NEMA Standards Publication No. HP 4-2000

Electrical And Electronic FEP (Fluorinated Ethylene Propylene) Insulated High Temperature Hook-Up Wire, Types KT (250 Volt), K (600 Volt), And KK (1000 Volt)

Published by:

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Foreword

This Standards Publication was developed by the NEMA High Performance Wire and Cable Section. This standard was developed to assure that these types of hook-up wire can be procured and that they will meet requirements associated with high reliability commercial electrical and electronic equipment in which it is used. Compliance with provisions of this Standards Publication is strictly voluntary and any certification of compliance is left to the discretion of the buyer and seller.

This Standard Publication was designed as a non-government standard for replacement of MIL-W-16878 FEP insulated wire specification sheets (/11, /12, and /13).

In the preparation of this Standard Publication, input of users and other interested parties has been considered. Inquiries, comments, and proposed or recommended revisions should be submitted to the concerned NEMA product Subdivision by contacting the:

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

This Standards Publication was developed by the NEMA High Performance Wire and Cable Section. Section approval of the 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 Section was composed of the following members:

Alcatel/Nexans—Elm City, NC
General Cable—Willimantic, CT
Cable USA Inc.—Naples, FL
Furon Company/Dekron Division—Akron, OH
Judd Wire Inc.—Turner Falls, MA
Quirk Wire Company Inc.—West Brookfield, MA
Radix Wire Company—Cleveland, OH
Raychem/Tyco Corporation—Menlo Park, CA
Rockbestos/Surprenant Cable Corp.—Clinton, MA

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Section 1
GENERAL

1.1 SCOPE

This Standards Publication covers specific requirements for FEP (Fluorinated Ethylene Propylene) insulated solid and stranded wire, designed for the internal wiring of high reliability electrical and electronic equipment. This Standards Publication addresses 250 volt (Type KT), 600 volt (Type K), and 1000 volt (Type KK) wire and permits continuous conductor temperature ratings of -65°C to +200°C with silver-coated or nickel-coated conductors and -65°C to +150°C with tin-coated conductors. These types of hook-up wire are used when the following requirements are called for:

- High temperature resistance
- Low temperature resistance
- Low dielectric constant
- Resistance to cleaning solutions or a variety of chemicals that may come in contact with either the wire or the equipment
- Good flexibility and flex life when stranded conductors are used

1.2 REFERENCED STANDARDS AND SPECIFICATIONS

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

B 3-95	Soft or Annealed Copper Wire
B 33-00	Tinned Soft or Annealed Copper Wire
B 286-95	Copper Conductors for Use in Hook-up Wire for Electronic Equipment
B 298-99	Silver-Coated Soft or Annealed Copper Wire
B 355-95	Nickel-Coated Soft or Annealed Copper Wire
B 452-93	Copper Clad Steel Wire for Electronic Applications
B 501-99	Silver-Coated Copper-Clad Steel Wire for Electronic Applications
B 559-93	Nickel-Coated Copper-Clad Steel Wire for Electronic Applications
B 624-99	High-Strength, High Conductivity Copper-Alloy Wire for Electronic Application
D 2116-97	FEP Fluorocarbon Molding and Extrusion Materials
D 3032-98	Methods of Testing Hook-Up Wire Insulation

American Society for Quality Control
611 E. Wisconsin Ave.
Milwaukee, WI 53202

ANSI/ASQC Z1.4	Sampling Procedures and Tables for Inspection by Attributes

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Electronic Industries Association
2500 Wilson Blvd.
Arlington, VA 22201

EIA-359-A-85 EIA Standard Colors for Color Identification and Coding

DODISS-Customer Service
Bldg. 4D
700 Robbins Ave.
Philadelphia, PA 19111-5094

MIL-STD-2223 Test Methods for Insulated Electric Wire

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209

WC 52-1985 (R1991) High Temperature and Electronic Insulated Wire-Impulse Dielectric Testing

WC 56-1993 (R2000) 3.0 kHz Insulation Continuity Proof Testing of Hook-Up Wire

1.3 RECOMMENDED USES OF WIRE TYPES

1.3.1 Type KT

Type KT wire is intended for use in low voltage, high temperature applications. It is considered suitable for use up to a maximum of 250 volts rms (root mean square) and/or for high frequency circuitry.

Wires having KT thin wall insulation are relatively fragile and can be damaged. They should not be used where a mechanical stress or an abrasive environment may exist.

1.3.2 Type K

Type K is intended for high temperature applications and is considered suitable for use at a maximum of 600 volts rms and/or for high frequency circuitry.

1.3.3 Type KK

Type KK is intended for high temperature applications and is considered suitable for use at a maximum of 1000 volts rms and/or for high frequency circuitry.

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1.4 PART IDENTIFICATION NUMBER (PIN)

The part numbers shall be of the following form:

HP4- (TYPE)-(AWG)(NUMBER OF STRANDS)(CONDUCTOR MATERIAL)(COLOR)

NEMA STANDARD

For FEP insulated wire

TYPE KT, K, KK
As described above

Example:
HP4-K-GAB9

FEP, Type K, 20 AWG, Solid, Silver Coated Copper, White

AWG NOMINAL CONDUCTOR SIZE

AWG	Letter	AWG	Letter	AWG	Letter	AWG	Letter
32	A	20	G	8	N	00	W
30	B	18	H	6	P	000	Y
28	C	16	J	4	R	0000	Z
26	D	14	K	2	S		
24	E	12	L	1	T		
22	F	10	M	0	U		

NUMBER OF STRANDS

Letter	Number Of Strands	Letter	Number Of Strands
A	1	R	817
B	7	S	1045
E	19	T	1330
G	37	V	1665
L	133	W	2109
P	665		

CONDUCTOR MATERIAL AND COATING

Letter	Conductor Material & Coating	Letter	Conductor Coating & Material
B	Silver-coated Copper (SCC)	E	Nickel-coated high-strength copper alloy (NCA)
C	Nickel-coated Copper (NCC)	F	Silver-coated copper clad steel (SCCCS)
D	Silver-coated high-strength copper alloy (SCA)	G	Nickel-coated copper clad steel (NCCCS)
		H	Tin-coated copper (TCC)

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COLOR (SEE PARA. 4.1)

Color	Number Designator	Color	Number Designator
Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet (Purple)	7
Orange	3	Gray (Slate)	8
Yellow	4	White	9

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Section 2
CONDUCTORS

2.1 CONDUCTOR MATERIALS

The base conductor material shall be composed of soft or annealed copper conforming to ASTM B 3, copper-clad steel conforming to ASTM B 452 Class 40A, or a copper alloy conforming to ASTM B 624. Conductor strands shall be individually coated. The addition of the coating material after stranding shall not be permitted.

2.2 CONDUCTOR COATINGS

2.2.1 Silver-Coated Conductors

Silver-coated conductors may be employed for applications up to conductor temperatures of 200°C. The silver coating shall be commercially pure silver and not less than 40 microinches in thickness for copper and copper alloys and not less than 50 microinches for copper-clad steel. The conductor shall be tested prior to stranding for continuity of coating and coating thickness in accordance with ASTM B 298 for silver-coated copper and copper alloy or ASTM B 501 for silver-coated copper-clad steel.

2.2.2 Nickel-Coated Conductors

Nickel-coated conductors may be employed for applications up to conductor temperatures of 200°C. The nickel coating shall be commercially pure nickel and not less than 50 microinches in thickness for all conductor materials. The conductor shall be tested prior to stranding for continuity of coating and coating thickness in accordance with ASTM B 355 for nickel-coated copper and copper alloy or ASTM B 559 for nickel-coated copper-clad steel.

2.2.3 Tin-Coated Conductors

Tin-coated conductors may be employed for applications up to conductor temperatures of 150°C. The conductor shall be tested prior to stranding for continuity of coating in accordance with ASTM B 33.

2.3 STRANDING

Stranding shall be in accordance with Table 2. The lay length of the outer layer shall be 8 to 16 times the maximum conductor diameter. All requirements for stranded conductors, not specified in Table 2, shall be in accordance with the applicable requirements of ASTM B 286.

2.4 MINIMUM WIRE DIAMETER

Minimum wire diameter shall be controlled by maximum dc resistance per Table 2.

2.5 CONDUCTOR SPLICES

Splices shall not be made in a stranded conductor as a whole: however, individual strands and solid conductors may be spliced. Splices shall be made by cold welding, electro welding or brazing with silver composition solder.

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Table 2
DETAILS OF CONDUCTORS*

Size (AWG)	Stranding	Single End Strand Dia. Nominal (inches)	Nominal CMA	Conductor Diameter Nominal (inches)	Conductor Diameter Maximum (inches)	Maximum DC Resistance of Finished Wire (Ohms/1000 Ft. at 20 °C) TCC	SCC	NCC	SCA	NCA	SCCCS	NCCCS	Alloy Breaking Strength Minimum (Lbs.)
32	1 x 32	0.0080	64	0.0080	0.0083	178	166	177	196	210	424	433	2.94
	7 x 40	0.0031	67	0.0093	0.0102	182	170	186	199	223	433	449	2.97
	19 x 44	0.0020	76	0.0094	0.0115	169	157	179	185	215	401	423	3.23
30	1 x 30	0.0100	100	0.0100	0.0103	114	106	110	124	131	270	273	4.62
	7 x 38	0.0040	112	0.0120	0.0129	108	100	110	118	132	256	265	5.02
	19 x 42	0.0025	119	0.0118	0.0140	106	98.6	112	116	135	251	265	5.16
28	1 x 28	0.0126	159	0.0126	0.0130	70.8	66.7	69.4	78.4	82.3	170	172	7.33
	7 x 36	0.0050	175	0.0150	0.0159	68.2	63.6	67.6	74.8	80.5	162	166	7.92
	19 x 40	0.0031	183	0.0146	0.0170	67.7	63.1	69.3	74.2	83.0	161	167	8.06
26	1 x 26	0.0159	253	0.0159	0.0164	44.5	41.9	43.6	49.2	51.7	107	108	11.7
	7 x 34	0.0063	278	0.0189	0.0198	42.6	39.7	42.2	46.7	50.3	101	103	12.7
	19 x 38	0.0040	304	0.0188	0.0215	40.1	37.3	41.0	43.9	49.1	95.2	98.7	13.6
24	1 x 24	0.0201	404	0.0201	0.0207	27.2	26.2	27.3	30.8	32.3	66.8	67.5	18.7
	7 x 32	0.0080	448	0.0240	0.0249	26.2	24.5	26.0	28.8	31.0	62.4	63.7	20.6
	19 x 36	0.0050	475	0.0235	0.0265	25.4	23.6	25.2	27.8	29.9	60.3	61.6	21.5
22	1 x 22	0.0253	640	0.0253	0.0261	17.2	16.5	17.2	19.4	20.4	42.2	42.6	29.6
	7 x 30	0.0100	700	0.0300	0.0309	16.7	15.6	16.2	18.3	19.2	39.7	40.1	32.3
	19 x 34	0.0063	754	0.0296	0.0330	15.9	14.8	15.7	17.4	18.7	37.7	38.5	34.4
20	1 x 20	0.0320	1024	0.0320	0.0330	10.7	10.3	10.8	12.2	12.8	26.4	26.6	47.3
	7 x 28	0.0126	1111	0.0378	0.0389	10.4	9.81	10.2	11.5	12.1	25.0	25.3	51.3
	19 x 32	0.0080	1216	0.0376	0.0415	9.76	9.10	9.68	10.7	11.5	23.2	23.7	55.9
18	1 x 18	0.0403	1624	0.0403	0.0415	6.78	6.52	6.79	7.67	8.04	16.6	16.8	75.0
	7 x 26	0.0159	1770	0.0477	0.0491	6.54	6.16	6.42	7.25	7.60	15.7	15.9	81.7
	19 x 30	0.0100	1900	0.0470	0.0515	6.22	5.79	6.03	6.81	7.15	14.8	14.9	87.8
16	1 x 16	0.0508	2581	0.0508	0.0523	4.26	4.10	4.27	4.82	5.06	10.5	10.6	112
	19 x 29	0.0113	2426	0.0531	0.0582	4.82	4.54	4.73	5.34	5.60	11.6	11.7	119
14	19 x 27	0.0142	3831	0.0667	0.0731	3.05	2.87	2.99					
12	19 x 25	0.0179	6088	0.0841	0.0922	1.92	1.81	1.88					
	37 x 28	0.0126	5874	0.0858	0.0908	2.01	1.89	1.97					
10	37 x 26	0.0159	9354	0.108	0.115	1.26	1.19	1.24					
8	133 x 29	0.0113	16983	0.161	0.175	0.701	0.661	0.688					
6	133 x 27	0.0142	26818	0.202	0.219	0.444	0.418	0.436					
4	133 x 25	0.0179	42615	0.266	0.277	0.280	0.263	0.274					
2	665 x 30	0.0100	66500	0.335	0.342	0.183	0.170	0.177					
1	817 x 30	0.0100	81700	0.378	0.382	0.149	0.139	0.144					
1/0	1045 x 30	0.0100	104500	0.410	0.431	0.116	0.108	0.113					
2/0	1330 x 30	0.0100	133000	0.477	0.486	0.0914	0.0851	0.0887					
3/0	1665 x 30	0.0100	166500	0.535	0.545	0.0727	0.0677	0.0705					
4/0	2109 x 30	0.0100	210900	0.601	0.635	0.0602	0.0537	0.0559					

*See Appendix A for Measurement and Calculation Data.

CMA - Circular Mil Area
TCC - Tin-coated copper
SCC - Silver-coated copper
NCC - Nickel-coated copper
SCA - Silver-coated high-strength copper alloy
NCA - Nickel-coated high-strength copper alloy
SCCCS - Silver-coated copper-clad steel
NCCCS - Nickel-coated copper-clad steel

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Section 3
INSULATION

3.1 GENERAL

The FEP insulating material shall conform to ASTM D 2116.

3.2 FEP INSULATION

The insulation shall be extruded concentrically about the conductor. The diameter of the insulated conductor shall be in accordance with Table 3 and as measured in accordance with paragraph 6.1.4.
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Table 3
DIMENSIONS-TYPE WIRES
(All Dimensions in Inches)

AWG	Wires	Stranding	Insulated Conductor Diameter (Minimum)	Insulated Conductor Diameter (Maximum)
32	KT	1 x 32	.018	.022
	KT	7 x 40	.020	.024
	KT	19 x 44	.020	.024
	K	1 x 32	.024	.032
	K	7 x 40	.026	.034
	K	19 x 44	.026	.034
	KK	1 x 32	.033	.041
	KK	7 x 40	.035	.043
	KK	19 x 44	.035	.043
30	KT	1 x 30	.020	.024
	KT	7 x 38	.022	.026
	KT	19 x 42	.022	.026
	K	1 x 30	.026	.034
	K	7 x 38	.028	.036
	K	19 x 42	.028	.036
	KK	1 x 30	.036	.044
	KK	7 x 38	.038	.046
	KK	19 x 42	.038	.046
28	KT	1 x 28	.023	.027
	KT	7 x 36	.025	.029
	KT	19 x 40	.025	.029
	K	1 x 28	.029	.037
	K	7 x 36	.031	.039
	K	19 x 40	.031	.039
	KK	1 x 28	.039	.047
	KK	7 x 36	.041	.049
	KK	19 x 40	.041	.049
26	KT	1 x 26	.026	.030
	KT	7 x 34	.029	.033
	KT	19 x 38	.029	.033
	K	1 x 26	.032	.040
	K	7 x 34	.035	.043
	K	19 x 38	.035	.043
	KK	1 x 26	.042	.050
	KK	7 x 34	.045	.053
	KK	19 x 38	.045	.053
24	KT	1 x 24	.030	.034
	KT	7 x 32	.034	.038
	KT	19 x 36	.034	.038
	K	1 x 24	.026	.044
	K	7 x 32	.040	.048
	K	19 x 36	.040	.048
	KK	1 x 24	.046	.054
	KK	7 x 32	.050	.058
	KK	19 x 36	.050	.058

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Table 3 (Continued)
DIMENSIONS-TYPE WIRES
(All Dimensions in Inches)

AWG	Wires	Stranding	Insulated Conductor Diameter (Minimum)	Insulated Conductor Diameter (Maximum)
22	KT	1 x 22	.035	.040
	KT	7 x 30	.040	.044
	KT	19 x 34	.040	.044
	K	1 x 22	.041	.050
	K	7 x 30	.046	.054
	K	19 x 34	.046	.054
	KK	1 x 22	.051	.060
	KK	7 x 30	.056	.064
	KK	19 x 34	.056	.064
20	KT	1 x 20	.042	.046
	KT	7 x 28	.048	.052
	KT	19 x 32	.048	.052
	K	1 x 20	.048	.056
	K	7 x 28	.054	.062
	K	19 x 32	.054	.062
	KK	1 x 20	.058	.066
	KK	7 x 28	.064	.072
	KK	19 x 32	.064	.072
18	K	1 x 18	.056	.066
	K	7 x 26	.064	.074
	K	19 x 30	.064	.074
	KK	1 x 18	.066	.076
	KK	7 x 26	.074	.084
	KK	19 x 30	.074	.084
16	K	1 x 16	.067	.081
	K	19 x 29	.073	.087
	KK	1 x 16	.077	.089
	KK	19 x 29	.083	.095
14	K	19 x 27	.088	.102
	KK	19 x 27	.098	.114
12	K	19 x 25	.107	.121
	K	37 x 28	.105	.119
	KK	19 x 25	.117	.133
	KK	37 x 28	.115	.131
10	K	37 x 26	.127	.141
	KK	37 x 26	.137	.153
8	K	133 x 29	.185	.199
	KK	133 x 29	.199	.219
6	KK	133 x 27	.286	.301
4	KK	133 x 25	.349	.369
2	KK	665 x 30	.395	.415
1	KK	817 x 30	.475	.495
1/0	KK	1045 x 30	.504	.524
2/0	KK	1330 x 30	.553	.577
3/0	KK	1665 x 30	.633	.657
4/0	KK	2109 x 30	.703	.727

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Section 4
WIRE IDENTIFICATION

4.1 CIRCUIT IDENTIFICATION

Circuit identification if required shall be accomplished by use of an insulation color in accordance with EIA-359-A-85 (R 1985). Colored stripe or band tracers on the insulation, and/or printed numbers or letters shall be permitted, in addition to the colored insulation.

4.1.1 Lay of Stripes

The length of lay of colored stripes shall conform to Table 4.

Table 4
Length of Lay of Stripes

Diameter Over Finished Wire (inch)	Length of Lay (inches, maximum)
0.000 to 0.083	1.00
0.084 to 0.110	1.50
0.111 and larger	2.00

4.2 IDENTIFICATION BY PRINTING

Identification by printing on the wire is available for Types K and KK wire for conductor sizes 22 AWG and larger. Print should be clear, legible and of a contrasting color to the insulation. Printing on Type KT wire is not recommended due to the thin wall construction. PIN printed on wire shall not include color designation. Identification marks shall not be applied by hot stamp marking or other methods which significantly penetrate the insulation.

4.2.1 Identification of Product

When specified, the printed identification shall be marked at intervals of 9 to 60 inches measured from the beginning of one complete marking to the beginning of the succeeding marking. Per paragraph 1.4, the identification shall consist of:

a. NEMA Standard for FEP (HP 4)
b. NEMA Type
c. Construction
d. Conductor material and coating AWG
e. Number of strands
f. Conductor material and coating
g. Color
h. Manufacturer's identification ("CAGE code")

Example:
HP4-K-GAB9 12345

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Section 5
PHYSICAL AND ELECTRICAL REQUIREMENTS

5.1 GENERAL

The physical and electrical requirements for Types KT, K, and KK wire shall be in accordance with this Section and Tables 2, 3, and 5. Testing shall be conducted in accordance with Section 6.

5.2 QUALITY CONFORMANCE INSPECTION OF FINISHED PRODUCT

5.2.1 Definitions

5.2.1.1 Inspection Lot

An inspection lot shall consist of all wire of the same part number, produced under essentially the same conditions, and presented for inspection at one time.

5.2.1.2 Unit of Product

The unit of product for determining lot size for sampling shall be the quantity of wire offered for inspection on one coil, one reel, or one spool, as applicable.

5.2.2 Sampling Inspection

All other tests shall use a sampling plan in accordance with special inspection level S-2 in ANSI/ASQC Z1.4.

5.3 WORKMANSHIP

The insulated wire shall be free of kinks, abrasions, and cracked or peeled surfaces. The wire should be a uniform and consistent product and should be free from defects which will adversely affect the serviceability of the product for the intended use, as described in Section 1.2.

5.4 MATERIALS CERTIFICATION

Suppliers shall maintain certifications that all materials used conform to the requirements in Section 2 and Section 3.

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Table 5
PHYSICAL AND ELECTRICAL REQUIREMENTS FOR TYPE KT, K, AND KK WIRES

Test	Requirements		
	KT	K	KK
Dimensional Inspection (See 6.1.4)	See Tables 2 and 3	See Tables 2 and 3	See Tables 2 and 3
Conductor Resistance (See 6.2.1)	See Table 2	See Table 2	See Table 2
High-Frequency Spark Test Voltage or	2.9 kV	4.6kV	5.7 kV
Impulse Spark Test Voltage (See 6.2.2)	4.0 kV	6.5 kV	8.0 kV
Heat Resistance & Dielectric Strength Peak Voltage (See 6.1.2 and 6.2.3)	1.5 kVrms	2.0 kV rms	3.0 kVrms
Insulation Tensile Strength (Minimum) (See 6.1.3)	2500 psi	2500 psi	2500 psi
Shrinkage (Maximum) (See 6.1.5)	0.125 inches	0.125 inches	0.125 inches
Concentricity (Minimum) (6.1.4.3)	70%	70%	70%
Insulation Elongation (Minimum) (See 6.1.3)	200 percent	200 percent	200 percent
Marking and Stripe Durability (See 6.1.6)	125 cycles (Minimum)	125 cycles (Minimum)	125 cycles (Minimum)

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Section 6
TEST PROCEDURES

6.1 PHYSICAL TESTS

Physical test on the conductor and insulated wire shall be made in accordance with the following procedures:

6.1.1 Test Temperature

Unless otherwise specified, physical tests shall be performed at a room temperature of 23 ± 2°C. The test specimens shall be kept at room temperature for not less than 30 minutes prior to the tests.

6.1.2 Heat Resistance

Specimens of insulated wire, each having a length of 12 inches plus the length required for winding on the mandrel, shall be placed in an air-circulating oven at 230 ± 2°C for silver or nickel-coated conductor wire and 180 ± 2°C for tin-coated conductor wires for 96 hours. They shall then be removed from the conditioning chamber and allowed to return to room temperature. The specimen shall be examined for cracks. The length of exposed conductor, if any, at each end of the specimen shall be considered as shrinkage of the insulation. In no case shall the shrinkage at either end exceed a maximum value of 1/8 inch.

Following the oven aging, specimens shall be wound tightly around a mandrel approximately but not more than, three times the overall diameter of the wire for five close turns and removed as a helical coil. Slight discoloration shall be considered normal and acceptable. The coiled sections shall then be subjected to the dielectric strength test, as specified in 6.2.3.

6.1.3 Insulation Tensile Strength and Elongation

The insulation tensile strength and elongation test shall be conducted in accordance with ASTM D 3032, Section 17, except that the rate of travel of the jaws shall be 2 inches minimum and 20 inches maximum per minute.

6.1.4 Dimensional Inspection

Using a micrometer or equivalent device capable of measuring to the nearest 0.0001 inch, determine the diameters of the conductor and insulation as described below.

6.1.4.1 Conductor Diameter

Remove the insulation for the specimen without damaging or distorting the conductor. Measure the outer diameter in at least three locations along the length of the stripped conductor. Each measurement shall consist of two micrometer readings taken 90 degrees from each other. For sizes 8 and larger, a circumferential measuring tape may be used. Report the average of the readings.

6.1.4.2 Insulation Diameter

Measure the outer diameter of the insulated wire in at least three locations along a 12 inch length of the specimen. Each measurement shall consist of two readings taken 90 degrees from each other. For sizes 8 and larger, a circumferential measuring tape may be used. Report the average of the readings.

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6.1.4.3 Concentricity

The concentricity of the insulation shall be measured on a cross section of the finished wire at 10 X magnification. In making the determination, the minimum thickness of the insulation shall be located and measured in the cross section. The maximum thickness of the insulation wall shall be located and measured in the same cross section. The percent concentricity is 100 times the ratio of the minimum measurement to the corresponding maximum measurement. Three cross sections shall be measured in each specimen. The failure of the concentricity of any cross section shall constitute failure of the entire specimen.

6.1.5 Shrinkage

Shrinkage of the insulation shall be measured using a 12 inch specimen with ends cut flush. Specimen shall be placed in an air-circulating oven at $230 \pm 3^{o}C$ for one hour. At the end of the conditioning period, allow specimen to cool to room temperature. Measure shrinkage on both ends. The maximum values shall not exceed the requirements in Table 5.

6.1.6 Marking and Stripe Durability

6.1.6.1 Specimen

The specimen shall consist of a piece of finished wire which shall have sufficient length for use in the test as specified in 6.1.6.3.

6.1.6.2 Special Apparatus

Apparatus shall include an abrading machine which shall support and secure the specimen such that it is straight and horizontal, and which shall abrade the specimen printed identification by means of a motor driven, transversely reciprocating steel pin. This steel pin shall have a diameter of 0.025 ± 0.001 inch where it abrades the specimen. The steel pin shall be horizontal and perpendicular to the specimen axis, shall ride along the top of the specimen and shall be weighted to bear down on the specimen with a force of 1 plus 1/16, minus 0 pound for wire size number 24 or larger, and 1/2 plus 1/8, minus 0 for wire size 26 and smaller. The pin shall be reciprocated at a rate of 60 ± 2 cycles per minute, such that the pin is drawn along the specimen for a distance of 3/8 plus 1/16, minus 0 inch in each direction (3/4 inch minimum total excursion) during each cycle. The abrading machine shall incorporate an automatic counter to total the number of cycles (a cycle is defined as one stroke forward and one stroke backwards across the specimen) the specimen is abraded by the steel pin during the test.

6.1.6.3 Procedure

The specimen shall be wiped with a clean, dry cloth to remove any lubricant or dirt, and shall be secured in the abrading machine with the specimen printed identification facing upwards, where it is to be abraded by the steel pin. The automatic counter shall be set initially to zero. The abrading machine motor shall then be turned on, allowing the steel pin to reciprocate and abrade the specimen printed identification until 125 cycles have been completed. This test shall next be repeated four more times (five times total), subjecting a fresh portion of the specimen printed identification to abrasion each time.

6.1.6.4 Observation

Specimen failure shall be construed if two or more abraded sites exhibit a complete line of obliteration.

6.2 ELECTRICAL TESTS

Electrical tests on the insulated conductors shall be made in accordance with the following procedures:

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6.2.1. Conductor Resistance

The dc resistance of the finished insulated wire shall be measured in accordance with MIL-STD-2223 Method 5003.

6.2.2 Spark or Impulse Test

Spark testing shall be conducted on 100 percent of all lengths of insulated wire per NEMA WC 52 or NEMA WC 56 at the voltages specified in the requirements of Table 5.

6.2.3 Dielectric Strength

One inch of insulation shall be removed from each end of the specimen and the conductor shall be attached to an electric lead. The specimen shall be immersed in tap water at 23 ± 5°C, except for the uninsulated ends. After immersion for 1 hour, the voltage specified in Table 5 at 60 Hz shall be applied between the conductor and an electrode in contact with liquid. The applied voltage shall be uniformly increased from zero to the specified peak voltage in 30 seconds, maintained at that voltage for a period of 1 minute, and uniformly reduced to zero in 30 seconds.

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Section 7
NOTES

7.1 PACKAGING REQUIREMENTS

Spools, reels, and packaging material(s) shall be sufficient to afford adequate protection against physical damage during shipment from the supply source to the customer. Any special packaging requirements must be specified in the ordering data.

7.2 LABELING

Part Identification Number (see 1.4)
Date (month, day, and year) of manufacture
Manufacturer's name or identifying mark

7.3 LENGTHS

Table 7 specifies the minimum lengths and quantity of lengths per spool or reel that are acceptable unless otherwise specified.

TABLE 7
Minimum Lengths For FEP Wire Constructions

AWG size	Percentage of Order	Length (feet) One Continuous Length	Max. No. of Lengths (Per Spool or Reel)	
			500-1000 ft.	1001-1500 ft.
32 to 22	25	50-75	3	5
	25	75-300		
	50	301 or more		
20 to 16	Unacceptable	Under 75	4	6
	20	75-100		
	50	101-300		
	30	301 or more		
14-10	Unacceptable	Under 50	5	7
	40	50-100		
	50	101-300		
	10	301 or more		
8 and larger	10	25-50	6	8
	70	51-100		
	20	101 or more		

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Section 8
ORDERING DATA

8.1 ORDERING INFORMATION

Purchasing documents should specify the following information:

1. Part Identification Number (see 1.4)
2. Packaging Requirements
3 Length Requirements
4. Quantity
5. Optional Identification (stripes, bands, tracers, printing, lot coding)

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Appendix A
Measurement and Calculation Data for Table 2

Minimum alloy breaking strength calculated based on the minimum diameter and tensile strength per ASTM B 624

Nominal CMA based on the square of the nominal single end diameter in mils times the number of ends.

Nominal conductor diameter based on nominal single end diameter per ASTM B 3, B 298, B 355, B 501, and B 559 which are all the same.

Three times the nominal single end diameter for 7 strand and 4.7 times for 19 strand was used. The OD for 19 strand was based on the unilay construction which is the most commonly used.

Maximum conductor diameter based on maximum single end diameters for nickel coated copper per ASTM B 355. Three times which represents the largest possible 19 and 37 strand diameter was used. A 19 X 7 true concentric rope which represents the largest diameter was used. Rope Stranding using bunched members maximum diameter is per ASTM B 286.

Maximum DC Resistance

SCC and NCC

- DC resistance based on formula in ASTM B 286 Note 2.

SCA

- DC resistance based on formula in ASTM B 286 Note 2 using a conductivity of 85% IACS minimum per ASTM B624

NCA

- DC resistance based on formula in ASTM B 286 Note 2 using a base conductivity of 85% IACS minimum per ASTM B 624 minus the effect of nickel per ASTM B 286.

Class 2: .0100" diameter and larger	81% IACS
Class 4: .0099" to .0050"	79% IACS
Class 7: .0049" to .0031"	76% IACS
Class 10: .0030" to .0020"	73% IACS

SCCCA

- DC resistance based on formula in ASTM B 286 Note 2 using a minimum conductivity of 39.2% IACS for type 40A per ASTM B 501

NCCCS

- DC resistance based on formula in ASTM B 286 Note 2 using the minimum conductivity for type 40A per ASTM B 559

Class 2: .0100" diameter and larger	38.2% IACS
Class 4: .0099" to .0050"	38.4% IACS
Class 7: .0049" to .0031"	37.8% IACS
Class 10: .0030" to .0020"	37.2% IACS

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