STANDARDS PUBLICATION NO. CP 9

nema

External Fuses For Shunt Capacitors

NEMA

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

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 CP*9 92 ■ 6470247 0503850 485 ■

NEMA STANDARDS PUBLICATION NO. CP 9-1992

EXTERNAL FUSES FOR SHUNT CAPACITORS

Published by

National Electrical Manufacturers Association
2101 L Street, NW
Washington, DC 20037

Copyright © 1993 National Electrical Manufacturers Association

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

		Page
	Foreword	i
	Scope	ii
Section 1	REFERENCED STANDARDS AND DEFINITIONS	
	Referenced Standards	1
	Definitions	1
Section 2	EXTERNAL FUSES FOR SHUNT CAPACITORS	
	General	3
	Disconnecting Requirements	3
	Fuse Ratings (Information to be Furnished to the User)	3
	Routing (Production Test on Fuses)	3
	Design Test of Fuses	3
Appendix A	GUIDE FOR APPLICATION AND COORDINATION OF CAPACITOR FUSES	7

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 standard was the product of a NEMA Joint Sections Committee (JSC) on Capacitor Fuses. The JSC was organized in 1975 and tasked with developing a standard for Fusing Power Shunt Capacitors. This effort was suspended until the publication of CP 1 in 1988. The JSC was disbanded in 1984.

With the publication of the revised CP 1-1988, the need to complete the work of the JSC was affirmed.

The Capacitor Section reviewed the last JSC draft and determined that, with minor revisions, it would fill a valuable need in the user community and facilitate the technical dialogue between manufacturers and users of both capacitors and fused capacitors.

These standards are periodically reviewed by the Capacitor Section of NEMA for any revisions necessary to keep them up to date with advancing technology. As future revisions to this publication are proposed, they will be introduced to both individuals and organizations in the public and private sector. Further participation in the development of this publication is welcomed.

Proposed or recommended revisions should be submitted to:

Vice President, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N. W.
Washington, D. C. 20037

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

Scope

This standard applies to external fuses used with individual power capacitor units or groups 0-21.6 kV, 60 Hz, AC rms, according to NEMA Standards Publication CP 1-1988, Shunt Capacitors, and ANSI/IEEE 18-1980 for Shunt Power Capacitors. The objective of this standard is to:

- Formulate uniform specification regarding performance, testing, and rating.
- Assist in the coordination and application of fuse protection to shunt capacitors.

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
REFERENCED STANDARDS AND DEFINITIONS

1.1 REFERENCED STANDARDS

The fuses shall, where applicable, be in conformance with the following Standards or latest revisions thereof. (It must be observed that the Standards below cover only inductive currents but this Standard deals with capacitive currents, also.):

NEMA
2101 L Street, N.W.
Washington, D.C. 20037

CP 1-1988 (R1992)*	*Shunt Capacitors*
SG 2-1986	*High-Voltage Fuses*
FU 1-1986	*Low-Voltage Cartridge Fuses*

ANSI
11 West 42nd Street
New York, NY 10036

C37.40-1981 (R1988)	*Service Conditions and Definitions for Distribution Cutouts and Fuse Links, Secondary Fuses, Distribution Enclosed Single-Pole Air Switches, Power Fuses, Fuse Disconnecting Switches, and Accessories*
C37.41-1989	*Design Tests for Distribution Cutouts and Fuse Links, Secondary Fuses, Distribution Enclosed Single-Pole Air Switches, Power Fuses, Fuse Disconnecting Switches, and Accessories*
C37.42-1989	*Specifications for Distribution Enclosed, Open, and Open-Link Cutouts*
C37.44-1981 (R1987)	*Specifications for Distribution Oil Cutouts and Fuse Links*
C37.46-1981 (R1987)	*Specifications for Power Fuses and Fuse Disconnecting Switches*
C37.47-1981 (R1988)	*Specification for Distribution Fuse Disconnecting Switches, Distribution Fuse Supports, and Distribution Current-Limiting Fuses*

*CP 1-1988 - If the service conditions are incompatible with the requirements of this Standard, the user should consult the manufacturers.

1.1.1 Fuses, according to this Standard, are intended to disconnect faulted capacitor units or groups of units in a capacitor equipment.

1.2 DEFINITIONS

It is recommended that the appropriate definitions in Publication NEMA CP 1 shall apply.

1.2.1 External Fuse

A fuse connected externally to, and in series with, a capacitor unit or group of units.

1.2.2 Expulsion Fuse or Fuse Unit

A vented fuse or fuse unit in which the expulsion effect of gases produced by the arc and lining of the fuseholder, either alone or aided by a spring, extinguishes the arc.

1.2.3 Current-limiting Fuse

A fuse that, when it is melted by a current within its specified current-limiting range, abruptly introduces a high arc voltage to reduce the current magnitude and duration.

Note: The values specified in standards for the threshold ratio, peak let-through current, and I^2t characteristic are used as the measures of current-limiting ability.

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

1.2.4 Bank Protection

Common name for all protective equipment for a capacitor bank or part thereof except the internal fuse.

1.2.5 Unbalance Protection

A device sensitive to capacitance difference between branches of the bank normally in balance with each other. The capacitor bank or part thereof except the internal fuse.

1.2.6 Stored Energy

The value of energy, measured in Joules (Watt-seconds) that is stored in a capacitor or group of capacitors at a given instantaneous value of voltage. Thus:

$$J = \frac{CE^2}{2}$$

Where:
J = Joules
C = Capacitance (Farads)
E = Instantaneous Voltage, volts

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
EXTERNAL FUSES FOR SHUNT CAPACITORS

2.1 GENERAL

The fuse is connected in series with the unit(s) which the fuse is intended to isolate if the unit(s) become(s) faulty. The range in currents and voltages for the fuse is, therefore, dependent on the parameters of the capacitor and the bank in which the fuse is connected.

The operation of the fuse is determined by one or both of the following two factors:

a. The power frequency over-current resulting from a faulted (or short-circuited) capacitor.
b. The discharged (stored) energy from units in parallel with the faulted capacitor.

2.2 DISCONNECTING REQUIREMENTS

These requirements are valid for capacitors switched by a restrike-free circuit breaker or switch. If the breaker or switch is not restrike-free, the crest values given in Table 2-1 shall not be exceeded.

The fuse shall be capable of disconnecting the faulty unit(s) with minimal disturbance to the system and to the capacitor unit involved at the maximum crest voltages specified in Table 2-1.

The fuse shall be capable of withstanding a crest recovery voltage which is the fundamental frequency voltage appearing across the blown fuse during the first cycle after interruption including any dc component. This fuse crest recovery voltage capability shall be as specified in Table 2-1.

Table 2-1
CREST VOLTAGE VALUES

Capacitor Unit Rated Voltage, V_R* (Volts)	Type of Fuse	Maximum Crest Voltage (Volts)**	Crest Recovery Voltage (Volts)
0–1199	All	$1.5V_R\sqrt{2}$	$1.5V_R\sqrt{2}$
1200–21600	Non-current Limiting	$1.1V_R\sqrt{2}$	$2.2V_R\sqrt{2}$
1200–21600	Current Limiting	$2.2V_R\sqrt{2}$	$2.2V_R\sqrt{2}$

* V_R = Voltage rating of the capacitor unit or bank in rms volts.
** The values are based on the voltages that normally can occur across the capacitor unit terminals. These values are transients of short duration, except that 1.1 $V_R\sqrt{2}$ may be steady state.

2.3 FUSE RATINGS

Information to be supplied to the user includes:

a. Time-Current characteristic of the fuse for total clearing and minimum melting current. (ANSI C37.41, paragraphs 12.3.2 and 12.3.3).
b. Maximum continuous current which the fuse will withstand without deterioration at an ambient temperature of 40°C for outdoor applications and 55°C for enclosed applications. This may differ from the nameplate rating of the fuse.
c. Minimum energy (in Joules) and/or minimum power frequency current required to create a current-limiting action. (Current-limiting fuses only).
d. Maximum withstand I^2t value which the fuse can be subjected to (see paragraph 2.5.2.1) without deterioration for five discharges at such a time difference that a temperature limit set by the manufacturer will not be exceeded.
e. Maximum withstand I^2t value which the fuse can be subjected to (see paragraph 2.5.2.1) without deterioration for 1000 discharges at such a time difference that a temperature limit set by the manufacturer will not be exceeded.
f. Maximum available stored energy (in Joules) which the noncurrent-limiting fuse can withstand (see paragraph 2.5.3).
g. Maximum available stored energy (in Joules) rating, if any, for current-limiting fuses beyond which the fuse will not operate properly.
h. Maximum peak recovery voltage at which the fuse will clear the circuit.
   Note: Due to the capacitive current the recovery voltage usually contains a dc component.
i. Maximum capacitive rms current interrupting rating at power frequency.
j. Minimum capacitive rms current interrupting rating at power frequency.
k. Maximum power frequency system fault (inductive) rms current interrupting rating per ANSI C37.41.

Maximum peak arc voltage for inductive fault currents.
Maximum design voltage rating, rms volts (V_F).

2.4 ROUTINE (PRODUCTION TEST ON FUSES)

Resistance tests shall be made.

2.5 DESIGN TEST OF FUSES

To comply with this Standard, the fuses shall be subjected to the tests specified in Table 2-2.

CAUTION: Fuses may rupture during these tests. Adequate safeguards should be provided to prevent injury to personnel or damage to adjacent equipment in the event of violent failure of a fuse during 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 2-2
FUSE TESTS

Tests	Fuses Applied Where Inductive Current Can Flow *		Fuses Applied Where Inductive Currents Are Not Likely to Flow**
	Line Fuses	Unit Fuses	
Inductive Current Interrupting Tests†	X	X	
Capacitive Current Interrupting Tests (See 2.5.1)††	X	X	X
Discharge Tests (See 2.5.2)	X	X	X

* Examples of such applications are:
— Group fuse
— Unit fuses in delta-connected banks without units in series
— Unit fuses in star-connected banks without units in series and with grounded neutral

** Examples of such applications are:
— Unit fuses in star-connected banks with ungrounded neutral
— Banks with units in series

† These tests shall comprise at least the following:
Design tests specified in ANSI C97.1 or Design tests specified in ANSI C37.41 Table 3 or Design tests specified in ANSI C37.41 Table 4, series 1, 2, and 3.

†† These tests are not required for fuses where capacitive limited currents are not likely to flow. Examples of such cases are:
Low voltage capacitors (single internal group of sections) connected in delta or solidly grounded wye without units in series.

2.5.1 Capacitive Current Interrupting Tests

These tests are intended to prove the ability of the fuse to interrupt capacitive currents and include two series of operations:

Series A: Verification of maximum capacitive rms current interrupting rating at power frequency.

Series B: Verification of minimum capacitive rms current interrupting rating at power frequency.

Three tests shall be made to Series A, two tests to Series B.

C_P shall be omitted when testing group fuses intended for application where other capacitors are not installed adjacent to the protected bank and on the same electrical circuit.

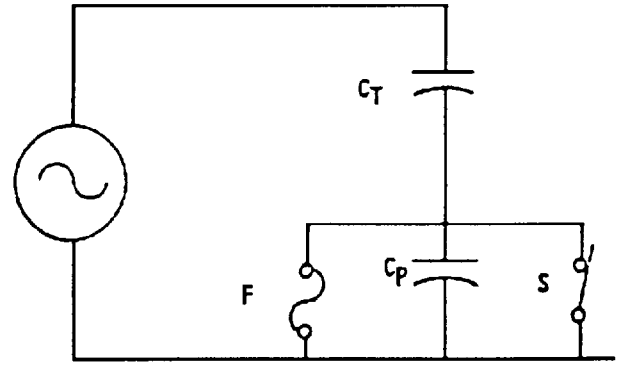
2.5.1.1 SERIES A TEST CIRCUIT

The test circuit for Series A shall be as shown in either Figure 2-1 or Figure 2-2 comprised of two capacitors C_T and C_P, with the fuse F under test placed in parallel with capacitor C_P.

C_T is the capacitance required to produce the desired current.

The circuit parameters shall be such that the steady state voltage across the fuse following interruption is V_F.

The power source circuit shall have as low an inductance as possible.



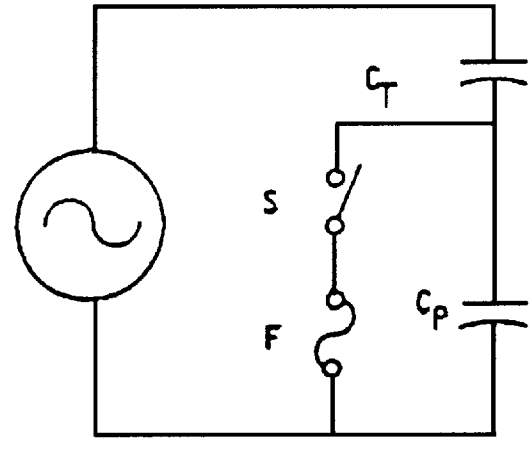
Where:
Value of C_P shall be:

$$C_P \geq \frac{1000}{V_F^2}$$

(C_P in μF)
(V_F in kV)

Fuse operation is initiated by opening switch S. Switch S must not restrike on opening.

Figure 2-1
SERIES A TEST CIRCUIT



Where:
Value of C_P shall be:

$$C_P \geq \frac{1000}{V_F^2}$$

(C_P in μF)
(V_F in kV)

Fuse operation is initiated by closing switch S. Switch S must close within 20 electrical degrees after voltage zero.

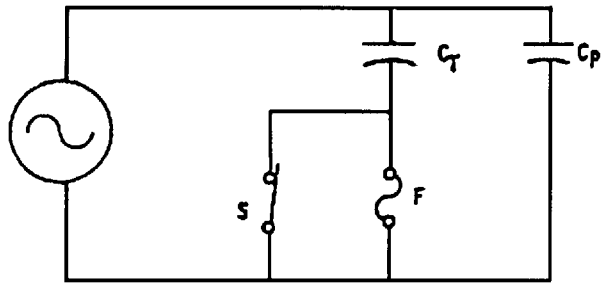
Figure 2-2
SERIES A TEST CIRCUIT

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

2.5.1.2 SERIES B TEST CIRCUIT

The test circuit for Series B shall be Figure 2-3. The circuit parameters shall be such that the steady state voltage across the fuse following interruption is V_F.

C_T is the capacitance required to produce the desired current.



$$C_P \geq \frac{1000}{V_P^2}$$

(C_P in μF)
(V_F in kV)

The fuse operation is initiated by opening switch S.

Figure 2-3
SERIES B TEST CIRCUIT

2.5.2 Discharge Tests

Tests shall be made on new fuses with the amounts of I^2t or of energy specified by the manufacturer (see 2.5).

These tests are made to verify:

a. the I^2t to which the fuse can be subjected for repetitive discharges (endurance discharge test).
b. the energy which the fuse can withstand without bursting (breaking discharge test).

2.5.2.1 ENDURANCE DISCHARGE TESTS

These tests may be made at any convenient voltage.

a. Five discharges on the same fuse within 10 minutes. The frequency shall be not less than f (kHz) = 0.8 V_F (kV) for fuses rated greater than 30A; 1.2 V_F (kV) for fuses rated 30A and below.
b. 1000 discharges on the same fuse at a time interval set by the manufacturer. The frequency shall be not less than 8 kHz.

The ratio between successive current peaks (reversal) shall be between .8 and .95. These requirements may be determined by an oscillographic record made at a reduced voltage.

The value of I^2t shall be estimated from the oscillogram of current through the fuse.

2.5.2.2 INTERRUPTING DISCHARGE TESTS

The capacitor used for the tests shall be charged by means of dc to the voltages shown in Table 2-1.

For non-current limiting fuses, the value of capacitance shall be such that the capacitor stores energy equal to the fuse stored energy capability per 2.3f.

For current limiting fuses, the value of capacitance shall be such that the capacitor stores energy equal to the fuse stored energy interrupting capability per 2.3g. If the above capacitance cannot be achieved, the charge voltage may be increased such that the maximum available stored energy rating is demonstrated. If no Joule limit is claimed, per 2.3g, then the charge voltage must be such that at the instant of interruption, the voltage remaining shall be not less than $2.0V_R\sqrt{2}$.

Two tests shall be made; each on a completely new fuse.

The frequency shall be not less than f (kHz) = 0.8 V_F (kV) where V_F is the rated maximum voltage of the fuse. No additional inductance shall be added to the test circuit. The ratio between successive current peaks (reversal) shall be between .8 and .95. This requirement may be determined by replacing the fuse with a shorting link and an oscillographic record made at a reduced voltage.

If the test circuit conditions do not permit the required discharge frequency to be obtained, then the actual discharge frequency recorded during the tests, must be specified along with the maximum available stored energy rating as defined in 2.3g.

For current limiting fuses not having a disconnect feature the voltage shall be maintained on the fuse for 10 minutes after operation. This requires the capacitor used for the test to be without discharge resistance. The voltage drop shall be measured immediately after the discharge to determine the amount of energy dissipated in the fuse.

The value of I^2t shall be estimated from the oscillogram of current through the fuse.

2.5.3 Criteria for Successful Interruption Tests

a. Flashover to ground or adjacent components shall not occur during operation when the fuse is mounted in accordance with manufacturer's recommendations.
b. After the fuse has operated, the components of the fuse, apart from those intended to be replaced after each operation, shall be in substantially the same condition as at the beginning of the test except for erosion of the bore of the fuse tube of expulsion fuses. However, after interrupting discharge tests the components of the fuse may be damaged and require replacement to restore the fuse to its operating condition.
c. After operation, the fuse shall be capable of withstanding the voltages specified in Table 2-1, column 4.

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

d. After the fuse(s) has operated, the fuse assembly shall withstand full unit voltage plus any unbalanced voltage due to fuse action, any momentary power frequency overvoltage in accordance with Table 2-3.

Table 2-3
MOMENTARY POWER FREQUENCY OVERVOLTAGE

Duration	Maximum Permissible rms Voltage (Multiplying Factor to Be Applied to Rated Voltage)
6 cycles	2.20
15 cycles	2.00
1 second	1.70
15 second	1.40
1 minute	1.30
30 minutes	1.25

2.5.4 Instrumentation

Oscillographic records shall be obtained for all short time interrupting tests (less than 1 second) to determine fuse arc voltage, recovery voltages, let-through current and I^2t.

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 A

GUIDE FOR APPLICATION AND COORDINATION OF CAPACITOR FUSES

A.1 Non-Current-Limiting Fuses

These fuses are usually of the expulsion-tube type, with renewal links. They have no current-limiting action either for power frequency current, or for stored energy discharge.

The total energy stored in the capacitors in parallel with the failed capacitor must not be greater than the fuse tube can withstand without failure, and should not be greater than that recommended in NEMA CP 1 (6.8). The Time-Current characteristic of the fuse should be such as to coordinate with the 60 Hz capacitor case rupture characteristics (As specified by the capacitor manufacturer).

This type of fuse may be used where the power frequency short-circuit current which can be supplied by the system is within the fuse interrupting rating, or where the short-circuit current is limited by floating the neutral of star-connected capacitor banks, or by connection of groups of capacitor units in series.

A.2 Current-Limiting Fuses

This type of fuse will limit high values of power frequency short-circuit current to less than that available and may force an early current zero ahead of the normal power frequency current zero.

A properly applied current-limiting fuse will limit the I^2t let-through to a value such that the energy dissipated in the shorted capacitor has a low probability of causing case rupture. These fuses are suitable where the power frequency short-circuit currents are high or where the maximum stored energy in parallel with a possible failed unit is high enough to cause rupturing of an expulsion fuse tube or the failed capacitor. Current-limiting fuses properly applied must have a maximum energy rating (see 2.3g) that exceeds the stored energy that is connected in parallel.

A.3 Fuse Voltage Rating

The voltage rating of fuses used for individually fused capacitors should be equal to, or greater than, the nameplate voltage rating of the capacitors. For group fusing of capacitors, the voltage ratings should be equal to, or greater than, the system voltage. If the bank's neutral is solidly grounded and no physical conditions exist that can impose line-to-line voltage across the fuse during a fault, then a line-to-neutral rated fuse may be used. If the fuse is a current-limiting type, the lowest voltage rating that exceeds the capacitor voltage rating should be used since use of a current-limiting device having too high a voltage rating could produce undesirable high peak arc voltages, which, in turn, impose high voltage transients on the power system.

A.4 Fuse Interrupting Rating

All fuses should have an interrupting rating that exceeds the available fault current to which the fuse may be subjected. The fault currents may be limited by current-limiting reactors, multiple series capacitors, a floating neutral, or other means.

The fuse(s) shall be so sized that, for the life of the capacitor, they will be capable, in general, of continuous operation at 135 percent of rated capacitor rms current. This is necessary due to the effects of harmonic currents, over-voltages and positive tolerances on capacitance.

The fuse(s) shall be able to carry the number of transient currents due to switching expected to happen during the life of the capacitor. For a large number of switching operations it is recommended that the maximum I^2t value of paragraph 2.5.5 shall be greater than the I^2t of the capacitor switching inrush current.

The fuses connected to undamaged unit(s) shall be able to carry the discharge currents due to the breakdown of unit(s) in the equipment occurring within the voltage range according to Table 2-1. It should be recognized that a bus flashover may cause spurious fuse operations due to multiple restrikes in the arc or total stored energy at elevated voltages. (See paragraph 2.5.4.)

Regular inspection of the capacitor installation on an established schedule should include a check of the fuses. Fuse surfaces should be cleaned periodically depending on the severity of conditions to which they are exposed.

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 STANDARDIZIATION BACKGROUND

The purpose of NEMA standards, their classification, and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

Purpose Of Standards

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

(Standardization Policies and Procedures, p. 1)

Definition of a Standard

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

(Standardization Policies and Procedures, p. 2)

Dimensions

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

(Standardization Policies and Procedures, p. 8)

Categories of Standards

National Electrical Manufacturers Association Standards are of three classes, which have received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture.
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp. 7 & 16)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 7 & 16)

Identification of Status

Standards in NEMA Standards Publications are identified as "NEMA Standard," "Suggested Standard for Future Design," or "Adoptive Standard." These indicate the status of the standard. A statement incorporating the auxiliary verb "shall" indicates that compliance with a requirement is mandatory for compliance with the standard. These classes of standards are identified in the foreword and throughout the text.

The material identified as "Authorized Engineering Information" is designated similarly. Statements incorporating other auxiliary verbs such as "should," "may," etc. refer to the authorized engineering information and not to procedures required for compliance with the standard.

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

CAPACITOR SECTION
OF THE NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

MEMBER COMPANIES

ABB Power T&D Company, Inc.
Bloomington, IN 47402-0341

AVX Corporation
New York, NY 10022-1208

Cooper Power Systems
Franksville, WI 53126

General Electric
Fort Edward, NY 12828

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