permissible operations, maintenance shall be performed according to the manufacturer's instructions.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

5.1.5.1 Schedule 1

10,000 operations interrupting no-load or load currents of less than 100 amperes, plus 5000 operations interrupting fault currents up to 350 amperes, plus one opening operation (O) at rated short-circuit current.

5.1.5.2 Schedule 2

2500 operations interrupting no-load or load currents less than 1200 amperes, plus 200 operations interrupting fault currents up to 3600 amperes, plus one opening operation (O) at rated short-circuit current.

5.1.5.3 Schedule 3

2000 operations interrupting no-load or load currents less than 2000 amperes, plus 200 operations interrupting fault currents up to 6000 amperes, plus one opening operation (O) at rated short-circuit current.

5.1.5.4 Schedule 4

1000 operations interrupting no-load or load currents less than 3000 amperes, plus 50 operations interrupting fault currents up to 9000 amperes, plus one opening operation (O) at rated short-circuit current.

5.1.5.5 Schedule 5

12,000 operations interrupting no-load or load currents less than circuit breaker continuous current rating, plus 3000 operations interrupting fault currents up to 4000 amperes, plus one opening operation (O) at rated short-circuit current.

--`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Section 6
RECOMMENDED INSTALLATION, OPERATION, AND MAINTENANCE PROCEDURES

6.1 GENERAL

It is impossible to cover here in detail the complete rules for the installation of each of the different types of circuit breakers manufactured, but the following information is given relative to the most important points to be considered. The instructions specified by the manufacturer shall be carefully studied and followed.

The requirements of ANSI/NFPA 70B, ANSI/NFPA 70E, ANSI C2, and applicable OSHA regulations shall be adhered to in connection with any maintenance or operation of high-voltage circuit breakers. Before performing any work in the vicinity of high-voltage circuit breakers, all conductors shall be tested for voltage and then grounded using appropriate test equipment and adequate grounding equipment conforming to ASTM F-855, using appropriate personnel protective devices. Any conductors which are not adequately grounded shall be treated as being energized.

6.2 SHIPMENT

Each circuit breaker, before leaving the factory, is carefully inspected and packed. Immediately upon arrival, circuit breakers shall be examined for any damage sustained while en-route. If damage is evident or indication of rough handling is visible, the carrier (transportation company) and the manufacturer shall be promptly notified.

6.3 STORAGE

When a circuit breaker can be set up immediately in its permanent location, it is advisable to do so even though the circuit breaker will not be placed in service for some time. If the circuit breaker is of the oil type, the tank shall be cleaned, dried, and then filled with oil which meets the specifications of the manufacturer.

If the circuit breaker cannot be installed in the proper location immediately, and it is necessary to store for an extended period of time, the circuit breaker interior parts including the mechanism shall be kept clean and dry. Heaters shall be connected to limit condensation. Any unassembled parts shall be adequately protected from moisture, contamination, corrosive gases such as chlorine, or possible mechanical damage.

Circuit breakers designed for indoor service shall be stored in a clean dry place. “Dry,” for the purpose of this specification, means that relative humidity is controlled to remain below 60 percent.

Machined parts shall be protected to prevent rusting and, if stored for extended periods of time, shall be inspected periodically to ensure good mechanical condition.

Particular care shall be taken to protect insulating parts which might absorb moisture. These parts shall be stored in a dry area. Where possible, space heaters shall be used to minimize condensation.

Before placing the circuit breaker into service after storage, first inspect it in accordance with the manufacturer’s instructions and follow the guidelines given in applicable industry standards, such as section 6.11 of this standard. Make sure that all parts are in “as new” condition and that the manufacturer’s specifications are met in all respects before energizing the circuit breaker.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

6.4 UNPACKING

When unpacking a circuit breaker, the crating or boxing shall be removed carefully with a nail puller. The bushings (especially porcelain type) and other parts are sometimes broken by driving the wrecking bar into crates or boxes carelessly.

Check all parts with the packing list.

Avoid bending, breaking, or damaging any parts.

Do not leave screws, bolts, nuts, or other parts, in the packing material.

Clean the parts before assembling them.

See that the manufacturer's instruction books and tags are kept with the circuit breaker.

A thorough inspection shall be made to see that the packing braces used to hold moving parts during shipment are taken out prior to placing the circuit breaker into service.

6.5 HANDLING

The manufacturer's instructions for the handling of each circuit breaker shall be carefully studied before any attempt is made to move or handle a circuit breaker.

Circuit breakers are usually top heavy due to their high center of gravity. Extreme care shall be exercised whenever handling or moving a circuit breaker to prevent the circuit breaker from tipping over or from being dropped.

Cranes are convenient for handling circuit breakers. When using cable slings to support the circuit breaker, do not allow the slings to strike the bushings or other fragile parts, as any strain on these may cause them to crack or break. Before attempting to handle circuit breakers, their weight shall be determined from the circuit breaker nameplate or by consulting the manufacturer in order that the lifting means will be of ample strength.

If a crane is not available, the circuit breaker shall be moved in any convenient way, provided proper precautions are taken for supporting the weight of the circuit breaker and preventing dangerous tilting. Special care shall be exercised to insure that the circuit breaker is not damaged through shocks or jars due to rough handling. Completely assembled apparatus shall not be lifted by the bushings or live parts.

6.6 SELECTION OF LOCATION FOR INSTALLATION

The circuit breaker shall be installed in a location free from the destructive action of acids, alkalis, or gases, such as chlorine, and where good ventilation can be secured. See service conditions in C37.04.

The circuit breaker shall be located so that it will be readily accessible for cleaning and inspection. Sufficient space shall be provided for the easy removal of tanks or other parts and for manual operation. Ample clearance shall be provided for doors and panels to swing open or to be removed for servicing the circuit breaker.

6.7 MOUNTINGS

6.7.1 Mounting in Cells

It is recommended that installation provide adequate ventilation in the top and bottom in order to permit free circulation of air through the cell and thus, to prevent an abnormal rise of temperature in the cell.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

6.7.2 Mounting on Structure

For a circuit breaker assembled to its mounting structure, it will only be necessary to correctly locate and fasten the frame in position on its foundation. The foundation bolts shall be left loose to permit the frame to be properly plumbed and leveled by inserting shims under floor flanges (or feet of frames) where necessary. After this has been done, the foundation bolts shall be tightened and the frame securely fastened to its foundation.

Frameworks are sometimes supplied with strengthening members for shipment. These members shall be removed after the framework has been placed in position and before the foundation bolts have been tightened.

The manufacturer's instructions shall be carefully followed in setting up a frame-mounted circuit breaker that is shipped partly disassembled. The general procedure is:

a. Set up and properly level the frames.
b. Inspect contacts and, if necessary, adjust them.

6.7.3 Floor Mounted

Each unit shall be placed in position on the floor and leveled. It shall be fastened securely to its foundation after the leveling shims have been installed, and prior to performing any mechanism adjustments.

The manufacturer's instructions shall be followed very carefully, making sure of the following points:

a. Carefully install the units on the foundation, making sure they are level, in line, and properly spaced.
b. Connect the operating mechanisms so they will work freely.
c. Inspect contacts and, if necessary, adjust them.

6.7.4 Bushings

When installing or handling the circuit breaker, the bushings (insulators) shall not be allowed to strike against parts of the framework, panel, or other objects.

Where heavy bushings have to be mounted in position by the purchaser, a rope sling will be found convenient for proper handling. The bushing shall be lowered into place very carefully, providing adequate clearances between the delicate edges of the bushing and the framework of the circuit breaker or other hard surfaces to avoid damage to the bushing during installation, such as cracking.

Before attempting to handle the bushings, their weight shall be determined from the circuit breaker manufacturer to ensure that the lifting means are of ample strength.

In the case of high-voltage bushings that shall be filled with oil at the time of installation, the drain plug at the lower end of the bushings shall be inspected and, if necessary, tightened so that the bushing will not leak.

6.7.5 Operating Mechanism

The proper alignment of the links, pins, and other moving parts of the operating mechanism is essential to the proper operation of the circuit breaker. These shall be carefully checked and the manufacturer's instructions followed explicitly. A circuit breaker shall not be operated until a thorough inspection is made of the operating mechanism.

For large multipole circuit breakers, the connecting rods or couplings between units must be aligned before satisfactory operation is possible. The connecting rods or couplings shall be adjusted so that, in closing or opening the circuit breaker, the contacts of each unit are made within manufacturers specified tolerances.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

6.7.6 Contacts

Contacts shall be cleaned, installed, and adjusted in accordance with the manufacturer's instructions.

6.7.7 Power Operated Circuit Breakers

The connecting links, shafting, and other moving parts between the circuit breaker pole unit mechanism and the operating mechanism (solenoid, motor, or other device) supplied for power operation shall all be carefully aligned. The circuit breaker shall be operated mechanically, without carrying primary circuit current, by hand (slowly, if designed to do so) before it is operated with control power. The operation shall be observed to see that it is smooth throughout the closing and opening of the circuit breaker, that no binding occurs, and that no excessive play is noticeable between parts. The clearances at the mechanism stops shall be checked to see that they are in accordance with the manufacturer's recommendations.

In the case of oil circuit breakers, the number of power operations without oil shall be restricted in accordance to the manufacturer’s recommendation.

Circuit breakers shall not be operated with the maintenance closing device when there is stored energy available to the mechanism.

6.8 INSULATING FLUID

6.8.1 Oil Testing

The device used for testing oil for dielectric withstand shall have a spark gap with electrodes 1 inch in diameter. The testing cups shall be cleaned thoroughly to remove any foreign matter and rinsed out with a portion of the oil to be tested.

The spark gap receptacle (cup) shall be nearly filled with oil and allowed to stand for a few minutes to give air bubbles time to escape before making the test.

The voltage shall be increased at a rate of approximately 3000 volts per second. Five breakdowns shall be made on each filling, after which the receptacle shall be emptied and refilled with fresh oil from the original sample. The average voltage of 15 tests (5 tests on each 3 fillings) is usually taken as the dielectric withstand of the oil. It is recommended that the test be continued until the averages of at least 3 fillings are essentially constant.

The dielectric withstand of the oil when shipped is at least 26,000 volts tested in the standard gap. If the oil in an oil circuit breaker in service tests at less than 16,500 volts or the minimum recommended by the manufacturer, it shall be filtered.

New oil having a dielectric withstand less than 22,000 volts shall not be put into the oil circuit breaker tank.

The oil shall be checked for acidity and, if necessary, treated to remove acids or replaced.

6.8.2 Oil Drying

In removing moisture from the oil, it is preferable to filter the oil from one tank or barrel and discharge it to another. If necessary, the oil may be drawn from the bottom of a tank or barrel and discharged at the top. If there is much water in the oil, the oil shall be allowed to settle, the moisture shall be drawn off, and any moisture remaining shall be treated separately. It shall be noted that the usual methods of drying oil do not remove acid.

Before draining the oil from the circuit breaker or circulating the oil through a pipe line connected to a filter press, the oil circuit breaker shall be disconnected from all electric power and the terminals shall be grounded.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

6.8.3 Filling Tanks With Oil

Before the oil circuit breaker is filled with oil, all accessories, such as valves and gauges, shall be fitted to the circuit breaker and made oil tight. The threads shall be filled with shellac or its equivalent before being put in place.

When drums of oil are brought into a room that is warmer than they are, they shall be allowed to stand before they are opened until there is no condensation on the outside and they are thoroughly dry. In outdoor installations, the preparation and filling of the circuit breaker tank shall be done on a clear, dry day or protection of some kind shall be provided to prevent the absorption of moisture by the oil during the filling process.

Metal or oilproof rubber shall be used. (Rubber hose containing sulphur shall not be used because oil dissolves the sulphur. This may cause trouble as sulphur attacks copper.)

It is very important that the surface of the oil when cold (77°F [25°C] American National Standard; 68°F [20°C] International Standard*) be at the proper oil level as indicated by the gauge or marking on the tank.

*See paragraph 3-15 of ANSI/IEEE 3.

6.8.4 Filling and Handling De-energized SF_6 Circuit Breakers

Before the breaker is operated or placed into service, it must be filled with sulfur hexafluoride gas according to the manufacturer's instructions.

Before performing any work on a circuit breaker which uses SF_6 gas, the user must know and understand the procedures involved with handling of the gas, must have the proper equipment for handling and processing of the gas, and must be trained in the proper use of the equipment. A comprehensive report on the proper handling and use of SF_6 gas has been prepared by a working group within IEC. This report, designated as Technical Report 61634, is entitled *High-Voltage Switchgear and Controlgear – Use and Handling of Sulfur Hexafluoride SF_6 in High-Voltage Switchgear and Controlgear*.

SF_6 gas shall not be vented into the atmosphere.

SF_6 circuit breakers are generally shipped with a positive pressure of approximately 5 psig (35 kPa) of SF_6, therefore, evacuation is not required before filling. Before filling with SF_6, check the pressure gauge to confirm that the pressure has not been lost due to damage or leakage. If pressure is reduced to 0 psig, it will be necessary to find and repair the cause of the leakage, and then pull a vacuum to approximately 1 mm of mercury and hold for 30 minutes before filling with SF_6. Maintaining the vacuum for a period of time is not required unless there has been exposure of the interior pole unit assemblies to the atmosphere, in which case the procedures in the maintenance section 6.13 and section 6.8.4.2 shall be followed.

6.8.4.1 Management of SF_6 Gas in High-Voltage Circuit Breakers

SF_6 is a powerful greenhouse gas so it should never be deliberately released to the atmosphere. However, it is not an ozone depletion gas. Maintain control of SF_6 by an inventory program that tracks:

a. SF_6 purchased
b. SF_6 received inside of and with electrical equipment
c. SF_6 in service in electrical equipment
d. SF_6 in storage
e. SF_6 in gas handling equipment
f. SF_6 returned to SF_6 supplier or equipment manufacturer

6.8.4.2 Use gas checking and handling equipment to approach the following target levels (check with equipment manufacturer to ensure that the equipment can accommodate the process):

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

a. Evacuate air to 1 mbar (100 Pa or 0.8 mmHg) from equipment, hoses, and fittings that are to be filled with SF_6. This keeps air contamination of SF_6 to acceptable levels of less than 0.02% per filling to a typical pressure of 5 bar (500 kPa or 60 psig). This is important because air cannot be removed by ordinary filters. Separation is difficult and does not recover all the SF_6.

b. Remove SF_6 from the equipment being tested, produced, or maintained to a vacuum of 1.3 mbar (130 Pa or 1 mmHg). This will keep handling losses for electrical equipment (typically filled at 5 bar or more (500 kPa or 60 psig) to below 0.02% per handling cycle. It will also, through subsequent dilution of any toxic SF_6 decomposition products in the equipment with the backfilled air, ensure that personnel are not exposed above tolerable limits.

c. Filter SF_6 being handled to remove moisture, decomposition products, and other possible filterable contaminants using a molecular sieve, activated alumina, and 1 micron or smaller particle filters. This will keep the SF_6 in good condition and also help ensure that personnel are never exposed to toxic decomposition products in SF_6.

d. Check quality of SF_6 intended for re-use in electrical equipment using:
   1. percentage of SF_6 instrument (2% air limit)
   2. hygrometer or dew point instrument for moisture (120 ppmv limit)
   3. chemical reagent tube for decomposition products (50 ppmv total or 12 ppmv SO_2 limit)

e. Leak check all equipment containing SF_6 with special attention to gas fittings, moving seals, gas handling equipment, and storage facilities. Eliminate leaks to keep overall SF_6 emission rate from leakage below 1% per year.

For more information see CIGRE Report #117, *SF_6 Recycling Guide — Re-Use of SF_6 Gas in Electrical Equipment and Final Disposal*, August, 1997.

6.9 CONNECTIONS

Before making any electrical connections, all leads to be connected to the circuit breaker shall be deenergized with proper safety grounds applied.

All terminals shall be fastened to the leads and tightly clamped to the connection studs.

Connections to the circuit breaker are made by terminals or connection bars fastened to the end of the bushing. When tightening the terminal or clamp bolts, care shall be taken not to turn the stud in the bushing (insulator).

All joints shall be clean, bright, free from dents or burns, and preferably silver-plated or the equivalent.

All nuts on the current-carrying stud shall be set up firmly against the terminal lugs to obtain good contact. The nut shall turn freely on the stud. If the nut does not turn freely, it shall not be forced down with a wrench but shall be tapped lightly on its outer surfaces with a hammer and, at the same time, turned by hand. A nut that cannot be worked down in this manner will ruin the thread if any attempt is made to force it. If the joints are not made correctly, excessive heating of the circuit breaker may result.

Cables and bars shall be properly supported so that the circuit breaker is not subjected to excessive strains. The studs shall not be subjected to cable or bus-bar strains. Any strains that at first have no apparent effect on the stud alignment will, in time, misalign the studs and adversely affect the closing of the circuit breaker, and poor contact may result.

To avoid undue heating, the connecting leads shall have a current-carrying capacity at least equal to that of the current-carrying parts of the circuit breaker.

To prevent weakening of the insulation, sharp turns, corners, and edges shall be avoided for insulated wiring. Care shall be observed in installing cables so that bends are not used with a radius smaller than that recommended by the cable manufacturer. Cables, bars, or other conductors shall be properly

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

designed, supported, and braced so as not to exert strains on the bushing or other circuit breaker parts. The use of bends, loops, or flexible connections is recommended.

6.9.1 Secondary and Control Wiring

All wires shall be run in conduit. Wires shall be separate and remote from high-voltage leads and shall not be in the same duct or even parallel to the high-voltage leads unless the distance separating the two sets of wiring is sufficient to provide isolation between them as a result of short circuits.

The wiring shall be so installed that trouble on one circuit breaker cannot be communicated to the wiring of another circuit breaker.

Wiring of adequate size shall be used for electrically operated circuit breakers so that, with the full operating current flowing to the operating mechanism, the voltage across the terminals of the operating mechanism will be within rated nominal but not less than the minimum voltage of the range given in C37.06.

6.9.2 Ground Connections

The frame of each unit of a circuit breaker shall be permanently grounded. The usual practice is to connect a heavy cable or solid copper bar to the frame ground pads and to the ground at two diametrically opposite sides of the circuit breaker. The ground connections shall be adequate to carry maximum line-to-ground fault current for the duration of the fault. Ground connections shall be in accordance with section 3.3.3. For additional detail on ground connections refer to IEEE Std. 80.

A good permanent low-resistance ground is very important for adequate protection.

WARNING: An inadequate ground can give a false sense of security to those working around equipment and may also result in loss of life or damage to the apparatus.

6.10 AUXILIARIES

6.10.1 Tank Lifters

Tank lifters for raising or lowering the oil tank are generally used when the weight of the tank is too great to allow ready handling by hand. One tank lifter in a station is usually sufficient for all oil circuit breakers of the same type and capacity. It may be operated to lower or raise a tank of one circuit breaker (or unit) and then be moved to another circuit breaker (or unit).

When it is necessary to remove the oil tank, care shall be taken that the bushings or contacts are not forced or jarred out of alignment. The tank shall contain sufficient oil before it is replaced, except in the case of tanks that have oil filling connections. It is necessary to have the oil at the correct level to keep the contacts covered properly and also to have the proper air chamber above the oil for best operation of the circuit breaker.

6.10.2 Other Lifters

In the case of oilless circuit breakers, care shall be used in removing heavy parts necessary for maintenance and inspection to prevent damage to the contacts or other parts. Where the parts are so heavy that they are difficult to handle by hand, suitable lifters shall be used.

6.10.3 Undervoltage Trip Device

The proper holding and releasing action of undervoltage coils and mechanisms is dependent upon both mechanical adjustment and upon the application of the voltage (and frequency for AC systems) specified on the nameplate. These devices shall be inspected periodically to insure continued smooth operation and to prevent unnecessary strain.

--`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

AC release mechanisms shall be examined periodically to see that the iron circuit is properly sealed and that the pole pieces are cleaned of rust and make a true flat contact. Care on this point will prevent or lessen humming and failure of coils from excessive current due to open iron circuits.

When undervoltage devices are supplied for use in series with resistors, the connections shall be carefully checked before full voltage is applied across the operating coils.

6.10.4 Auxiliary Switches

Follow the manufacturer's instructions for service.

Where applicable, the bearings of auxiliary switches shall be oiled occasionally. A thin coat of contact lubricant shall be applied to the contact surfaces. A periodic inspection of the contacts for wear is recommended.

6.11 FINAL INSTALLATION INSPECTION

After a circuit breaker has been installed and all mechanical and electrical connections have been completed, the following inspections and tests shall be made:

a. Check that the circuit breaker is properly set up and leveled on its supporting structure (panel, pipes, structural iron, steel frame, or other supports).

b. Check that heaters, where used, are operating correctly.

c. Check that all bearing surfaces of the operating mechanism have been lubricated where required.

d. While the circuit breaker is still disconnected from the primary circuit, close it by hand (slowly, if it is designed to do so), noting that the operating rod (or rods) and contacts are properly adjusted for correct alignment. Good contact shall be made with the circuit breaker closed. Circuit breakers using compressed air as an interrupting medium shall not be operated with the maintenance closing device if there is pressure in the air receiver.

e. Check that the tanks of oil circuit breakers are filled with clean, dry oil to the proper level (oil line or gauge).

f. Inspect all wiring to see that no damage has resulted during installation and that connections are tight.

g. Test the wiring for possible grounds, short circuits, or open circuits.

h. Check that all connections of control and secondary wiring are tight.

i. Check that all current-carrying parts are correctly insulated.

j. Check that all joints, whether bolted joints of copper bars or soldered (or clamped) joints made with wires and cables, are made correctly.

k. Check that all covers and bolted connections of circuit breakers are securely tightened so as to prevent the entrance of moisture and that tanks of all oil circuit breakers are drawn tightly against their gaskets.

l. In the case of air insulated circuit breakers, blow out all foreign material with dry air.

6.12 POWER OPERATED CIRCUIT BREAKERS

Follow the manufacturer's detailed checklist if provided.

Power operated circuit breakers shall be operated manually (by hand) first to insure that all parts move freely and without binding. After careful inspection has shown all parts to be in proper working order during the manual operation, the circuit breaker may be operated with power at normal operating voltage or air pressure.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

6.13 MAINTENANCE

The safety and the successful functioning of connected apparatus depend upon the proper operation of the circuit breaker. Therefore, the circuit breaker shall have regular systematic maintenance and inspection.

The following points require special attention:

a. The manufacturer's instructions for the circuit breaker shall be carefully studied before any maintenance, inspection, or servicing is performed. Selection of cleaning agents and lubricants must adhere to the manufacturer's recommendations.

b. Be sure that the circuit breaker and its mechanism are disconnected from all electric power, both high-voltage and control voltage, before it is inspected or repaired.

c. Exhaust the pressure from the air receiver of any compressed air circuit breaker before it is inspected or repaired.

d. After the circuit breaker has been disconnected from power lines, attach the grounding leads properly before touching any of the circuit breaker parts.

e. Inspect the operating mechanism periodically and keep the bearing surfaces of the toggles, rods, and levers adequately lubricated where required.

f. Keep the mechanism clean.

g. Maintain contacts in good condition, as described by the manufacturer.

h. Be sure the circuit breaker is well grounded.

i. Check that bolts, nuts, washers, cotter pins, other hardware, and all terminal connections are in place and tight.

j. Inspect the bushing (insulator) supports, as vibration due to the operation of the circuit breaker may cause the bushings to move slightly and result in misalignment of contacts.

k. Clean the bushings at regular intervals where abnormal conditions, such as salt deposits, cement dust, or acid fumes, prevail to avoid flashovers resulting from the accumulation of foreign substances on bushing surfaces.

l. Check that the oil is kept at the proper level in the tank (or tanks) and that the proper dielectric withstand of the oil is maintained. (See 6.8.1 for instructions for testing oil.)

m. Check that the moisture content in SF_6 circuit breakers is within the manufacturer's specification and that the circuit breaker has proper SF_6 pressure.

n. Test the circuit breaker oil every six months. Change or filter the oil if necessary.

o. Filter the oil after successive openings under load, short circuit, and such if it shows carbonization or if its dielectric withstand is lowered because of dirt or suspended matter. Test the oil before replacing it in the tank. Carbonization is indicated by a flaky, black precipitate that floats in the oil when disturbed.

p. Do not allow moisture to come into contact with the oil during filtering.

q. Remove all oil at least once a year and thoroughly clean the tank (or tanks) and other parts that have been in contact with the oil, e.g., liners, bushings, lift rods, guides, and similar components.

r. On all indoor oil and gas circuit breakers equipped with separating chambers to exhaust the circuit breaker during and after an operation, an exhaust header and necessary pipe lines shall be provided to exhaust the gases to the outdoors.

--`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

s. Before entering large circuit breaker tanks after the oil or gas has been drained, care shall be taken to ensure proper ventilation to meet OSHA or other regulatory code requirements.

t. Clean and, if necessary, dry the insulating materials across the interrupter to ground or parts of different potential on all air or oilless circuit breakers (refer to the manufacturer's instruction book for specific instructions for each type of circuit breaker).

u. At all inspections, operate the circuit breaker manually to see that the mechanism works smoothly and correctly before operating it with control power.

v. Circuit breakers with stored energy mechanisms (compressed air, hydraulic, and spring) shall not be operated with the maintenance closing devices when there is stored energy in the mechanism.

w. A circuit breaker with oil tanks removed shall not be operated with power except in accordance with manufacturer's instructions. For certain compressed gas (SF_6) circuit breakers, power operations without sufficient gas are not permitted.

x. When servicing vacuum circuit breakers, before attempting to touch the vacuum interrupters, be certain to remove the static charges by grounding both ends of the interrupter and the midband rings (if any). The reason for this is that high voltage static charges can remain trapped on a vacuum interrupter after it is removed from normal service or after dielectric tests are performed.

y. Check that the compartment heaters, where provided, are operating.

z. Perform insulation resistance tests or high potential tests to check dielectric withstand as prescribed by the manufacturer.

6.14 SPARE PARTS

It is recommended that sufficient spare parts be carried in stock to enable the user of circuit breakers to promptly replace any worn, broken, or damaged parts. The manufacturer will provide the purchaser with a list of recommended spare parts upon request.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

[The information in Appendices A and B was taken from the last revision of this standard. This information is not considered pertinent to the circuit breakers currently being manufactured. The information is considered valuable reference information for circuit breakers currently installed in power systems and has been moved to the appendix for reference.]

Appendix A
BUSHING POTENTIAL DEVICES FOR TANK-TYPE OUTDOOR OIL CIRCUIT BREAKERS

A.1 GENERAL

Tank-type outdoor oil circuit breakers rated 121 kV and higher shall have tapped bushings and mounting provisions suitable for connecting one bushing potential device to each high-voltage bushing.

A.2 CHARACTERISTICS

A.2.1 The potential device network includes a potential transformer and suitable variable inductive and capacitive reactances that permit adjustment of the output voltage to be substantially in phase and proportional to the high-voltage line-to-ground voltage impressed on the high-voltage bushing to which the potential device is connected.

A.2.2 The transformer protective gap shall be set at not less than twice the maximum continuous operating tap voltage of the potential device when operating at primary line-to-ground voltage, rated burden, and rated frequency.

A.2.3 The transformer grounding switch for use in adjustment and maintenance shall be so arranged that, when closed, the point of connection of the potential device network to the high-voltage bushing is effectively grounded, thus reducing the operating tap voltage to zero, without interrupting the high-voltage line operation.

The high-voltage bushing should not be continuously energized with the transformer grounding switch closed or with any potential device connections which will remove the voltage from the tapped portion of the bushing. Consult the manufacturer for details.

A.2.4 The potential device shall have a tapped capacitor or other equivalent means in the secondary circuit to correct the power factor of the applied burden to a net power factor of unity on the potential device. The minimum values of power-factor correction to be provided shall be in accordance with Table A-1 in steps not greater than 3.75 volt-amperes.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table A-1
RATED VOLTAGE CLASSES, RATED BURDENS, AND SECONDARY VOLTAGES FOR BUSHING POTENTIAL DEVICES

Nominal voltage class, rms*	Rated maximum voltage, kV*, rms	Rated primary line-to-ground voltage, KV*, rms	Rated burden watts**	Rated secondary voltage, volts	Minimum power factor correction (volt-amperes reactive)†
115	123	70	25	123 or 70	20
138	145	84	35	123 or 70	28
161	170	98	45	123 or 70	36
230‡	245	140	80	123 or 70	64
345	362	210	125	123 or 70	75

*See A.3.1, A.3.2, and A.3.3.

**When the potential device has extra secondary voltage windings or taps, the rated burden represents the total of the simultaneous burdens of all windings, taps, or both. The rated burden for each winding, tap, or both, shall be as shown on the nameplate.

†See A.3.4.

‡This device shall be used with high-voltage bushings rated 230/196kV, and it shall have the same output and performance characteristics when energized at rated primary line-to-ground voltage of 119 kV.

A.2.5 The potential device shall have a lead-in cable consisting of an insulated conductor with equivalent fittings for connection between the voltage tap of the bushing and the potential device network.

A.3 CLASS AND RATINGS

A.3.1 Potential devices for use with high-voltage bushings rated 121 kV and above shall be Class A (in-phase) devices.

A.3.2 The ratings for bushing potential devices shall be in accordance with Table A-1. These ratings and the performance characteristics given in A.4 apply to potential devices used on systems operating at 60 Hz and at the rated primary line-to-ground voltages given in Table A-1. The ratings and performance characteristics, when the potential devices are used on systems operating at other frequencies and voltages, shall be in accordance with A.3 and A.4.

A.3.3 When the operating voltage of the circuit on which the circuit breaker is specified for use is the next rated circuit voltage class lower than the usual rated circuit voltage corresponding to the voltage class of the high-voltage bushing, the rated burden, in watts, shall be 80 percent of the value specified in Table A-1, and the design shall be such that accuracy will be maintained at rated secondary voltage as shown in A.4. Where potential devices are required on systems having operating voltages below the above specified values, consult the manufacturer.

A.3.4 When the system frequency of the circuit on which the circuit breaker is specified for use is 50 Hz, the rated burden, in watts, shall be 80 percent of the value specified in Table A-1, and accuracy shall be maintained at rated secondary voltage as shown in A.4. (When potential devices are required on systems having frequencies other than 60 or 50 Hz, the manufacturer should be consulted.)

--`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

A.4 PERFORMANCE CHARACTERISTICS

The performance characteristics are given in terms of the voltage regulation and the burden regulation when the device operates at the ratings specified in A.3.2, A.3.3, and A.3.4.

A.4.1 The voltage regulation shall be not greater than the following:

Variation in primary voltage*, percent	Ratio, percent (plus or minus)	Phase angle, degrees (plus or minus)
100	1	1
25	3	3
5	5	5

*When devices are initially adjusted within these limits at rated burden, their performance will be substantially within the same limits between 90 percent and 110 percent of rated primary voltage.

A.4.2 The burden regulation shall be not greater than the following:

Variation in rated burden*, percent	Ratio, percent (plus or minus)	Phase angle, degrees (plus or minus)
100	1	1
50	6	4
5	12	8

*The device shall be initially adjusted within these limits at rated primary line-to-ground voltage.

A.5 ADJUSTMENT

The maximum range over which adjustment shall be required and the maximum steps of adjustment of the potential devices shall be in accordance with the following:

Maximum range of adjustment required (plus or minus)		Maximum steps of adjustment	
Ratio, percent	Phase angle, degrees	Ratio, percent	Phase angle, degrees
5	5	1	1

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

A.6 POLARITY

The relative instantaneous polarity of the primary and secondary terminals of potential devices shall be clearly indicated. Permanent markings shall be so made that they cannot be easily obliterated.

A.7 NAMEPLATES

Potential devices shall be provided with nameplates that include the following minimum information:

a. Manufacturer's name or the equivalent
b. Identification number
c. Type and form designation or the equivalent
d. Nominal voltage class
e. Rated primary line-to-ground voltage
f. Secondary voltage ratings
g. Rated burden of each secondary voltage winding and total simultaneous burden
h. Rated frequency
i. Device class
j. Instruction book number
k. Weight

A.8 BUSHING POTENTIAL DEVICE TEST (PRODUCTION TEST)

Bushing potential devices shall be given both a dielectric and electrical test.

The dielectric tests shall consist of the following power-frequency 1-minute tests.

The primary windings of the potential device network transformer, lead-in cable, the shunt or auxiliary capacitor (when used), and other equipment in the tap circuit, exclusive of the protective gap, shall be given a power-frequency test having a value of four times the maximum operating tap voltage at rated voltage, burden, and frequency.

The protective gap shall withstand a 60-Hz flashover test within the limits of its setting as specified in A.2.2.

The power-factor-correction capacitor, phase angle capacitor (if used), and other equipment in the secondary circuit of the potential device network shall be given a power-frequency test having a value of four times the maximum operating voltage impressed between terminals on the respective component parts when the potential device is operated at rated voltage, burden, and frequency. The secondary circuits and associated windings shall also be given a power-frequency test of 2500 volts between the terminals on the adjusting panel and ground.

The electrical tests shall consist of the necessary electrical measurements on the potential device network, or its component parts, to ensure proper operation of the potential device. Measurements of the electrical constants of the component parts of the potential network, such as resistances, inductive and capacitive reactances, turn ratios, and tap locations, shall be made at the adjusting panel, insofar as practical, to insure that the parts are correctly connected in accordance with the connection diagram.

A.9 OIL SAMPLING

The container used in sampling oil shall be cleaned, dried, and free from moisture before it is used.

The sample of oil for dielectric tests shall be at least 1 pint (16 ounces) (0.5 liters) and, if a number of tests are to be made, 1 quart (32 ounces) (1 liter).

--`,,`-`-`,,`,,`,`,,`---

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Tests samples shall be taken only after the oil has settled for some time, varying from 8 hours for a barrel to several days for a large oil circuit breaker tank. Cold oil is much slower in settling. Oil samples from large oil circuit breakers shall be taken from the valve at the bottom of the tank. Oil samples from small oil circuit breakers, which have no valves, and from barrels, shall be taken from the bottom. A brass or glass "thief" can be conveniently used for this purpose. The same method shall be used for cleaning the thief as is used for cleaning the oil sample container.

When drawing samples from the bottom of a large oil circuit breaker or a large tank, sufficient oil shall first be drawn off to make sure that the sample will be composed of oil from the bottom of the tank and not from the oil stored in the sampling pipe. A glass receptacle is desired so that water, if present, may be readily observed. If moisture is found, an investigation of the cause shall be made and a remedy applied. If water is not present in sufficient quantity to settle out, the oil may still contain considerable moisture in a suspended state and shall be tested for dielectric withstand.

A.10 PREFERRED MOUNTING FLANGE DIMENSIONS FOR BUSHINGS TO BE USED WITH OIL-FILLED APPARATUS

Refer to C57.19.01-1992 for the preferred dimensions.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Appendix B

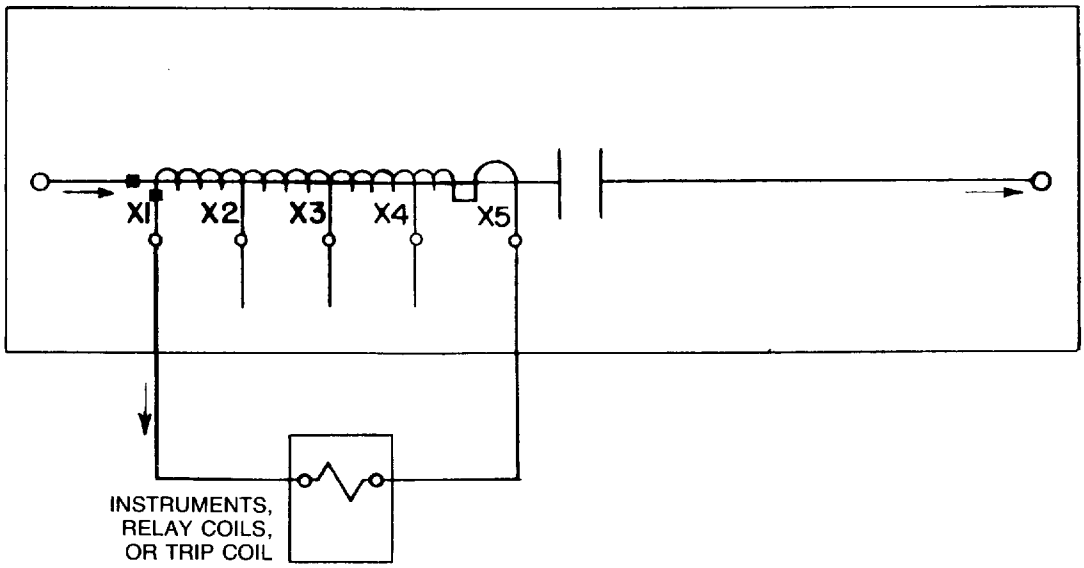

Figure B-1
TYPICAL CONNECTION OF SECONDARY BURDENS ONE CURRENT TRANSFORMER PER CIRCUIT BREAKER POLE

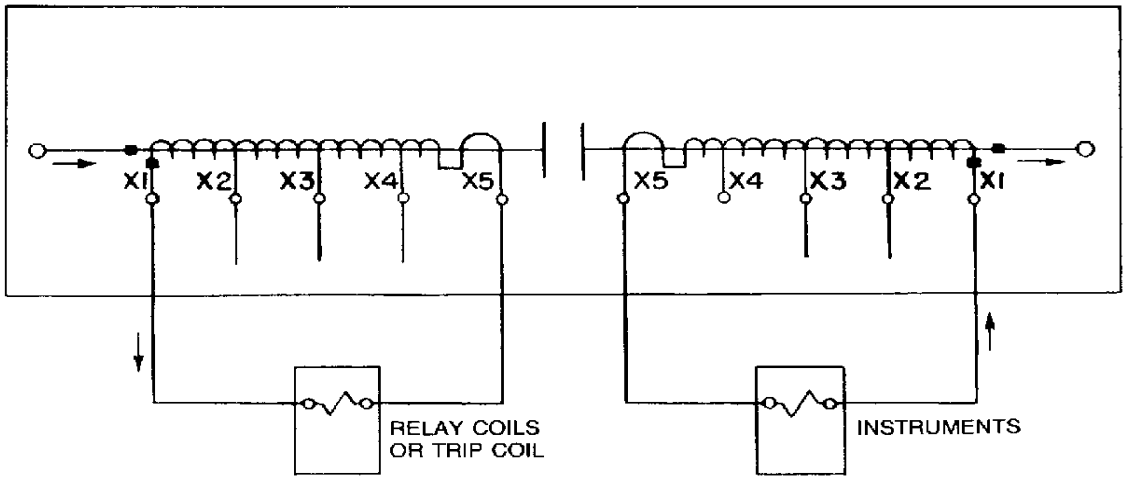

Figure B-2
TYPICAL CONNECTION OF SECONDARY BURDENS TWO CURRENT TRANSFORMERS PER CIRCUIT BREAKER POLE CONNECT INDEPENDENTLY

NOTE—It is recommended that instruments be operated on a separate current transformer.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

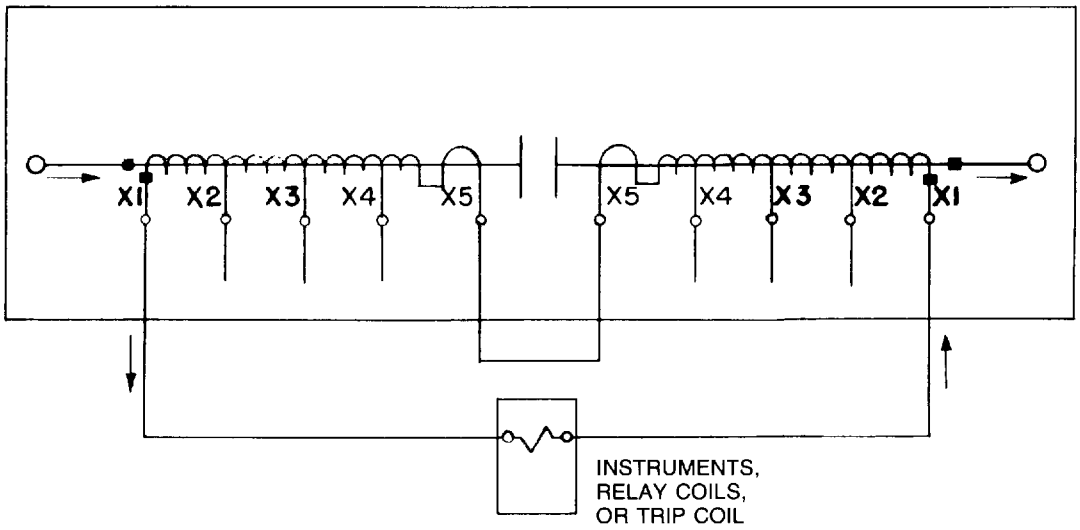

Figure B-3
CONNECTION OF SECONDARY BURDENS TWO CURRENT TRANSFORMERS PER CIRCUIT BREAKER POLE CONNECTION IN SERIES USED WHEN BURDENS ARE LARGE

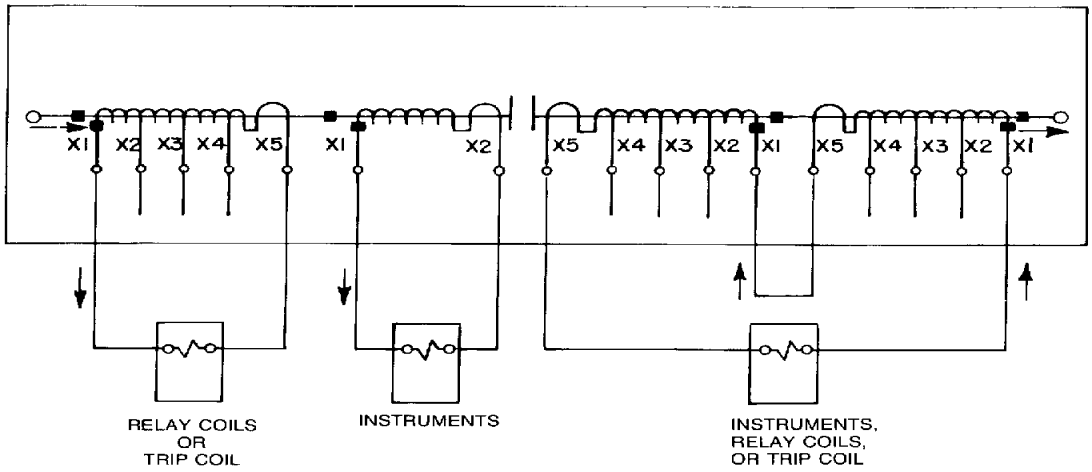

Figure B-4
CONNECTION OF SECONDARY BURDENS FOUR CURRENT TRANSFORMERS PER CIRCUIT BREAKER POLE TWO PER TERMINAL CONNECTED INDEPENDENTLY AND TWO PER TERMINAL CONNECTED IN SERIES

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale