NEMA WC*63.1 96 6470247 0509620 32T

NEMA STANDARDS PUBLICATION NO. WC 63.1

PERFORMANCE STANDARD FOR TWISTED PAIR PREMISE VOICE AND DATA COMMUNICATIONS CABLES

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

NEMA Standards Publication No. WC 63.1-1996

PERFORMANCE STANDARD FOR
TWISTED PAIR PREMISE VOICE AND DATA COMMUNICATIONS CABLES

Published by

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

© 1996 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 ii

Section 1 GENERAL

Scope 1
Referenced Standards 1

Section 2 TWISTED PAIR NOMINAL 100 AND 150 OHM CABLES

General 3
Materials and Mechanical Specifications 4
Electrical Specifications 5

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

The user's attention is called to the possibility that compliance with this Standard may require use of an invention covered by patent rights. By publication of this Standard, no position is taken with respect to the validity of this claim or of any patent rights in connection therewith. The patent holder has, however, filed a statement of willingness to grant a license under these rights on reasonable and non-discriminatory terms and conditions to applicants desiring to obtain such a license. Details may be obtained from the publisher.

This standard has been developed by the High Performance Wire and Cable Section of NEMA in close coordination between manufacturers, users, third party certifying agencies and others having specialized experience. The High Performance Wire and Cable Section of NEMA periodically reviews this standard for any revisions necessary to keep it up to date. Proposed revisions or comments should be submitted to:

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

This standards publication was developed by the Premise Wiring Subcommittee of the High Performance Wire and Cable Section of the National Electrical Manufacturers Association. Section approval of this standard does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the Premise Wiring Subcommittee had the following members:

Belden Wire & Cable Company—Richmond, IN
Berk-Tek, Inc.—New Holland, PA
BICC Brand-Rex Company—Willimantic, CT
CommScope Network Cable Division—Claremont, NC
Helix/Hi-Temp Cables, Inc.—Franklin, MA
Hitachi Cable Manchester, Inc.—Manchester, NH
Judd Wire Inc.—Turner Falls, MA
Lucent Technologies—Norcross, GA
Mohawk/CDT—Leominster, MA
Montrose/CDT—Auburn, MA
Nodx/CDT (Nortel/Northern Telecom)—Lachine, PQ Canada
Teledyne Thermatics—Elm City, NC

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 standard defines minimum electrical performance characteristics, material and mechanical specifications of premise wiring cables for voice and data applications. Definitions and applicable test methods are included.

The products covered in this Standard shall conform to the requirements of Part 68 of the FCC rules and regulations as well as the applicable article(s) of the *National Electrical Code* and/or other national and local codes and safety standards.

The performance requirements contained in this document are for cables as manufactured. The installed cable interconnect system may have different characteristics. The performance of the installed cable is outside the scope of this document.

This standard covers 100 ohm unshielded and shielded twisted pair and 150 ohm shielded twisted pair cables for voice and/or data communication systems.

1.2 REFERENCED STANDARDS

Copies of referenced documents may be obtained from the appropriate sources as follows.

American Society for Testing and Materials (ASTM)
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

ASTM B 3-90	*Soft or Annealed Copper Wire*
ASTM B 8-90	*Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft*
ASTM B 33-91	*Tinned Soft or Annealed Copper Wire for Electrical Purposes*
ASTM B 286-89	*Copper Conductors for Use in Hookup Wire for Electronic Equipment*
ASTM D 4566-94	*Standard Test Methods for Electrical Performance Properties of Insulations and Jackets for Telecommunications Wire & Cable*

Federal Communications Commission (FCC)
1919 M Street, N.W.
Washington, D.C. 20554

Code of Federal Regulations, Title 47, Telecommunications, Chapter 1-FCC, Part 68

Institute of Electrical & Electronic Engineers (IEEE)
445 Hoes Lane, IEEE Service Center
P.O. Box 1331
Piscataway, NJ 08855-1331

ANSI/IEEE 802.3 ISO/IEC 8802-3, Fourth Edition, 1993	*Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications*

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

Not for Resale

National Electrical Manufacturers Association (NEMA)
1300 North 17th Street
Rosslyn, Virginia 22209

NEMA WC 61-1992 — *Standard for Transfer Impedance Testing*

National Fire Protection Association (NFPA)
Batterymarch Park
Quincy, MA 02269

ANSI/NFPA 70-1996 — *National Electrical Code (NEC)*

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

UL 13-90 — *Standard for Power-Limited Circuit Cables*
UL 444-94 — *Standard for Communications Cables*

Insulated Cable Engineers Association
P.O. Box 440
South Yarmouth, Massachusetts

ICEA S-90-661 — *Individually Unshielded Twisted Pair Indoor Cables for Use in Communication Wiring Systems*

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

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
TWISTED PAIR NOMINAL 100 AND 150 OHM CABLES

2.1 GENERAL

This section covers requirements and performance characteristics of 100 ohm and 150 ohm paired cables. The NEMA Category designations for twisted pair designs and the highest referenced frequency for each category are described in Table 2-1.

2.1.1 Part Numbering System

The part numbers shall be of the following form:

WC 63-(Category)(AWG)(Coating)(PR)(Shield)(Drain)

Where:

Category = Character for NEMA Category as determined in Table 2-1
AWG = Character for conductor gauge size as determined from Table 2-2
Coating = Character for conductor coating. "B" for Bare Copper or "T" for Tinned Copper
PR = Number of pairs in cable (ie: 2, 4, 12, 25, etc.)
Shield = Character for type of shield as determined from Table 2-3
Drain = Character for drain wire. "D" if present or specified else null

Table 2-1
NEMA CATEGORY DESIGNATIONS

Type	Description
3	100 Ohm, 24 AWG or 22 AWG, Shielded or Unshielded, Specified at frequencies up to 16 MHz
4	100 Ohm, 24 AWG or 22 AWG, Shielded or Unshielded, Specified at frequencies up to 20 MHz
5	100 Ohm, 24 AWG or 22 AWG, Shielded or Unshielded, Specified at frequencies up to 100 MHz
A	150 Ohm, 22 AWG or 26 AWG, Shielded, Specified at frequencies up to 300 MHz

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
ALLOWABLE AWG SIZES AND STRANDING

Character	AWG Size	Stranding	Character	AWG Size	Stranding
A	22	Solid	F	24	7
B	24	Solid	G	24	19
C	26	Solid	H	26	7
D	22	7	J	26	19
E	22	19			

Table 2-3
ALLOWABLE SHIELDING TYPES

Character	Description
U	Unshielded
S	Individually shielded pair, foil
K	Individually shielded pair, braid
F	Overall shielded, foil
B	Overall shielded, braid

The following are examples of possible part numbers:

WC63-3AB2U: 100 Ohm, 16 MHz upper frequency, 22 AWG, bare copper, 2 pair, unshielded.
WC63-4ET4F: 100 Ohm, 20 MHz upper frequency, 22(19) AWG, tinned copper, 4 pair, overall foil shield.
WC63-5BB4U: 100 Ohm, 100 MHz upper frequency, 24 AWG, bare copper, 4 pair, unshielded
WC63-AHT4SB: 150 Ohm, 300 MHz upper frequency, 26(7) AWG, tinned copper, 4 pair, individually foil shielded pairs with an overall braid.

2.2 MATERIALS AND MECHANICAL SPECIFICATIONS

2.2.1 Conductors

Conductors shall conform to the requirements listed below except the minimum dimensions and maximum strand lay shall be in accordance with UL 444. Minimum elongation of solid conductors from a finished cable shall be in accordance with ICEA S-90-661.

2.2.1.1 Bare Copper Wire

Bare copper wire shall conform to soft or annealed wire in accordance with ASTM B3 except that the requirements for "Dimensions and Permissible Variations" shall be waived.

2.2.1.2 Tin-Coated Copper Wire

Tin-coated copper wire shall conform to soft or annealed wire in accordance with ASTM B33 except that the requirements for "Dimensions and Permissible Variations" shall be waived.

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

2.2.1.3 Stranded copper wire

Stranded bare or tin-coated copper wire shall conform to ASTM B8 or B286.

2.2.2 Insulation, Shield and Jacket

2.2.2.1 Material

The copper conductors shall be insulated with one or more layers of solid or expanded material. The core consisting of two or more conductors and other construction components shall be protected with an overall covering generally referred to as an "outer jacket." The insulation, jacket, plus other components such as core wrap, shield, and inner jackets should be suitable for the intended application environment. The outer jacket should be of a material that adequately protects the cable prior to, during, and after installation.

2.2.2.2 Mechanical, Physical, Dimensional, and Safety Considerations

The cable shall conform to the applicable requirements of UL 444. These will be determined primarily by the wide variety of insulation and jacket material choices. Additionally, the functional electrical characteristics as required by this standard will influence cable design parameters.

2.3 ELECTRICAL SPECIFICATIONS

2.3.1 Definitions

2.3.1.1 Resistance

2.3.1.1.1 DC Conductor Resistance

The resistance of any conductor is defined as the ratio of the voltage to the resulting current when the conductor is attached to the output terminals of a constant voltage, non-time varying (zero frequency) source.

2.3.1.1.2 DC Resistance Unbalance

The dc resistance unbalance between the two conductors of any pair is defined as:

$$R_{UB} = \frac{(R_{max} - R_{min})}{R_{min}} \times 100\%$$

Where:

R_{max} = The resistance, in ohms, of the conductor with higher resistance value
R_{min} = The resistance, in ohms, of the conductor with lower resistance value

2.3.1.1.3 Insulation Resistance

Insulation resistance is defined as the measured resistance between any single conductor and ground. All other conductors and shields, if present, in the cable are grounded.

2.3.1.3 Capacitance

2.3.1.3.1 Mutual Capacitance

Mutual capacitance of any pair is defined as the effective capacitance between the two conductors. The mutual capacitance is defined as:

$$C_m = C_{ab} + \frac{C_{ag} \times C_{bg}}{C_{ag} + C_{bg}}$$

Where:

C_m = Mutual capacitance

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

C_{ab} = The capacitance between conductor "a" and conductor "b" with all other conductors in the cable and the shield (if present) connected to ground (guarded)

C_{ag} = The capacitance between conductor "a" and all other conductors in the cable, the shield (if present), with conductor "b" connected to ground (guarded)

C_{bg} = The capacitance between conductor "b" and all other conductors in the cable, the shield (if present) with conductor "a" connected to ground (guarded)

2.3.1.3.2 Pair-to-Ground Capacitance Unbalance

The pair-to-ground capacitance unbalance of any pair is defined as:

$$C_{upg} = C_{ag} - C_{bg}$$

Where:

C_{upg} = Pair-to-ground capacitance unbalance

C_{ag} = The capacitance between conductor "a" and all other conductors in the cable, the shield (if present) with conductor "b" connected to ground (guarded)

C_{bg} = The capacitance between conductor "b" and all other conductors in the cable, the shield (if present) with conductor "a" connected to ground (guarded)

2.3.1.4 Characteristic Impedance

The complex characteristic impedance of any pair is defined as:

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

Where:

Z_0 = The complex characteristic impedance in ohms
R = The loop resistance in ohms/unit length
L = The loop inductance in henrys/unit length
G = The mutual conductance in siemens/unit length
C = The mutual capacitance in farads/unit length
w = The angular frequency in radians/sec.
j = an imaginary number defined as $j^2 = -1$(unitless)

2.3.1.5 Structural Return Loss

The structural return loss of any pair relates the complex input impedance to the complex characteristic impedance. It is defined as:

$$SRL = -20 \log_{10} \left| \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \right|$$

Where:

SRL = Structural return loss in decibels
Z_{in} = Complex input impedance in ohms
Z_0 = Complex fitted impedance in ohms

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

2.3.1.6 Input Impedance

The complex input impedance of any pair is defined as:

$$Z_{in} = \sqrt{Z_{open} \times Z_{short}}$$

Where:

Z_{in} = Complex input impedance in ohms
Z_{open} = Complex measured open circuit impedance in ohms
Z_{short} = Complex measured short circuit impedance in ohms

Note—The input impedance is used to derive the characteristic impedance.

2.3.1.7 Attenuation

The attenuation of any pair is defined as:

$$\alpha = 10\log_{10}\frac{P_1}{P_2} = 20\log_{10}\frac{V_1}{V_2}(dB)$$

Where:

α = The attenuation in decibels per unit length
P_1 = The input power in watts
P_2 = The output power in watts
V_1 = The input voltage in volts
V_2 = The output voltage in volts

2.3.1.8 Crosstalk

2.3.1.8.1 Near-End Crosstalk

Near-end crosstalk loss of any pair combination is defined as:

$$NEXT = 10\log_{10}\frac{P_{1N}}{P_{2N}} = 20\log_{10}\frac{V_{1N}}{V_{2N}}(dB)$$

Where:

NEXT = Near-end crosstalk loss in decibels
P_{1N} = The input power of the disturbing pair in watts
P_{2N} = The output power of the disturbed pair at the near end of the cable in watts
V_{1N} = The input voltage of the disturbing pair in volts
V_{2N} = The output voltage of the disturbed pair at the near end of the cable in volts

2.3.1.8.2 Power Sum Near-End Crosstalk

Power sum near-end crosstalk loss of any disturbed pair is defined as:

$$PSNEXT = 10\log_{10}\sum_{i=1}^{n}10^{(\frac{x_i}{10})}$$

Where:

PSNEXT = Power sum near-end crosstalk loss in decibels

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

x_i = Measured near-end crosstalk loss in decibels of the pair combination consisting of the disturbed pair, and the ith disturbing pair
n = number of disturbing pairs (the number of pairs in the cable minus one)
i = disturbing pair number

2.3.1.9 Transfer Impedance

The transfer impedance (Z_t) of the shield in an electrically short, longitudinally uniform cable is defined as the ratio of the longitudinal electromotive force induced in the disturbed circuit to the current flowing in the interfering circuit.

2.3.1.10 Phase Velocity

Phase velocity of any pair is defined as:

$$v = \frac{\omega}{\beta}$$

Where:
n = Phase velocity in meters/second
w = Angular frequency in radians/second
b = Phase constant in radians

2.3.1.11 Phase Delay Skew

Phase delay skew of any pair is defined as the difference in phase delay between any two pairs. Phase delay is the inverse of the phase velocity.

2.3.2 Test Methods

2.3.2.1 General

Unless otherwise specified below, measurements shall be in accordance with ASTM D 4566.

Measurements shall be performed on a cable sample which is a minimum of 100 m (328 ft) in length, unless otherwise specified.

The measurements of mutual capacitance, capacitance unbalance, characteristic impedance, SRL, attenuation, and NEXT should be performed on cable samples removed from the reel or packages and supported in an aerial span. Measurements performed on-reel or packaged, loosely coiled, or streched along a non-conducting surface that satisfy the performance requirements are acceptable. However, the aerial span method shall be the referee method.

2.3.2.2 Characteristic Impedance

Characteristic impedance shall be measured using Method 3 in Section 44 of ASTM D 4566.

2.3.2.3 Input Impedance

Input impedance shall be measured using Method 2 in Section 44 in ASTM D 4566.

2.3.2.4 Attenuation

The sample length shall exhibit no less than 3 decibels at the lowest frequency tested and no more than 50 decibels for applicable frequencies. More than one length may be required to test a full range of frequencies.

2.3.2.5 Transfer Impedance

The transfer impedance of a shielded cable shall be measured using the method outlined in NEMA WC 61.

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

2.3.2.6 Phase Velocity

The phase velocity shall be measured using the method outlined in Section 41 of ASTM D 4566. The phase velocity shall be determined by calculating the average of all phase delay values for all frequencies between 2 Mhz and the highest referenced frequency.

2.3.2.7 Phase Delay

Phase delay shall be determined from the phase velocity using the following equation:

$$t_d = \frac{100\,l}{V_p\,C}$$

Where:

t_d	=	time delay in ns/100 m [ns/328 ft]
l	=	reference length in meters (usually 100).
V_p	=	phase velocity as a percent of the speed of light in free space.
c	=	speed of light in free space in m/nsec (0.3 m/nsec).

2.3.2.8 Phase Delay Skew

The phase delay skew shall be calculated by determining the maximum difference in phase delay between all pairs.

2.3.3 Electrical Requirements for Category 3, Category 4, and Category 5 Cables

Table 2-10, Table 2-11, Table 2-12, Table 2-13, and Table 2-14 are included for reference only.

2.3.3.1 DC Resistance

2.3.3.1.1 The maximum dc resistance of 24 AWG conductors, solid or stranded, shall be 9.38 Ω/100 m (328 ft.) at or corrected to 20°C.

2.3.3.1.2 The maximum dc resistance of 22 AWG conductors, solid or stranded, shall be 5.91 Ω/100 m (328 ft.) at or corrected to 20°C.

2.3.3.1.3 The maximum dc resistance unbalance of any pair shall be 5%.

2.3.3.1.4 The minimum insulation resistance of any insulated conductor shall be 1500 MΩ × 100 m (328 ft.).

2.3.3.2 Capacitance

2.3.3.2.1 Mutual Capacitance

Mutual capacitance values are provided for information purposes only. The maximum mutual capacitance, measured at a frequency of 1 kHz, should be 6.6 nF/100 m (328 ft.) for Category 3 cables and 5.6 nF/100 m (328 ft.) for Category 4 or Category 5 cables.

2.3.3.2.2 Pair-to-Ground Capacitance Unbalance

The pair-to-ground capacitance unbalance of any pair shall not exceed 330 pF/100 m (328 ft.) for Category 3, Category 4, or Category 5 Cables when measured at a frequency of 1 kHz.

2.3.3.3 Characteristic Impedance

The characteristic impedance of any pair shall meet the requirements in Table 2-4.

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

Table 2-4
CHARACTERISTIC IMPEDANCE (Ohms)

Frequency (MHz)	Category 3	Category 4	Category 5
1.0–16.0	100 ± 15%	100 ± 15%	100 ± 15%
16.0–20.0	—	100 ± 15%	100 ± 15%
20.0–100.0	—	—	100 ± 15%

2.3.3.4 Structural Return Loss

The minimum structural return loss of any pair shall meet or exceed the values determined using Table 2-5 for all frequencies, from 1 MHz to the highest referenced frequency:

Table 2-5
STRUCTURAL RETURN LOSS (dB)

Frequency (MHz)	Category 3	Category 4	Category 5
1.0–10.0	12	21	23
10.0–16.0	12–10Log(f/10)	21–10Log(f/10)	23
16.0–20.0	—	21– 0Log(f/10)	23
20.0–100.0	—	—	23–10Log(f/20)

Where:

f = frequency in MHz

2.3.3.5 Attenuation

2.3.3.5.1 Solid Conductors

The maximum attenuation of any pair at or corrected to a temperature of 20°C, shall be less than or equal to the value determined using the following formula rounded to one digit after the decimal point for all frequencies from 0.772 Mhz to the highest referenced frequency.

$$\alpha(f) = k_1\sqrt{f} + k_2F + \frac{k_3}{\sqrt{f}}$$

Where:

a = attenuation in dB/100m (328 ft)
f = frequency in MHz
k_1 = Constant as defined in Table 2-6, below
k_2 = Constant as defined in Table 2-6, below
k_3 = Constant as defined in Table 2-6, below

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 2-6
COEFFICIENTS FOR ATTENUATION FORMULA

Conductor Gauge	24 AWG			22 AWG		
Coefficient	k_1	k_2	k_3	k_1	k_2	k_3
Category 3	2.320	0.238	0.000	1.810	0.250	0.140
Category 4	2.050	0.043	0.057	1.680	0.022	0.140
Category 5	1.967	0.023	0.050	1.670	0.020	0.100

The cable attenuation, for Category 4 and Category 5 cables, shall be verified at a temperature of 40 degrees Celsius and 60 degrees Celsius and shall meet the requirements of the formula above after adjusting the formula for temperature. The maximum attenuation determined using the above formula shall be adjusted at elevated temperatures using a factor of 0.4% increase per degree Celsius.

Table 2-10, Table 2-11, and Table 2-12 give attenuation values at specific frequencies in the band of interest for cables employing solid conductors. These values are for reference only and are derived from the above formula.

2.3.3.5.2 Stranded Conductors

The requirements for attenuation for cables employing stranded conductors shall be 20% higher than the values determined by the formula in 2.3.3.5.1 rounded to one digit after the decimal point.

2.3.3.6 Crosstalk

2.3.3.6.1 Near-End Crosstalk

The near-end crosstalk loss of any pair combination shall be greater than or equal to the value determined using the following formula for all frequencies from 0.772 MHz to the highest referenced frequency:

$$NEXT(f) = NEXT(0.772) - 15\log_{10}\left(\frac{f}{0.772}\right)$$

Where:

NEXT = Near-end crosstalk loss in dB
NEXT(0.772) = 43 dB for category 3 cables; 58 dB for category 4 cables; 64 dB for category 5 cables
f = frequency in MHz

2.3.3.6.2 Power Sum Near-End Crosstalk

The power sum near-end crosstalk loss of any pair, in cables employing more than four pairs, shall be greater than or equal to the value determined using the following formula for all frequencies from 0.772 MHz to the highest referenced frequency:

$$PSNEXT(f) = PSNEXT(0.772) - 15\log_{10}\left(\frac{f}{0.772}\right)$$

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

Where:

PSNEXT = Power sum near-end crosstalk loss in dB
PSNEXT(0.772) = 43 dB for category 3 cables; 58 dB for category 4 cables; 64 dB for category 5 cables
f = frequency in MHz

2.3.3.6.2.1 Calculation for Subgroups or Subunits

For cables with more than twenty-five pairs, the power sum near end crosstalk may be computed for each pair using only the pair combinations within the twenty-five pair binder group. In this case, subgroups within any twenty-five pair binder group shall be considered part of the twenty-five pair group and all twenty-five pairs shall be used in the power sum near end crosstalk computation for that binder group.

2.3.3.7 Transfer Impedance

The common mode transfer impedance for cables which contain individually shielded pairs or overall shield(s) shall be less than or equal to the value determined using the following formula for all frequencies from 0.772 MHz to the highest referenced frequency:

$$Z_t(f) = 37 + 4f + 4\sqrt{f} + 5\sqrt[3]{f}$$

Where:

Z_t = transfer impedance, in mW/m
f = frequency in MHz

2.3.3.8 Phase Velocity

The minimum phase velocity for any pair shall be as follows:

Frequency (Mhz)	Category	Phase Velocity (%)
4.0 to 16.0	3	58.5%
4.0 to 20.0	4	60.0%
4.0 to 100.0	5	60.0%

2.3.3.9 Phase Delay Skew

The maximum phase delay skew shall be 50 nanoseconds/100 m (328 ft) for frequencies from 4 MHz to the highest referenced frequency.

2.3.4 Electrical Requirements for Type A Cable

Table 2-14 is included for reference only.

2.3.4.1 DC Resistance

2.3.4.1.1 The maximum dc resistance of 22 AWG conductors, solid or stranded, shall be 5.6 Ω/100m (328 ft) at, or corrected to, 20°C.

2.3.4.1.2 The maximum dc resistance of 26 AWG conductors, solid or stranded, shall be 14.8 Ω/100 m (328 ft) at, or corrected to, 20°C.

2.3.4.1.3 The maximum dc resistance unbalance of any pair shall be 4%

2.3.4.1.4 The minimum insulation resistance of any pair shall be 15000 MΩ × 100m (328 ft).

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

2.3.4.2 Capacitance

2.3.4.2.1 Pair-to-Ground Capacitance Unbalance

The pair-to-ground capacitance unbalance of any pair shall not exceed 100 pF/100m (328 ft.) when measured at a frequency of 1 kHz.

2.3.4.3 Characteristic Impedance

The characteristic impedance of any pair shall meet the requirements in Table 2-6.

Table 2-6
CHARACTERISTIC IMPEDANCE (Ohms)

Frequency (MHz)	22 AWG	26 AWG
0.0096	270 ± 10%	390 ± 15%
0.0384	185 ± 10%	235 ± 15%
3 to 300	150 ± 10%	150 ± 10%

2.3.4.4 Structural Return Loss

The minimum structural return loss of any pair shall meet the requirements in Table 2-7 for all frequencies from 3 MHz to the highest referenced frequency.

Table 2-7
STRUCTURAL RETURN LOSS REQUIREMENTS

Frequency (MHz)	Structural Return Loss (dB)
3–20	25
20–300	$25–10 \log_{10} (f/20)$

Where:

f = frequency in MHz

2.3.4.5 Attenuation

The attenuation of any pair shall not exceed the requirements of the following formula of Table 2-8:

$$\text{Attenuation}(f) \leq k_o \sqrt{\frac{f}{4}}$$

Where:

k_o = 2.2 for 22 AWG Cables and 3.3 for 26 AWG Cables
f = frequency between 4 MHz and 20 MHz

$$\text{Attenuation}(f) \leq k_o \sqrt{\frac{f}{62.5}}$$

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

Where:

k_o = 9.75 for 22 AWG cables and 14.75 for 26 AWG cables
f = frequency between 20 MHz and 300 MHz

2.3.4.6 Near-End Crosstalk

The near-end crosstalk loss (NEXT) of any pair combination, shall be greater than or equal to the requirements of Table 2-9 for all frequencies from 0.0096 MHz to the highest referenced frequency.

Table 2-9
NEAR-END CROSSTALK REQUIREMENTS (dB)

Frequency (MHz)	22 AWG	26 AWG
0.0096 – 5	58.0	52.0
5–16	58.0–15 Log_{10} (f/5)	52.0–15 Log_{10} (f/5)
16–300	58.0–15 Log_{10} (f/5)	Not Specified

Where:

f = frequency in MHz.

2.3.4.7 Transfer Impedance

The transfer impedance requirements of 150 Ω, shielded cables are currently under study.

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 2-10
ELECTRICAL PERFORMANCE REFERENCE FOR 100 OHM, CATEGORY 3 CABLES

	Category 3*	
	24 AWG	22 AWG
Maximum dc Resistance @ 20°C (Ohms/100 m [328 ft])	9.38	5.91
Maximum dc Resistance Unbalance (%)	5	
Minimum Insulation Resistance (MΩ . 100 m [328 ft])	1500	
Maximum Mutual Capacitance of a Pair @ 1 kHz (nF/100 m [328 ft])	6.6	
Maximum Pair to Ground Capacitance Unbalance (pF/100 m [328 ft])	330	
Minimum Phase Velocity from 4 to 16 MHz (%)	58.5	
Maximum Phase Delay Skew from 4 to 16 MHz (ns/ 100 m [328 ft])	50	

Frequency (MHz)	Characteristic Impedance (Ohms)	Minimum Structural Return Loss (dB)	Maximum Attenuation** (dB/100m, [328 ft])		Minimum NEXT (dB)	Maximum Transfer Impedance*** m Ω / m
			24 AWG	22 AWG		
0.256	—	—	1.3	1.0	—	—
0.512	—	—	1.8	1.5	—	—
0.772	102 ± 15%	—	2.2	1.9	43	48
1.0	100 ± 15%	12	2.6	2.2	41	50
4.0	100 ± 15%	12	5.6	4.9	32	69
8.0	100 ± 15%	12	8.5	7.3	27	90
10.0	100 ± 15%	12	9.7	8.2	26	100
16.0	100 ± 15%	10	13.1	11.2	23	130

* Applies to shielded and unshielded cables
** Values for stranded conductors are 20% higher than the values shown in the table
*** Applies to shielded cables only

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 2-11
ELECTRICAL PERFORMANCE REFERENCE FOR 100 OHM, CATEGORY 4 CABLES

	Category 4*	
	24 AWG	22 AWG
Maximum DC Resistance @ 20°C (Ohms/100 m [328 ft])	9.38	5.91
Maximum DC Resistance Unbalance (%)	5	
Minimum Insulation Resistance (MΩ - 100 m [328 ft])	1500	
Maximum Mutual Capacitance of a Pair (nF/100 m [328 ft])	5.6	
Maximum Pair to Ground Capacitance Unbalance (pF/100 m [328 ft])	330	
Minimum Phase Velocity from 4 to 20 MHz(%)	60	
Maximum Phase Delay Skew from 4 to 20 MHz (ns/ 100 m [328 ft])	50	

Frequency (MHz)	Characteristic Impedance (Ohms)	Minimum Structural Return Loss (dB)	Maximum Attenuation** (dB/100, [328 ft])		Minimum NEXT (dB)	Maximum Transfer Impedance*** m Ω / m
			24 AWG	22 AWG		
0.256	—	—	1.1	0.9	—	—
0.512	—	—	1.5	1.2	—	—
0.772	102 ± 15%	—	1.9	1.5	58	48
1.0	100 ± 15%	21	2.2	1.8	56	50
4.0	100 ± 15%	21	4.3	3.6	47	69
8.0	100 ± 15%	21	6.2	5.1	42	90
10.0	100 ± 15%	21	6.9	5.6	41	100
16.0	100 ± 15%	19	8 .9	7.2	38	130
20	100 ± 15%	18	10.0	7.9	36	149

• Applies to shielded and unshielded cables
** Values for stranded conductors are 20% higher than the values shown in the table
***Applies to shielded cables only

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 2-12
ELECTRICAL PERFORMANCE REFERENCE FOR 100 OHM, CATEGORY 5 CABLES

	Category 5*	
	24 AWG	22 AWG
Maximum DC Resistance @ 20°C (Ohms/100 m [328 ft])	9.38	5.91
Maximum DC Resistance Unbalance (%)	5	
Minimum Insulation Resistance (MΩ - 100 m [328 ft])	1500	
Maximum Mutual Capacitance of a Pair (nF/100 m [328 ft])	5.6	
Maximum Pair to Ground Capacitance Unbalance (pF/100 m [328 ft])	330	
Minimum Phase Velocity from 4 to 100 MHz (%)	60.0	
Maximum Phase Delay Skew from 4 to 100 MHz (ns/100 m [328 ft])	50	

Frequency (MHz)	Characteristic Impedance (Ohms)	Minimum Structural Return Loss (dB) (Minimum)	Maximum Attenuation** (dB/100, [328 ft]) (Maximum)		Minimum NEXT (dB) (Minimum)	Maximum Transfer Impedance*** mΩ / m (Maximum)
			24 AWG	22 AWG		
0.256	—	—	1.1	1.0	—	—
0.512	—	—	1.5	1.3	—	—
0.772	102 ± 15%	—	1.8	1.6	64	48
1.0	100 ± 15%	23	2.0	1.8	62	50
4.0	100 ± 15%	23	4.1	3.5	53	69
8.0	100 ± 15%	23	5.8	4.9	48	90
10.0	100 ± 15%	23	6.5	5.5	47	100
16.0	100 ± 15%	23	8.3	7.0	44	130
20.0	100 ± 15%	23	9.3	7.9	42	149
25.0	100 ± 15%	22	10.4	8.9	41	172
31.25	100 ± 15%	21	11.7	10.0	39	200
62.5	100 ± 15%	18	17.1	14.5	35	339
100	100 ± 15%	16	22.0	18.7	32	500

* Applies to shielded and unshielded cables
** Values for stranded conductors are 20% higher than the values shown in the table
***Applies to shielded cables only

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 2-13
ELECTRICAL PERFORMANCE REFERENCE FOR 150 OHM, TYPE A CABLES

	Type A	
	22 AWG	26 AWG
Maximum DC Resistance @ 20°C (Ohms/100 m [328 ft])	5.60	14.8
Maximum DC Resistance Unbalance (%)	4	
Minimum Insulation Resistance (MΩ - 100 m [328 ft])	15000	
Maximum Pair to Ground Capacitance Unbalance (pF/100 m [328 ft])	150	

Frequency (MHz)	Characteristic Impedance (Ohms)		Minimum Structural Return Loss (dB) (Minimum)	Maximum Attenuation (dB/100, [328 ft])		Minimum NEXT (dB)		Maximum Transfer Impedance m Ω / m
	22 AWG	26 AWG		22 AWG	26 AWG	22 AWG	26 AWG	
0.0096	270 ± 10%	390±15%	—	0.3	0.6	58	52	T.B.D
0.0384	185 ± 10%	235±15%	—	0.5	0.7	58	52	T.B.D
3.0	150 ± 10%		25	—	—	58	52	T.B.D
4.0	150 ± 10%		25	2.2	3.3	58	52	T.B.D
8.0	150 ± 10%		25	3.1	4.7	55	52	T.B.D
10.0	150 ± 10%		25	3.5	5.2	54	48	T.B.D
16.0	150 ± 10%		25	4.4	6.6	50	44	T.B.D
20.0	150 ± 10%		25	4.9	7.4	49	43	T.B.D
25.0	150 ± 10%		24	6.2	9.3	48	42	T.B.D
31.25	150 ± 10%		23	6.9	10.4	46	40	T.B.D
62.5	150 ± 10%		20	9.8	14.8	42	36	T.B.D
100.0	150 ± 10%		18	12.3	18.7	38	33	T.B.D
300.0	150 ± 10%		13	21.4	32.3	31	25	T.B.D

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 STANDARDIZATION 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.

Definition of a Standard

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

(Standardization Policies and Procedures, p. 1)

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. 6)

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:

NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture.

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.

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, p. 5)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data or 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, p. 5)

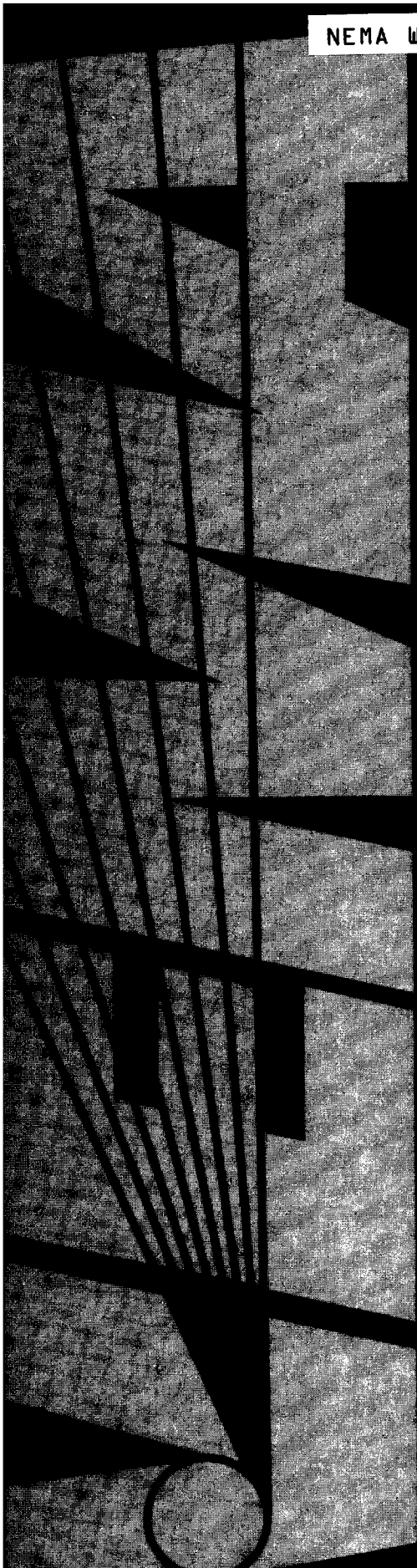
Identification of Status

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 or 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

NEMA WC*63.1 96 6470247 0509619 608



NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION • 1300 N. 17TH STREET • ROSSLYN, VA 22209

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

Not for Resale