National Wire & Cable
Custom Cable Manufacturing

Wire & Cable Design Guide

Visit us online at:
www.NationalWire.com

CABLE DESIGNERS GUIDE
TABLE OF CONTENTS

CABLE GEOMETRY

Design Geometry of Multi-Conductor Cables

To those outside of the industry, the geometric design principles used in cable-making may not be apparent. To assist the customer in comprehensively discussing his needs with our factory engineering staff, we offer a brief guide to the major design options and tradeoffs available. A designers check list for specifying cable is offered elsewhere in this section. Not all are aware that for a given number of wires, several different geometry's may be used to form the wires into a helical cable bundle. Any of them may be justified, depending on cost, intended use and performance, or limitations of the manufacturers' equipment. National Wire & Cable Corp. has perhaps the widest and most versatile selection of modern cable-making equipment in the custom cable industry. We welcome your knotty design problems. Our 40 years of experience in wire & cable field are at your disposal.

Conductor Layup Geometry Options

A. Layer Upon layer

When all conductors have equal diameters they can be cabled in simple layers around a suitable core or central wire. Theoretically, every layer will contain 6 more wires than the preceding inner layer. This can be shown with a few round disks or coins. In practice this is not always true. Tolerances of insulation diameters enter the picture. Further, the conductors spiral in a helical path when formed into cable, and thus occupy an elliptically-shaped area around the circumference of the core. Typically, the eccentricity of the ellipse is about 5%. Thus about 19 conductors may fit, where 20 should if they were assumed to occupy a circular cross-section.

B. Subcabeling

For some constructions small groups of wires are helically cabled into subcables, which are then helically cabled to form the finished bundle. They may take these forms due to the end use requirements, (i.e.: where the design calls for twisted pairs, trios, etc.) or may do so mainly for the convenience of the lay-up of the required number of wires in an available site within the cable cross-section. Advantages of this method are improved flexibility of the cable, possible convenience in the intended end-use for the cable and the wide selection of geometry's it offers the designer. Disadvantages compared to the layer-on layer method are usually increased diameter and cost. Where there are hundreds of conductors in a cable, this method is often used to permit cabling on relatively small cabling machines.

C. Filling Interstices

When a cable contains a wide mixture of wire diameters, the larger wire sizes or subcables may be cable-formed so as to deliberately leave interstices large enough for the smaller wires to lie within tangent to two adjacent large wires, but not in contact with the inner layer or core.

D. Use of Fillers

Where a layer requires more wires than are available to properly fill all positions in that layer, round fillers are used to occupy the otherwise vacant sites. Their use ensures a round shape and provides adequate support for the outer layers of the construction. These may be spare wires, or of plastic rod, jute, or twisted yarns or tapes. They are often used as a core member, and may be deliberately designed into a layer to permit circumferential compression in a layer during flexing of the cable.

Cable Flexibility

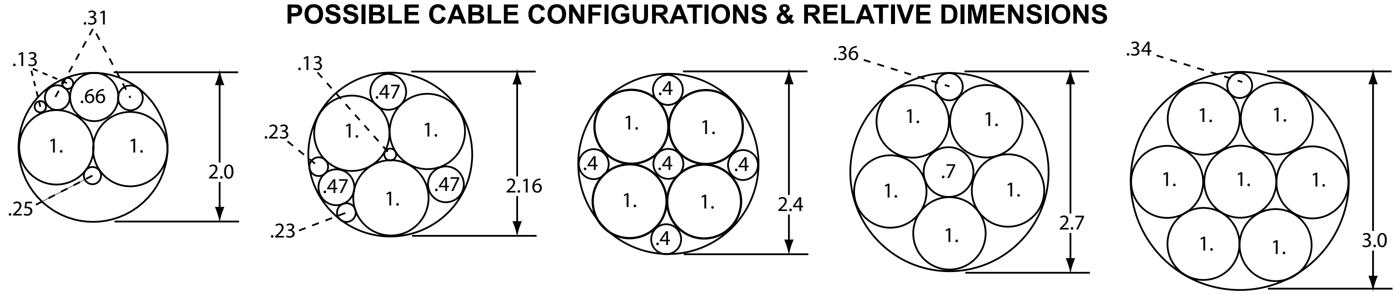
When a helically cabled bundle is flexed, each of the wires in a layer tend to slide along their helical path slightly with respect to the wires adjacent. If the wires are in firm contact around the entire layer, the friction between them inhibits the desired sliding action, and additional stiffness is imparted to the cable. Interlayer friction can also contribute to cable stiffness. In general, any stored radial forces which contribute to the friction should be avoided by proper design and manufacturing techniques. These forces may be from unduly snug jackets, braids, wraps, or serves.

Cable Flexibility Design Assistance

Due to the many variable factors which influence cable designs, we strongly recommend that the customer consult with our technical staff to ensure proper choice of dimensions and tolerances when he generates his own specification.

For design reference, a few of the common geometry's for subcabled and intersticed constructions are shown. The diameter of the large members is taken to be one unit of diameter. The size of the other members are shown as some decimal which relates their size to that of the large member. For layer-on-layer constructions, the table shows the factor by which the wire diameter can be multiplied to obtain the cabled bundle diameter.

POSSIBLE CABLE CONFIGURATIONS & RELATIVE DIMENSIONS



PAIR | TRIO | QUAD | QUINT | 6 AROUND 1

DIAMETER OF HELICALLY CABLED BUNDLES*

TO FIND THE CABLED DIAMETER OF A LAYER-ON-LAYER CONSTRUCTION, MULTIPLY THE DIAMETER OF A WIRE BY THE FACTOR SHOWN.**

No. of Conductors	Diameter Factor	No. of Conductors	Diameter Factor	Number of Conductors	Diameter Factor	Number of Conductors	Diameter Factor
-	-	13-14	4.4	34-37	7.0	64-67	9.7
2	2.0	15-16	4.7	38-39	7.3	68-73	10.0
3	2.16	17-19	5.0	40-42	7.7	74	10.1
4	2.4	20	5.3	43-47	8.0	75-78	10.4
5	2.7	21-22	5.7	48	8.1	79-83	10.7
6-7	3.0	23-26	6.0	49-51	8.4	84-89	11.0
8	3.7	27	6.1	52-55	8.7	90-93	11.3
9-11	4.0	28-30	6.4	56-60	9.0	94-98	11.7
12	4.1	31-33	6.7	61-63	9.3	99-105	12.0

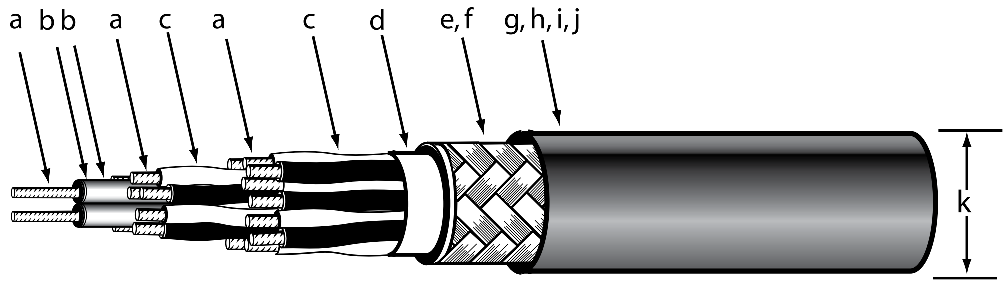
* All conductors are the same diameter

** (these factors are typical for standard helical cabling prectices; slight variations may occur on certain combinations)

HOW TO SPECIFY CABLE

Custom Cable Design Guide

If you plan to specify a special cable, we highly recommend a call to our "user Friendly" technical staff who can help speed you over the bumps.



In the absence of your own cable specification, the following checklist will assist you to completely specify the cable you want:

A. Number and gauge of conductors.
B. Specification type of wire (military or commercial).
C. Coding of conductors or subcables, striping or numbering, if any.
D. Tape barrier, used as first mechanical protective layer. Can be of Vinyl, Mylar, Tedlar, Polyethylene, or paper-fiberglass laminates.
E. Type of electrical shielding or mechanical armor.
F. % coverage required for electrical shielding
G. Type of outer jacket material.
H. Color of outer jacket, sheath markings.
I. Wall thickness of outer jacket.
J. Necessary physical or environmental requirements, see below.
K. Minimum and maximum overall diameter.

Physical Requirements

1. Length, tolerance; Diameter, tolerance.
2. Overall tensile strength, if applicable.
3. Weight limitations.
4. Minimum bend radius.

Environmental Requirements

1. Minimum and maximum operating temperatures.
2. Physical abuse: terrain, degree of movement of flexing, possible sudden impacts or pressures, etc.
3. Surrounding medium: water, oil, sunlight, ice, fuels, air, etc.

Electrical Requirements

1. Voltage rating of the conductor insulation.
2. Maximum current expected in the conductors.
3. Amount of electrical or magnetic shielding required.
4. Capacitance requirements.

HOW TO SPECIFY CABLE

Insulated Conductors

Specify quantity, gauge, stranding and insulation type for the conductors. Allowance of 10% spares is a common practice.

Preferably suggest an agency specification for the wires. (i.e.: UL, CSA, MIL and their proper type or style no.)

You may need a MIL reference to preferred wire types and jacket materials in various applications and environments.

Fillers

Fillers are used in lieu of a wire to fill space in a cable bundle so that it can retain its controlled shape and geometry. Their use promotes roundness and uniform flexibility.

Preferable fillers are plastic rods, tapes, or fibers, having physical properties similar to those of the wire insulation. Round glass-fiber braid can be used for high temperature applications. Fibrillated polypropylene is commonly used; cotton or jute is used less frequently.

Cables (within the main cable)

Individually cabled groups of wires within the cable may be referred to as sub-cables.

The constructional details of sub-cables should be just as complete as the main cable in which they are used. (i.e.: wire details, cabling, coding, shields, jacketing.)

Sub-cabling permits neat and simple formation of branch legs from the main cable and can be used to aid in identifying wire groups.

Subcables may be individually jacketed. Jackets may be solid colors, or may be color-striped over solid colors.

Cabling

The purpose of helical twist used in cabling the wires into a round bundle is twofold. It holds the wires in a unit, and it will act to neutralize the tension and compression forces which occur in the wires each time the cable is bent or flexed. Since most cables use stranded wires the cable forming must be done without untwisting the strands of the individual insulated stranded wires. This requires very special machinery, not just a drill motor.

Suggested wording: “Cabling shall be done on a tubular or planetary-type helical cabling machine in such a fashion that no residual twist is introduced into the individual cable members.”

The axial distance per turn is called the lay length. The lay length should be between 8 to 16 times the pitch diameter of that layer of wires. (Pitch diameter is measured from center-to-center of diametrically opposed wires in a given layer.)

Although the rotation direction may be the same for all layers of wires opposite directions of rotation for each layer in a cable is usually preferred and is called contra-helical construction.

Overall RFI Shielding (Over the cabled bundle of wires)

1. *Metal-Foil Faced tape RFI shields*

The lowest-cost, lightest and least effective shield method. Can be applied single or double-sided, in single or multiple layers. Usually applied in contact with an uninsulated “drain” wire used for connection of shield. Usually made with aluminum or copper metal foil glued to a thermoplastic polyester (Mylar) backing, the most common thickness’ of material are 0.00035” of metal foil and 0.0005” of backing tape, plus perhaps 0.00015” of glue for finished thickness of 0.001 “ . NWC normally uses a heavier backing (0.001”) for a total thickness of 0.0015” to avoid shielding degradation. Shield performance will degrade if cable handling causes tape to deform, or stretch so that metal begins to flake or crack. Cable flexibility is reduced slightly when a foil shield is added.

2. *Braided RFI shields*

The most common and perhaps the most durable cable shield is a braided tubular shield made of small copper wires. Wire sizes range from #38 to #32 AWG. A braid is the standard coaxial cable outer conductor. It may be applied in one or more layers. In conjunction with metallic tape or foils, performance becomes very good. Braiding is a continuous operation, any desired length can be made. A braid is machine-formed directly onto the cable as contra-helical interlocking spirals of groups of fine wires. The effectiveness of the shield braid depends on how well it covers up the surface of the cable. A minimum coverage requirement of 90% of the cable surface is common. Machinery limitations make coverage in excess of 96% impractical for a single-layer braid. For braids that must “push-back” or swell easily, the braid angle should be specified. We recommend angles between 20 and 38 degrees for that service. Various methods of shielding can be combined for optimum RFI protection. See “Shielding Effectiveness” elsewhere in this section.

Outer Jacket/Sheath

The choice of outer cable covering material is usually a compromise between cost, agency recognition/ratings, flexibility and durability.

A chart of relative properties is shown in Table A.

A thin-wall jacket is usually most flexible; however it can be prone to wrinkle at tight bends, and often shows more “wireform” of the underlying cable surface.

For plastic jacketed cables, typical wall thickness is 10% of the unjacketed diameter or 0.010” minimum. Cable jacket walls below 0.010” are not recommended. Maximum walls rarely need to exceed 0.125” in plastics, or 0.250” in rubbers.

Some agencies (UL, CSA) have their own preferred wall sizes which must be met to obtain their sanction for their stated use.

Type	Flexibility	Abrasion	Weathering	Temp F	Burial
Vinyls	Better	Better	Good	-40 +221	Good
Neoprene	Best	Best	Better	- 65 +180	Better
Polyethylenes	Good	Good	Best	-65 +160	Best
Polyurethane	Better	Best	Better	-65 +160	Better
TPR	Best	Good	Good	-65 +125	n/a

Colors

Cable sheath plastic compounds can be pigmented nearly any color, and are often color-matched to customer requirements. However, nearly all materials will discolor in sunlight or ultraviolet. Use of carbon-black pigment is very common as it readily makes the jackets opaque to UV and sunlight. Best to supply your own color sample for matching if not using black. Color samples preferably should be of the same material as the jacket compound. Specify if color must be correct for both fluorescent and daylight.

Jacket Markings

Almost any legend of your choice can be indented or ink marked continuously onto the jacket.

Agency Specifications

Contact us for a list of wire & cable specifications from various agencies.

Details of cabling design are available elsewhere in this section under “Designer’s Guide on Cable Geometry.”

BASIC INTRODUCTORY INFO

Electrical Capacitance

Electrical capacitance exists between each conductive surface in a cable and all other conductive surfaces in and around the cable An understanding of the relative amount of capacitance to be expected in a cable is helpful in specifying cable and designing terminal equipment for the cable to be used. Although capacitance in a cable may have negligible effect on DC or 60 cycle AC cable circuits used for power or control, it does affect higher frequency AC voltages.

Charge on Conductive Surfaces

Elementary electron theory states that the electron is the basic unit of negative electric charge; that a large charge is simply a large collection of electrons. The more electrons that are concentrated on a surface, the larger the electric charge on that surface. Positively charged surfaces may be regarded as having a deficiency of electrons. Charge is measured in coulombs. One coulomb consists of many trillions of electrons. Since they repel each other, a collection of electrons will distribute over a surface.

Current

We can force an exchange of charge (electrons) between two conductive surfaces if we connect any source of voltage, such as a battery, between them. Since electrons in motion constitute an electric current, flows off one surface through the battery onto the other, until the repulsion of charges being forced onto the surfaces equals the forcing voltage. When the battery is removed, a voltage equal to that of the battery exists between the surfaces due to the stored charge. If the voltage source is AC, the charge exchange occurs each half cycle. The voltage source thus must handle this charging current in addition to any other current which may pass through circuitry connected to the two surfaces.

Capacitance

This behavior of charge on surfaces is termed capacitance. Capacitance may be defined as the ratio of voltage between two surfaces, divided by their difference in charge; and is measured in units called farads. Capacitors, or condensers, are sets of surfaces deliberately arranged to control the capacitance between them. Shielded wires and cables also have capacitance between the conductors and shields which should be considered in their design and application. Commonly used values of capacitance are microfarads (mfd) or (10-6 fd) and picofarads (pf) or (10-12 fd).

Dielectrics

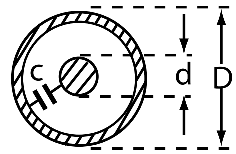
The spacing or insulating material between two surfaces of a capacitor is called a dielectric. It may be vacuum, air, or one of many insulating materials. With the exception of gases, all insulating materials increase the capacitance between the surfaces. The term dielectric constant is used to show how large this effect is for various materials. If the space between two surfaces is filled with a material having a dielectric constant of 2, then the capacitance between the surfaces will be 2 times greater than it would be for an air or vacuum dielectric.

Wire Insulation

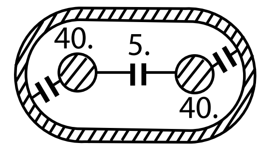
Not all dielectrics are suitable for use on wire and cable. The more commonly used insulation's are listed in Table A. Most wire insulation choices are based on a compromise among cost, electrical performance, and the physical and chemical properties required for the application. With the exception of Polytetrafluoroethylene (PTFE) and some polyolefins, most wire insulation's exhibit appreciable increases in their dielectric constant and insulation leakage with increasing temperature or frequency. This may make them undesirable for use where the capacitance, characteristic impedance or the leakage must be constant, such as in coaxial cable or instrumentation cables.

Geometry

The shape, diameter and spacing of the conductors and shields determine the capacity between them. Coaxial cables are a special application version of a single shielded conductor and may be treated in the same way.



Coaxial Conductor FIG 1.



Shielded Pairs FIG 2.

Coaxial Wires (Fig 1)

The capacitance per foot between a single insulated wire and a shield around it is:

$$C = \frac{(7.36) \times (e)}{Lg_{10}\ (D/d)} \text{ mmfd per foot}$$

...where e is the dielectric constant of the insulation between wire and shield; and D/d is the diameter ratio of shield ID to conductor OD. The only way in which the capacitance can be selected is by choice of insulation having a low dielectric constant, or by choosing a suitable value of D/d.

Shielded Pairs (Fig 2)

Shielded pairs have three capacitance's involved which combine to produce the effective wire to wire capacitance. Fig. 2 illustrates these capacities. Since the wire-to-shield capacitance's of each conductor are essentially in series, the effect of the two 40, mmfd capacitance's is to produce an apparent 20 mmfd between the two wires in addition to the 5. mmfd which will exist whether the shield is present or not. Thus the effective capacitance is 20. + 5. = 25. mmfd./ft from wire to wire.

(Ref. to Mil-C-17.)

Multi-Conductor Cable Bundles

The capacitance from a wire to all else in a large cable bundle of identical wires may vary widely depending on insulation and geometry. In general, however, it will have values ranging from 40. to 65. mmfd/ft for PVC insulation (where C=4.), and will vary from this for other materials. Conductors in the outer layer of a cable bundle which is overall-shielded will tend to have a higher capacitance than those closer to the bundle center. Typical variation for PVC' insulated wires will be a 15-20% rise in capacitance for conductors in the layer closest to the overall shield.

BASIC INTRODUCTORY INFO

Inductance

When current flows in a wire it creates a magnetic field about the wire, which generates voltages along the same wire as the current changes. These opposing voltages act to limit the rate at which the current can change. This effect is termed inductance and is measured in units called henrys. The self inductance of a round straight copper wire is on the order of .4 micro-henry/ft, and is relatively unaffected by diameter or length of wire. The self inductance of twisted pairs of wires is on the order of .08 micro-henry/ft; while the mutual inductance of a coaxial construction is .14 Lg10(D/d) micro-henrys/ft.

Signal Delay in Cables

Mechanical Delay

The electronic systems designer should consider possible problems which may arise due to cable delay. For instance, in a multi-conductor cable of coax, the coax in the center of the bundle will be shorter than those in the outer layers by 4% to 6%, which mechanically can introduce delay in the signals traveling the long path.

Dielectric Delay

Although radio waves travel at the speed of light in free space or in air, this speed is much less when the wave is guided through coax or other shielded cables, where the electric field is contained in an insulator other than air.

Suppose that a radio-frequency sine-wave signal generator is connected to both an antenna and a 1000 foot length of coaxial cable, so that its signals will be launched simultaneously into both, and we go to the far end of the cable to see which arrives first.

When the generator is keyed on, the signal from the antenna arrives first, traveling at the speed of light in air, taking about one microsecond to make the trip.

Shortly thereafter, the same identical signal will arrive at the end of the coax cable, having taken longer to travel the same distance. It did not travel as fast, so its arrival at the end of the cable was “delayed” compared to the arrival of signal from the antenna.

TABLE A

Insulation Type	Dielectric Constant “e”	Propagation of Velocity %	Transit Time Micro/Sec/1000ft
Air	--****	Nom 95.0%****	1.06****
Polyethylene	2.26	65.9%	1.54
Polytetrafluoroethylene (PTFE) (TFE & EEP)	2.0	70.0%	1.45
Polypropylene	2.1	69.0%	1.47
Foam Polyethylene	1.55	80.0%	1.27
polyvinylchloride	4.0***	50.0%	2.03
Nylon (#610)	3.0**	57.8%	1.76
Neoprene	5.0***	44.6%	2.28
Rubber (Buna S)	2.9***	58.7%	1.73
Rubber (Butyl)	2.35***	65.3%	1.56
Silicone Rubber (SE972)	3.16***	56.3%	1.80

The velocity of a wave in a coax is usually expressed as a percentage of the velocity of light. For instance, a polyethylene insulation gives a “propagation velocity” of 65.9% of light velocity. This is sometimes expressed as a velocity factor of .659.

Characteristic Impedance

A transmission line such as a coaxial cable or shielded pair can be considered as a wave-guiding device in the broad sense. The relative amplitudes of the electric and magnetic fields due to a signal within the cable are determined by the capacitance and inductance per unit length of cable (assuming no reflections from the load.)

The characteristic impedance (Z) is the ratio of the two fields, or

$$Z = E/H = \sqrt{L/C}$$ where C and L are farads and henrys

Another equation for finding the value of Z is:

$$Z = \frac{101600}{(C)\ (\%\ V.P.)}$$

where C is in pf/ft and V.P. is the propagation velocity expressed in percent.

The resistance of the conductors and shield attenuates the signal in a transmission line, but at radio frequencies has little effect in determining the characteristic impedance.

Pulse Cables

Cables designed for transmission of pulses for digital signals have carefully controlled surge impedances and capaticance. Generally they are 93 to 120 ohm constructions. A series of these for general use are shown in the instrument cable section.

Reference Books

Radio Engineers Handbook; Terman; McGraw-Hill
Pulse, Digital, & Switching Waveforms; Millman & Taub; McGraw-Hill
Reference Data For Radio Engineers; I. T. & T. Corp.; Stratford Press

Additional Information

National Wire & Cable Corp. invites our inquiry about special-purpose shielded cable, whether coaxial or multi-conductor.

National is prepared to discuss your particular needs, provide design information and fabricate cable to meet your specifications.

FOR TABLE A:
* One microsecond is one millionth of a second
** Susceptible to changes due to humidity. Absorbes moisture
***Dielectric constant varies widely with frequency. Many different values of dielectric constant may be obtained since the materials are a blend of filler and plasticizers with the base material, all of which have differing values of e.
****varies depending on the method used to support the center conductor of the cable. Inductance of shield and conductor linit upper value to about 96%.

Accelerator - A chemical additive which hastens the chemical reaction under given conditions, known also as a promoter.

Acceptance Test – A test made to demonstrate the degree of compliance with specified requirements.

Adhesive - A material capable of holding other materials together by surface attachment.

Aging – The change in properties of a material with time under given conditions.

Ambient Temperature – The temperature of a surrounding cooling medium, such as gas or liquid, which comes into contact with heated parts of an apparatus.

Angle of Advance - The angle between a line perpendicular to the axis of the cable and the axis of any one member or strand of the braid.

Annealed Wire – Wire which has been softened by heating. Sometimes referred to as soft drawn wire.

Armored Cable – A cable covered with a heavy outer braid of metal or spiral steel tapes for the purpose of mechanical protection.

Attenuation – The power drop or signal loss in a circuit, expressed in decibels, db.

AWG – American Wire Gauge. The standard for copper wire sizes. The diameters of successive sizes vary in geometrical progression.

B and S Gauge – Brown and Sharpe wire gauge where the conductor sizes ruse n geometrical progression. Adopted as the American Wire Gauge standard.

B.C. – Abbreviation for bare copper.

Blown Jacket – The common term given to an outer covering of insulation of a cable, that was applied by the controlled inflation of the cured jacket tube and the pulling of the cable through it.

Bond Strength – The amount of adhesion between bonded surfaces.

Braid – A woven protective outer covering over a conductor or cable. It may be composed of any filamentary materials such as cotton, glass, nylon, tinned copper, silver, or asbestos fibers.

Braid Angle – The angle between the axis of the cable and axis of any one member or strand of the braid. (Also known as Angle of Advance).

Breakdown (Puncture) – A disruptive discharge through insulation.

Breakout – A breakout is the common name given to the exit point of a conductor or number of conductors from a cable of which they are a part. This point is usually harnessed or sealed with some synthetic rubber compound.

Buna Rubber – A synthetic rubber made by polymerization of butadiene. Buna-N is a copolymer of butadiene and acrylonitrile (C3 H3 N3). Buna-S is a copolymer of butadiene and styrene.

Bunched Lay – In a bunched lay conductor or cable, the stranded members are twisted together in the same direction without regard to geometrical arrangement.

Capacitance (Capacity) - that property of a system of conductors and dielectrics which permits the storage of electricity when potential differences exist between the conductors. Its value is expressed as the ratio of a quantity of electricity to a potential difference, in farads (microfarads). A capacitance value is always positive.

Cavity – Depression in a mold.

Chromel-Alumel – Two alloys used in forming one type of thermocouple pair. Chromel is primarily an alloy of chrome and nickel, and Alumel an alloy of Aluminum, nickel, manganese, and silicone.

Circular Mil – A circular mil is a unit of area equal to Pi 4 of 78.54 percent of a square mil. The cross-sectional area of a circle in circular mils is, therefore, equal to the square of its diameter in mils. A circular inch is equal to 1,000,00 circular mils.

Coax – Abbreviation for coaxial cable. A single solid or stranded conductor over which is extruded a dielectric material. An over-all RF Shield of wire braid. Mylar-backed foil, or metal tubing is added over the inner dielectric materials with an outer sheath of dielectric material extruded over the shield to form a protective covering.

Cold Bend – Normally used with reference to a test. Cold Bend Test, which is a procedure whereby a sample of wire or cable is attached to a mandrel within a cold chamber, and when a specified temperature is reached, the wire or cable is wound around the mandrel a given number of turns at a given rate of speed. The sample is then removed and examined for defects or deteriorations. In the materials construction.

Cold Flow – See Creep.

Cold Molding – Shaping at room temperature and curing by subsequent baking.

Color Coding – Color coding is the application of a colored jacketing material on the conduction wire. Also color coding may be accomplished by the application of helically striped color on the outer surface of a jacketed wire.

Color Shades – These are the basic 12 colors as specified in MIL-STD-104, within certain limits of light and dark as shown on the color chips accompanying the standard specification. In the case of synthetic or rubber insulation, Polychloroprene (Neoprene) nylon or compound filled tapes for circuit identification, somewhat wider limits will be permitted in color shades provided all colors in the cable are easily distinguishable from each over.

Compression Molding – A method of molding thermosets. Compound (usually preheated) is placed in an open mold, is closed, and heat and pressure applied until material is cured. This process can also be used with synthetic rubber materials.

Compressive Strength – Crushing load at failure divided by the original sectional area of the specimen.

Concentric Lay – A concentric lay conductor or cable is composed of a central core surrounded by one or more layers of helically wound strands or insulated conductors.

Concentric Stranding – Stranding in which the individual filaments are spiraled in layers around a central core. As a general rule, each layer after the first has six more strands than the preceding layer and is applied in a direction contrahelical of the layer under it.

Condensation – A chemical reaction in which two or more molecules combine resulting in a molecule of greater density. For example, water vapor condenses to form water.

Conductor – A conductor is a slender rod or filament of drawn metal of circular cross section or group of such rods or filaments not insulated from one another, suitable for transmitting current.

Contrahelical – In the wire and cable industry the term is used to mean the direction of a layer with respect to the previous layer. Thus it would mean a layer spiraling in a opposite direction than a preceding layer within a wire or cable.

Copolene – A dielectric material composed of polyisobutylene and polystyrene, developed as a substitute for polystyrene. However, polyethylene is more commonly used instead of copolene.

Copper Constantan – Two alloys used in forming one type of thermocoupler pair. Constantan is an alloy of copper, nickel, manganese and iron.

Copperweld – Copperweld is the trade name for copper covered steel wire manufactured by the Copperweld steel Company. A drawing process enables a thick copper covering to be placed over a steel core so that the “copperweld” performs as one metal. Hot rolling, cold drawing, pounding or temperature changes do not affect its properties.

Corona – A luminous discharge caused by the ionization of the gas surrounding a conductor around which exists a voltage gradient exceeding a certain critical value.

Creep – the dimensional changes of a material under pressure over a period of time.

Cross-Sectional Area of a Conductor – The cross-section area of a conductor is the summation of all cross sectional areas of the individual strands in the conductor, expressed in square inches or more commonly in circular mils.

Crosstalk – Undesirable electro-magnetic coupling between adjacent signal carrying conductor pairs which may be reduced by proper overall shielding of these conductor pairs which may be reduced by proper overall shielding of these conductor pairs.

Creepage Surface – An insulating surface which provides physical separation as a form of insulation between two electrical conductors of different potential.

Cure – To change the physical properties of a material by chemical reaction, the action of heat and catalysts, alone or in combination, with or without pressure.

Curing Temperature – Temperature at which a material is subject to curing.

Curing Time – In the molding of thermosetting plastics, the time it takes for the material to be properly cured.

Curing Temperature – Temperature at which a material is subjected to curing.

Curing Time – In the molding of thermosetting plastics, the time it takes for the material to be properly cured.

Decibel (db) – Unit used to express the ratio between two amounts of power, voltage or current between two points.

$$\text{No of (db)} = 10\ \text{Log}_{10}\frac{P1}{P2} = 20\ \text{Log}_{10}\frac{V1}{V2} = 20\ \text{Log}_{10}\frac{I\,1}{I\,2}$$

The voltages of currents in question are measured at points having identical impedances.

Density – Weight per unit volume of a substance.

Dielectric – A non-conducting material or a material having the property that the energy required to establish an electric field is recoverable, in whole or in part, as electric energy. A vacuum is a dielectric.

Dielectric Absorption – That property of an imperfect dielectric whereby there is an accumulation of electric charges within the body of the material when it is placed in an electric field.

Dielectric Constant (Specific Inductive Capacity) – that property of a dielectric which determines the electrostatic energy stored per unit volume for unit potential gradient.

Dielectric Loss – The time rate at which electric energy is transformed into heat in a dielectric when it is subjected to a changing electric field

Dielectric Power Factor – An expression of the energy loss in an electric current due to the effect of the dielectric.

Strength (Disruptive Gradient) – The maximum potential gradient that a material can withstand without rupture. The value obtained for the electric strength will depend upon the thickness of the material and on the method and conditions of the test. Usually expressed as a voltage gradient (such as volts per mil.)

Dielectric Tests – Tests which consist of the application of voltage higher than the rated voltage for a specific time for the purpose of determining the adequacy against breakdown of insulating materials and spacings under normal conditions.

Direction of Lay – the direction in which the individual members of a cable or stranded conductor spiral over the top of the cable in a direction going away from the observer who is standing behind the twisting apparatus.

Drain Wire – An uninsulated stranded or solid conductor which is located directly under a shield. This wire, since it comes in contact with the shield throughout the entire length of the cable, may be used to terminate the shield and eliminate a considerable amount of the inductive effects of spiral type shielding.

EIA – Abbreviation for Electronic Industries Association, formerly RETMA (Radio Electronic Television Manufacturers' Association.)

Elongation – Elongation is the extension or increase in length produced by a tension load in a section of a test specimen between branch marks placed on it, and is either expressed as a percentage of the original length between bench marks or indicated by specifying a minimum distance between benchmarks.

Epoxy Resins – Straight chain thermoplastics and thermosetting resins based on ethylene oxide, its derivatives or homologs.

Extrusion – Compacting a natural or synthetic material and forcing it through an orifice in a continuous fashion.

FEP – An abbreviation for fluorinated ethylene propylene. A thermoplastic material used as a wire insulation. FEP has outstanding insulating characteristics and retains them over a wide range of temperatures and frequencies.

Filler – Fillers are used in multi-conductor cable to occupy the interstices formed by the assembled conductors.

Flame Resistance – The ability of a material to extinguish flame once the source of the heat is removed.

Flammability – Measure of a material's ability to support combustion.

Flex-Life – The time of heat aging that an insulating material can withstand before failure when bent around a specific radius (used to evaluate thermal endurance.

Flexural Strength – The strength of a material in bending.

Foam Polyethylene – A polyethylene compound which has been whipped in the presence of an inert gas. The resulting compound has a lower dielectric constant than does basic polyethylene.

Hard Drawn – A term that refers to the temper of conductors that are drawn without annealing or that may work harden in the drawing process.

Heat Endurance – The time of heat aging that a material can withstand before failing a specific physical test.

Hi-Pot – A test designed to determine the highest potential that can be applied to a conductor without breaking through the insulation.

Hygroscopic – Having the tendency to absorb moisture.

IACS – International Annealed Copper Standard.

Impact Resistance – Relative susceptibility of material to fracture by shock.

Impedance – The apparent resistance in a circuit to the flow of an alternating current, analogous to the actual resistance to a direct current.

Impregnate – To fill the voids and interstices of a material with a compound. (This does not imply complete fill or complete coating of the surfaces by a hole-free film.)

Injection Molding – A molding procedure where by a heat softened material is forced from a cylinder into a mold cavity to give a desired shape. Cure is obtained under heat and pressure.

Insulation Resistance – The insulation resistance of an insulated conductor is the electrical resistance offered by its insulation to an impressed direct current potential tending to product leakage of current through the same. For wire usually measured in megohomes per 1000 feet.

Insulator – A material of such low electrical conductivity that it will not support electric current.

IPCEA – Insulated Power Cable Engineers Association.

Iron Constantan – A combination of metals used in thermocouplers, thermocouple wires and thermocouple lead wires. Constantan is an alloy of copper, nickel, manganese and iron.

Jacket – A protective sheath or outer covering extruded or "blown on" over a conductor or cable.

Jute – A natural fiber of plant base formed into rope like strands. Used in cables for filling the interstices to give a round cross-section.

Karma – Trade name for resistance wire composed of 74.5% nickel, 20% chromium, 2.75% aluminum and 2.75% copper.

Kel-F – Polymonochlorotrifluorethylene per MIL-W-12349. Used on hook up wire as a high temperature insulation and for tubing where temperatures are beyond the operating temperature range of PVC and where resistance to solvents is desired (-55ºC to +135ºC.)

Layer – Consecutive turns of a coil lying in a single plane.

Lay Length – The lay length of any helically wound strand or insulated conductor is the axial length of one turn of the helix, usually expressed in inches or a multiple of the pitch diameter.

Lead Cured – In applications of cable jackets, a jacket that is cured or vulcanized in an extruded metallic lead sheath is lead cured.

Litz Wire – A stranded conductor in which each strand is separately insulated.

Loss Factor – Product of the dielectric constant and the power factor and proportional to the actual power in a dielectric.

Magnet Wire – Insulated wire intended for use in windings on motor and transformer coils. The insulation is generally thinner than that for normal hook up wire.

Marker Thread – A colored thread layered parallel and adjacent to the strands of an insulated conductor which identifies the wire manufacturer and often the specification under which the wire is constructed.

MIL – 0.001" (a 1/1000 inch.)

MIL SPEC – A specification issued by the Armed Forces of the United States of America.

Mylar – A molecularly oriented polyester film with very high dielectric and tensile strength manufactured by the E.I. du Pont de Nemours and Company. It is normally used as a tape wrap over a cable bundle.

NAS-Standards – National Aerospace Standards. These are specifications compiled on different items by the Aerospace Industries Association of America, Inc.

N.E.M.A. – National Electrical Manufacturers Association. It is known for its standardization of electrical motors, components and wire / cable specifications.

Neoprene – A trade name of E.I. du Pont de Nemours for polychioroprene, a rubber-like compound which is known for its resistance to the effects of oil, solvents and abrasion.

Non-Hydroscopic – Opposite of hygryscopic, will not absorb moisture.

Nylon – A generic trade name by the E.I. du Pont de Nemours for synthetic fiber forming polyamides. A polymer of nitrogen, carbon and oxygen. Its chemical unbalance and tendency to absorb moisture limit its use as a dielectric or insulating material. However, it is often used in the wire and cable field as a jacket over polyethylene or PVC to increase temperature stability and abrasion resistance.

Nylon Jacketed – Refers to the outer covering of Nylon on wire or cable which can be either an extruded layer or a braid of Nylon filaments.

Ozone – A faintly blue, gaseous allatropic form of oxygen obtained by the silent discharge of electricity in ordinary oxygen or in air. It has the odor of weak chlorine.

pH – The measure of acidity or alkalinity of a substance. pH values run from 0 to 14, 7 indicating neutrality, numbers less than 7 increasing acidity and numbers greater than 7 increasing alkalinity.

Pitch Diameter – The pitch diameter is the diameter of the helix described by the strands or insulated conductors in any layer.

Plastic – High polymeric substances, including both natural and synthetic products that are capable of flowing under heat and pressure into desired shapes and hardening in those shapes. There are two basic classes: thermosetting and Thermoplastic.

Plastic Deformation – The change in the dimensions of an object under load that is not recovered when the load is removed.

Plasticizer – A chemical agent added to plastics to make them more soft and more flexible.

Polyamide – A compound characterized by more than one amide group. The term is generally used in the wire and cable industry as a synonym for Nylon. See NYLON.

Polychloroprene – the chemical name for neoprene. It is used for wire and cable jacketing where the wire or cable will be subject to rough usage, oils, greases, moisture, solvents and other chemicals. The name, itself indicates that it is a polymer of chloroprene, a combination of vinyl acetylene and hydrogen chloride.

Polyester – A resin formed by the reaction between a dibasic acid and dihydroxy alcohol.

Polyethylene – A thermoplastic material with exceptionally low dielectric losses at all frequencies that is composed of ethylene gas polymers.

Polymer – the resulting compound formed by polymerization which sets up a union of monomers or the continued reaction between lower molecular weights.

Polymerize – The change, by union of two or more molecules of the same kind into another compound having the same elements in the same proportions but a higher molecular weight and different physical properties.

Polystyrene – A thermoplastic produced by the polymerization of styrenes, vinyl benzene.

Polyurethane – A copolymer of urethane similar in properties to neoprene. Usually used as a cold curing molding compound.

Polyvinylchloride (PVC) – This is a family of thermoplastic insulating compounds composed of polymers of polyvinyl chloride or its copolymer, vinyl acetate, in combination with certain plasticizers, stabilizers, fillers and pigments.

Potted – A common term used in cable manufacturing to mean the filling or voids with some form of sealing compound.

Potting – Similar to encapsulation except that complete penetration of all of the voids in the object is insured before the resin hardens.

Primary Insulation – A non-conductive material placed directly over a current carrying conductor whose prime function is to act as an electrical barrier for the applied potential. It does not always have the purpose of abrasion resistance. See secondary insulation.

QPL – A QPL source of supply is a manufacturer that has been registered by the U.S. Government and issued a QPL number as a qualified producer of a given commodity. There are, however, other manufacturers who product identical products equal or better in quality and performance, but because unregistered, sell the product at a lower price.

Quad – A four conductor cable.

Random Winding – A winding where the wires do not lie in an even pattern.

Relative Humidity – The ratio of the quantity of water vapor present in the atmosphere to the quantity which would saturate it at the existing temperature.

Resin – An organic substance of natural or synthetic origin characterized by being polymeric in structure and predominately amorphous. Most resins, though not all, are of high molecular weight and consist of long chain or network molecular structure. Usually resins are more soluble in their lower molecular weight forms.

Resistivity – the ability of a material to resist passage of electrical current either through its cross section or on the surface. The unit of volume resistivity is the OHM-CM; of surface resistivity, the OHM.

RETMA – See EIA

RF – Abbreviation for the term "radio frequency." Usually considered the frequency spectrum above 10,000 cycles (10 kc.)

RMS – Abbreviation for "root mean square." When the term is applied to voltages and currents it means the effective value, that is, it produces the same heating effect as a direct current or voltage of the same magnitude. Example: $I_{rms} = I_{max} / \sqrt{2}$

Rope Lay – In a rope lay conductor or cable, stranded members are twisted together with a concentric lay; the stranded members themselves may have either a bunched, concentric or rope lay.

S – An abbreviation for the term "shielded."

Secondary Insulation – A non-conductive material whose prime functions are to protect the conductor against abrasion and provide a second electrical barrier placed over the primary insulation or the shield.

Serve – With reference to cable construction, a type of separator applied directly over the conductor or conductors. The serve may consist of one or more materials such as paper, cotton, silk, nylon or rayon. These materials may be applied spirally or laterally.

Shield – A metallic sheath placed around an insulated conductor or group of conductors to protect against extraneous currents and fields. Generally this shield is a metallic braid but it could be spiraled copper, aluminum backed Mylar tape or conductive vinyl or rubber.

Shielded Conductor – An insulated conductor which has been shielded by a copper braid or tape or aluminum foil or copper foil or a semi-conductive vinyl. The purpose is to confine or reject extraneous electrical fields.

Shielded Pair – A shielded pair is a twisted pair over which a metal covering has been applied. The metal covering is usually in the form of a bare or tinned copper braid but may be metal ribbon or metal-backed Mylar tape.

Silicone – Polymeric materials in which the recurring chemical group contains silicon and oxygen atoms as links in the main chain. A thermosetting plastic material used for wire and cable covering that is thermally stable and with electrical properties exceeding those of most organic polymers.

SJ – Abbreviation for "shielded and jacketed."

SJN – Abbreviation for "shielded and jacketed with Nylon."

SJP – Abbreviation for "shielded and jacketed with polyvinylchloride."

Solvent – A liquid substance which dissolves other substances.

Spark Test – A test performed on wire and cable to determine the amount of detrimental porosity or defects in insulation.

Specific Gravity – The density (mass per unit volume) of any material divided by that of water at a standard temperature.

Stabilizer – An ingredient added to some plastics to maintain physical and chemical properties throughout processing and service life.

Strand – A single metallic conductor.

Surface Leakage – The passage of current over the boundary surfaces of an insulator as distinguished from passage through its volume.

Surge – A transient variation in the current and or potential at any point of the circuit.

Tape – A relatively narrow, woven or cut strip of paper, fabric or film material.

T.C. – Abbreviation for "tinned copper."

Tedlar – Trade name for E.I. du Pont Company for polyvinyl fluoride film with outstanding weatherability and thermoformability properties.

Polytetrafluoroethylene (PTFE) – is produced by the total substitution of fluorine and hydrogen in the polyethylene molecule. This material excels all other commercially available thermoplastics in chemical inertness and operating temperature range and is well suited for high frequency applications.

Tensile Strength – The pulling stress required to break a given specimen.

Thermal Conductivity – The ability of a given material to conduct heat.

Thermal Expansion (Coefficient of) – the fractional change in length (sometimes volume) of a material for a unit change in temperature.

Thermocouple – Thermocouples are pairs of wires of dissimilar metals connected at both ends in which a voltage is generated due to a difference in temperature at the junctions, the voltage generated is of the order or magnitude of micro – or millivolts.

Thermocouple Wire – Wire drawn from special metals or alloys and calibrated to establish specifications for use as thermocouple pair. For example: Iron, Constantan, Alumel, etc.

Thermoplastic – A classification of synthetic resins that can be readily softened and resoftened by repeated heating and reharden when heat is removed.

Thermosetting – A classification of synthetic resin which hardens by chemical reaction when heated and, when hardened cannot be resoftened by heat.

Thiokol – Made from petroleum gas and used as a sealing compound for connectors, breakouts, etc. It has excellent electrical insulation and oil and solvent resistant properties.

Tolerance – A specified allowance for error from a standard or given dimension, weight or property.

Triax – A type of shielded conductor that employs a shield and jacket over the primary insulation plus a second shield and jacket overall. Aside from applications requiring maximum attenuation or radiated signals or minimum pickup of external interference, this cable can also be used to carry two separate signals.

Twisted Pair (TP) – Two insulated conductors twisted together and often color coded.

UL – "Underwriters Laboratories." A corporation supported by underwriters for the purpose of establishing safety standards on types of equipment and components.

Viscosity – A measure of resistance to fluid flow, usually through a specific orifice.

VSWR (or SWVR) – The abbreviation for "voltage standing wave ratio." It is the ratio of voltage maximum to voltage minimum in a transmission line.

Vulcanization – A chemical reaction in which the physical properties of an elastomer are changed by reacting it with sulfur or other cross-linking agents.

Working Life – The period of time during which a liquid resin or adhesive remains usable after mixing with a catalyst, solvent or other compounding ingredients.

Working Voltage – the recommended maximum voltage of operation for an insulated conductor. Usually set at approximately 1/3 of the breakdown voltage.

Yield Strength – the lowest stress at which a material undergoes plastic deformation. Below this stress, the material is elastic; above it, viscous.

WIRE AWG 2% VOLTAGE DROP

CONDUCTOR SIZES TO MAINTAIN TWO PERCENT MAXIMUN VOLTAGE DROP

Based on 2 (single phase) and 3 conductors in conduit, for copper temperature at 75ºC
Voltage drop calculated at the maximum for power factor between 45% and unity.

Current in Amperes	110 Volts									220 Volts								
	Distance in Feet to Center of Distribution																	
	25	50	75	100	150	200	300	400	500	25	50	75	100	150	200	300	400	500
	Conductor Size required -- AWG																	
SINGLE-PHASE A-C CIRCUIT (In Conduit)																		
1	...	...	...	...	...	...	14	12	10	...	...	...	...	...	...	...	...	14
1.5	...	...	...	...	14	14	12	10	10	...	...	...	...	...	...	14	14	12
2	...	...	...	...	14	12	10	10	8	...	...	...	...	...	...	14	12	12
3	...	...	14	14	12	10	8	8	6	...	...	...	...	14	14	12	10	10
4	...	...	14	12	10	10	8	6	6	...	...	...		14	12	10	10	8
5	...	14	12	12	10	8	6	6	4	...	...	...	14	12	12	10	8	8
6	...	14	12	10	8	8	6	4	4	...	...	14	14	12	10	8	8	6
7	...	14	12	10	8	8	6	4	2	...	...	14	14	12	10	8	8	6
8	...	12	10	10	8	6	4	2	2	...	...	14	12	10	10	8	6	6
9	...	12	10	8	8	6	4	2	2	...	14	14	12	10	8	8	6	4
10	14	12	10	8	6	6	4	2	2	...	14	12	12	10	8	6	6	4
12	14	10	8	8	6	4	2	1	1	...	14	12	10	8	8	6	4	4
14	14	10	8	8	6	4	2	0	0	...	14	12	10	8	8	6	4	2
16	12	10	8	6	4	4	2	0	00	...	12	10	10	8	6	4	4	2
18	12	8	8	6	4	2	1	00	00	12*	12	10	8	8	6	4	2	2
20	12	8	6	6	4	2	1	00	000	12*	12	10	8	6	6	4	2	2
25	10	8	6	4	2	2	0	000	0000	10*	10	8	8	6	4	2	2	1
30	10	6	4	4	2	1	00	...	...	10*	10	8	6	4	4	2	1	0
35	8*	6	4	2	2	0	000	...	...	8*	8*	8	6	4	2	2	0	00
40	8	6	4	2	1	00	0000	...	...	8*	8	6	6	4	2	1	00	0000
45	8	4	4	2	0	00	...	...	...	8*	8	6	4	4	2	0	00	0000
50	6*	4	2	2	0	0000	...	...	...	6*	6*	6	4	2	2	0	000	0000
60	6	4	2	1	00	0000	...	...	...	6*	6	4	4	2	1	00	0000	...
70	4	2	2	0	000	...	...	...	...	4*	4*	4	2	2	0	000	...	...
80	4*	2	1	00	0000	...	...	...	...	4*	4*	4	2	1	00	0000	...	...
90	2*	2	0	00	...	...	...	...	...	2*	2*	2*	2	0	00	...	...	...
100	2*	2	0	000	...	...	...	...	...	2*	2*	2	2	0	000	...	...	...
120	1*	1	00	0000	...	...	...	...	...	1*	1*	1*	1	00	0000	...	...	...

Current in Amperes	220 Volts									440 Volts								
	Distance in Feet to Center of Distribution																	
	25	50	75	100	150	200	300	400	500	25	50	75	100	150	200	300	400	500
	Conductor Size required -- AWG																	
THREE-PHASE A-C CIRCUIT (In Conduit)																		
1.5	...	...	...	...	...	...	...	14	14	...	...	...	...	...	...	...	...	...
2	...	...	...	...	...	...	14	14	12	...	...	...	...	...	...	...	...	...
3	...	...	...	...	...	14	12	12	10	...	...	...	...	...	...	...	14	14
4	...	...	...	...	14	14	12	10	10	...	...	...	...	...	...	14	14	12
5	...	...	...	...	14	12	10	10	8	...	...	...	...	...	...	14	12	12
6	...	...	...	14	12	12	10	8	8	...	...	...	...	...	14	12	12	10
7	...	...	14	14	12	10	8	8	6	...	...	...	...	14	14	12	10	10
8	...	...	14	14	12	10	8	6	6	...	...	...	...	14	14	12	10	10
9	...	...	14	12	10	10	8	6	6	...	...	...	...	14	12	10	10	8
10	...	...	14	12	10	10	8	6	6	...	...	...	...	14	12	10	10	8
12	...	14	12	12	10	8	6	6	4	...	...	...	14	12	12	10	8	8
14	...	14	12	10	8	8	6	4	4	...	...	14	14	12	10	8	8	6
16	...	14	12	10	8	8	6	4	2	...	...	12*	12*	12	10	8	8	6
18	...	12	10	10	8	6	4	4	2	...	...	12*	12	10	10	8	6	6
20	...	12	10	10	8	6	4	2	2	...	...	12*	12	10	10	8	6	6
25	10*	10*	10	8	6	6	4	2	1	...	10*	10*	10*	10	8	6	6	4
30	10*	10	8	8	6	4	2	2	0	...	10*	10*	10	8	8	6	6	4
35	8*	8*	8	6	4	4	2	1	0	...	8*	8*	8	8	6	4	4	4
40	8*	8*	8	6	4	2	2	0	00	...	8*	8*	8*	8	6	4	2	2
45	8*	8	6	6	4	2	1	0	000	8*	8*	8*	8	6	6	4	2	2
50	6*	6*	6	4	4	2	0	00	000	6*	6*	6*	6*	6	6	4	2	1
60	6*	6*	6	4	2	2	0	000	...	6*	6*	6*	6*	6	4	2	2	0
70	4*	4*	4	4	2	1	00	0000	...	4*	4*	4*	4*	4	4	2	1	0
80	4*	4	4	2	2	0	000	...	...	4*	4*	4*	4*	4	2	2	0	00
90	2*	2*	2*	2	1	0	0000	...	...	2*	2*	2*	2*	2*	2	1	0	000
100	2*	2*	2*	2	0	00	...	...	...	2*	2*	2*	2*	2*	2	0	00	000
120	1*	1*	1*	1*	0	0000	...	...	...	1*	1*	1*	1*	1*	1	0	000	0000

SYNOPSIS OF WIRE SPECIFICATIONS

MIL-C-13777	Cable Multiconductor, Missile Ground Support
MIL-C-23437	Cable, Electrical, Shielded Pairs
MIL-C-24145	(Ships) Cable, Shipboard
MIL-C-25038	Conductors, Insulated, Nickel Clad, 750 deg.
MIL-C-24643	Cable, Electrical, Low Smoke, Shipboard
MIL-C-26468	(USAF) Cables, Missile
MIL-C-27072	Cable, Multi-conductor, Ground Support
MIL-C-27212	Cable, Power, Airport Lighting Control
MIL-C-27500	Cables, Aircraft & Missile
MIL-C-55021	Cable, Pairs & Triples, Internal
MIL-C-85045	Cable, Fiber Optic

MIL-W-76	Hookup Wires, Vinyl Insulated, Types LW, MW, HW
MIL-W-538	Wire, Magnet, Electrical
MIL-W-3861	Wire, Electrical, Bare Copper
MIL-W-5086	Wire, Aircraft, Vinyl Insulated, 600V
MIL-W-5845	Wire, Electrical, Iron/Constantan Thermocouple
MIL-W-5846	Wire, Electrical, Chromel or Alumel, Thermo
MIL-W-5908	Wire, Electrical, Copper/Constantan, Thermo
MIL-W-7139	Wire, Aircraft, Polytetrafluoroethylene (PTFE)
MIL-W-8777	Wire, Aircraft, Silicone Rubber
MIL-W-16878	Wire, Electronic Hookup (many popular types)
MIL-W-19150	Wire, Insulated, Hard-drawn Copper
MIL-W-22759	Wire, Insulated Hookup (many popular types)
MIL-W-25038	Wire, Insulated, High Temperature
MIL-W-27300	Wire, Aircraft, TFE Insulated
MIL-W-81044	Wire, Insulated, X-Linked, PVF & Polyalkene
MIL-W-81381	Wire, Polyimide Insulated (Kapton, H-film)

MIL-STANDARDS:

MIL-STD-104	Color Limits for Insulation Colors
MIL-STD-122	Color Coding, Chassis Electronic
MIL-STD-681	Color Coding, Identification, Hookup Wire
MIL-STD-685	Coding of Telephone Cables
MIL-STD-686	Cable Identification & Coding

NON-GOVERNMENT AGENCIES:

ASTM: American Society for Testing & materials

ASTM B-3	soft or annealed copper wire
ASTM B-33	tinned soft or annealed copper wire
ASTM B-286	copper conductors for use in hookup wire

C.S.A.: Canadian Standards Asociation

C22.2 #16	insulated conductors for power-operated electronic dev.
C22,2 #127	equipment wires

E.I.A.: Electronic Industry Association

RS-232	bi-polar serial digital signaling (5 to 15 V)
RS-359	color coding
RS-422	balanced digital interface circuits (5 V)
RS-423	unbalanced digital interface circuits (5 V)
RS-449	general purpose serial interface, 37 & 9 pos.
RS-485	balanced digital generators, receivers, multipt.

I.E.E.E.: Institute of Electrical & Electronic Engineering

IEEE383	nuclear reactor cables

IPCEA: Insulated Power Cable Engineer Association

S-61-402	thermoplastic-insulated power cables
S-19-81	rubber insulated wire& cable, power

U.L.: Underwriter's Laboratories

UL 62	flexible cord & fixture wire
UL 758	appliance wiring material (numerous styles)
UL 1581	ref. standard for electrical wires, cables and cords

GOVERNMENTAL AGENCIES -- Federal Standards

STD. 228	test method 228, cables
QQ-W-343	wire, copper, uninsulated

MILITARY:

MIL-C-17	cables, coaxial
MIL-C-2164	shipboard cables
MIL-C-5756	rubber insulated portable cord, low temp.
MIL-C-7078	aircraft wires, shielded

MIL-STD-681 COLOR CODING

Used on many of our standard cables. For new design, National recommends this color code system.

NO.	BASE COLOR	FIRST TRACER	SECOND TRACER	THIRD TRACER
0	Black			
1	Brown			
2	Red			
3	Orange			
4	Yellow			
5	Green			
6	Blue			
7	Violet			
8	Grey			
9	White			
10	White	Black		
11	White	Brown		
12	White	Red		
13	White	Orange		
14	White	Yellow		
15	White	Green		
16	White	Blue		
17	White	Violet		
18	White	Grey		
19	White	Black	Brown	
20	White	Black	Red	
21	White	Black	Orange	
22	White	Black	Yellow	
23	White	Black	Green	
24	White	Black	Blue	
25	White	Black	Violet	
26	White	Black	Grey	
27	White	Brown	Red	
28	White	Brown	Orange	
29	White	Brown	Yellow	
30	White	Brown	Green	
31	White	Brown	Blue	
32	White	Brown	Violet	
33	White	Brown	Grey	
34	White	Red	Orange	
35	White	Red	Yellow	
36	White	Red	Green	
37	White	Red	Blue	
38	White	Red	Violet	
39	White	Red	Grey	
40	White	Orange	Yellow	
41	White	Orange	Green	
42	White	Orange	Blue	
43	White	Orange	Violet	
44	White	Orange	Grey	
45	White	Yellow	Green	
46	White	Yellow	Blue	
47	White	Yellow	Violet	
48	White	Yellow	Grey	
49	White	Green	Blue	
50	White	Green	Violet	
51	White	Green	Grey	
52	White	Blue	Violet	
53	White	Blue	Grey	
54	White	Violet	Grey	
55	White	Black	Brown	Red
56	White	Black	Brown	Orange
57	White	Black	Brown	Yellow
58	White	Black	Brown	Green
59	White	Black	Brown	Blue
60	White	Black	Brown	Violet
61	White	Black	Brown	Grey
62	White	Black	Red	Orange
63	White	Black	Red	Yellow
64	White	Black	Red	Green
65	White	Black	Red	Blue
66	White	Black	Red	Violet
67	White	Black	Red	Grey
68	White	Black	Orange	Yellow
69	White	Black	Orange	Green
70	White	Black	Orange	Blue
71	White	Black	Orange	Violet
72	White	Black	Orange	Grey
73	White	Black	Yellow	Green
74	White	Black	Yellow	Blue
75	White	Black	Yellow	Violet
76	White	Black	Yellow	Grey
77	White	Black	Green	Blue
78	White	Black	Green	Violet
79	White	Black	Green	Grey
80	White	Black	Blue	Violet
81	White	Black	Blue	Grey
82	White	Black	Violet	Grey
83	White	Brown	Red	Orange
84	White	Brown	Red	Yellow
85	White	Brown	Red	Green
86	White	Brown	Red	Blue
87	White	Brown	Red	Violet
88	White	Brown	Red	Grey
89	White	Brown	Orange	Yellow
90	White	Brown	Orange	Green
91	White	Brown	Orange	Blue
92	White	Brown	Orange	Violet
93	White	Brown	Orange	Grey
94	White	Brown	Yellow	Green
95	White	Brown	Yellow	Blue
96	White	Brown	Yellow	Violet
97	White	Brown	Yellow	Grey
98	White	Brown	Green	Blue
99	White	Brown	Green	Violet
100	White	Brown	Green	Grey
101	White	Brown	Blue	Violet
102	White	Brown	Blue	Grey
103	White	Brown	Violet	Grey
104	White	Red	Orange	Yellow
105	White	Red	Orange	Green
106	White	Red	Orange	Blue
107	White	Red	Orange	Violet
108	White	Red	Orange	Grey
109	White	Red	Yellow	Green
110	White	Red	Yellow	Blue
110	White	Red	Yellow	Violet
112	White	Red	Yellow	Grey
113	White	Red	Green	Blue
114	White	Red	Green	Violet
115	White	Red	Green	Grey
116	White	Red	Blue	Violet
117	White	Red	Blue	Grey
118	White	Red	Violet	Grey
119	White	Orange	Yellow	Green
120	White	Orange	Yellow	Blue
121	White	Orange	Yellow	Violet
122	White	Orange	Yellow	Grey
123	White	Orange	Green	Blue
124	White	Orange	Green	Violet
125	White	Orange	Green	Grey
126	White	Orange	Blue	Violet
127	White	Orange	Blue	Grey
128	White	Orange	Violet	Grey
129	White	Yellow	Green	Blue
130	White	Yellow	Green	Violet
131	White	Yellow	Green	Grey
132	White	Yellow	Blue	Violet
133	White	Yellow	Blue	Grey
134	White	Yellow	Violet	Grey
135	White	Green	Blue	Violet
136	White	Green	Blue	Grey
137	White	Green	Violet	Grey

MINIATURE SIGNAL & CONTROL CABLES - COLOR CODING

National Wire & Cable's
Table of Color Codes of Twisted Pairs
used in National's multiconductor cable families of NQP cables and NWP cables

PR#	PAIR COLORS	PR#	PAIR COLORS	PR#	PAIR COLORS	PR#	PAIR COLORS
1	White with Black	16	Black with Violet	31	Orange with Yellow	46	White /Black Striped Wire with Black
2	White with Brown	17	Black with Gray	32	Orange with Green	47	White/Black Striped Wire with Brown
3	White with Red	18	Brown with Red	33	Orange with Blue	48	White/Black Striped Wire with Red
4	White with Orange	19	Brown with Orange	34	Orange with Violet	49	White/Black Striped Wire with Orange
5	White with Yellow	20	Brown with Yellow	35	Orange with Gray	50	White/Black Striped Wire with Yellow
6	White with Green	21	Brown with Green	36	Yellow with Green	51	White/Black Striped Wire with Green
7	White with Blue	22	Brown with Blue	37	Yellow with Blue	52	White/Black Striped Wire with Blue
8	White with Violet	23	Brown with Violet	38	Yellow with Violet	53	White/Black Striped Wire with Violet
9	White with Gray	24	Brown with Gray	39	Yellow with Gray	54	White/Black Striped Wire with Gray
10	Black with Brown	25	Red with Orange	40	Green with Blue	55	White/Brown Striped Wirewith Black
11	Black with Red	26	Red with Yellow	41	Green with Violet	56	White/Brown Striped Wirewith Brown
12	Black with Orange	27	Red with Green	42	Green with Gray	57	White/Brown Striped Wirewith Red
13	Black with Yellow	28	Red with Blue	43	Blue with Violet	58	White/Brown Striped Wirewith Orange
14	Black with Green	29	Red with Violet	44	Blue with Gray	59	White/Brown Striped Wirewith Yellow
15	Black with Blue	30	Red with Gray	45	Violet with Gray	60	White/Brown Striped Wirewith Green

TABLE OF COMPARATIVE PROPERTIES

Fluorinated Ethylene Propylene (FEP)

is a modification of the basic ethylene molecule by the addition of a propyl radical held by a single chemical bond to a Carbon atom and the substitution of Fluorine atoms for all Hydrogen. FEP demonstrates excellent electrical stability over a temperature range from -65ºC to +200ºC and is suitable for ultra-high frequency applications.

Nylon (polyhexamethylene-adipamide)

is a readily extrudable complex polymer of Nitrogen, Carbon and Oxygen and is also known by its general family name, polyamide. Because of its relatively poor electrical characteristics, it is rarely used as a primary insulation wire. However, it makes an excellent outer covering when applied over vinyl insulations. Extruded Nylon Jackets are tough and are resistant to abrasion, cold flow, oils, etc. and have the tendency to increase the temperature stability of the primary insulation.

Polyethylene

is one of the most commonly used dielectric materials. The basic Carbon-Hydrogen molecule is in perfect balance. Polymerization is accomplished by breaking the double bond and connecting a large number of identical molecules in a chain. Because of its electrical balance, the polymer is excellent for high-frequency applications. Polyethylene possesses definite limitations as an insulating material due to its physical properties: safe maximum operating temperature of only 80ºC, will burn freely in the presence of an open flame, is difficult to color code and its low abrasion resistance. Some of these shortcomings have been overcome by the introduction of LINEAR or HIGH DENSITY polyethylene, This type of insulation can be used continuously at temperatures of 100ºC, has greater physical toughness, improved abrasion and chemical resistance, plus lower rates of permeability to water vapor and temperature coefficient of expansion.

Tetrafluoroethylene (TFE)

better known as Polytetrafluoroethylene (PTFE), is produced by the total substitution of Fluorine for Hydrogen in the basic ethylene molecule. Like the Carbon-Hydrogen molecule in polyethylene, this Carbon-Fluorine molecule is in excellent electrical balance and therefore is well suited for high-frequency applications. One of the better commercially available thermoplastics in chemical inertness and operating temperature range, it has provided access to the solution of different and more difficult design problems. However, its good points are often overshadowed by the fact that inherent problems of its extrusion process limit continuous lengths to one or two thousand feet. FEP, similar in temperature stability and chemical composition to Polytetrafluoroethylene (PTFE), can be readily extruded in long lengths and is being utilized in place of TFE in many cases.

Polyvinylchloride (PVC)

is a modification of the basic polyethylene structure with one Chlorine atom replacing one Hydrogen atom. This results in physical properties that surpass those of the basic polyethylene: greater abrasion resistance, better dimensional stability, higher operating temperatures and increased resistance to flame. PVC is readily extrudable by conventional thermoplastic techniques. However, the electrical unbalance of this molecule precludes the use of PVC at elevated frequencies. PVC does provide the necessary electrical protection with the least possible increase in over-all diameter and stiffness and is excellent in low-frequency applications where resistance to moisture, flame, oils, aging and many acids and alkalies is important.

Silicone Rubber (Dimethyl Siloxane Polymer)

is finding widespread applications as a wire insulation because of its high operating temperature (continuously at +200ºC and +300ºC for short intervals), constant dielectric strength over its entire operating temperature range and low temperature flexibility. However, in the presence of flame, Silicone will burn to a non-conductive ash, which, if held in place, could function as insulation in emergencies. Its abrasion resistance is usually greatly improved by the addition of a saturated glass outer braid. Unlike vinyls, polyethylene and nylon, silicone rubbers are thermo setting plastics.

WIRE TABLES

TEMPERATURE CONVERSION TABLE

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-40	-40	-10	14	20	68	50	122	80	176	110	230	140	284
-39	-38.2	-9	15.8	21	69.8	51	123.8	81	177.8	111	231.8	141	285.8
-38	-36.4	-8	17.6	22	71.6	52	125.6	82	179.6	112	233.6	142	287.6
-37	-34.6	-7	19.4	23	73.4	53	127.4	83	181.4	113	235.4	143	289.4
-36	-32.8	-6	21.2	24	75.2	54	129.2	84	183.2	114	237.2	144	291.2
-35	-31	-5	23	25	77	55	131	85	185	115	239	145	293
-34	29.2	-4	24.8	26	78.8	56	132.8	86	186.8	116	240.8	146	294.8
-33	-27.4	-3	26.6	27	80.6	57	134.6	87	188.6	117	242.6	147	296.6
-32	-25.6	-2	28.4	28	82.4	58	136.4	88	190.4	118	244.4	148	298.4
-31	-23.8	-1	30.2	29	84.2	59	138.2	89	192.2	119	246.2	149	300.2
-30	-22	0	32	30	86	60	140	90	194	120	248	150	302
-29	-20.2	1	33.8	31	87.8	61	141.8	91	195.8	121	249.8	151	303.8
-28	-18.4	2	35.6	32	89.6	62	143.6	92	197.6	122	251.6	152	305.6
-27	-16.6	3	37.4	33	91.4	63	145.4	93	199.4	123	253.4	153	307.4
-26	-14.8	4	39.2	34	93.2	64	147.2	94	201.2	124	255.2	154	309.2
-25	-13	5	41	35	95	65	149	95	203	125	257	155	311
-24	-11.2	6	42.8	36	96.8	66	150.8	96	204.8	126	258.8	156	312.8
-23	-9.4	7	44.6	37	98.6	67	152.6	97	206.6	127	260.6	157	314.6
-22	-7.6	8	46.4	38	100.4	68	154.4	98	208.4	128	262.4	158	316.4
-21	-5.8	9	48.2	39	102.2	69	156.2	99	210.2	129	264.2	159	318.2
-20	-4	10	50	40	104	70	158	100	212	130	266	160	320
-19	-2.2	11	51.8	41	105.8	71	159.8	101	213.8	131	267.8	161	321.8
-18	-0.4	12	53.6	42	107.6	72	161.6	102	215.6	132	269.6	162	323.6
-17	1.4	13	55.4	43	109.4	73	163.4	103	217.4	133	271.4	163	325.4
-16	3.2	14	57.2	44	111.2	74	165.2	104	219.2	134	273.2	164	327.2
-15	5	15	59	45	113	75	167	105	221	135	275	165	329
-14	6.8	16	60.8	46	114.8	76	168.8	106	222.8	136	276.8	166	330.8
-13	8.6	17	62.6	47	116.6	77	170.6	107	224.6	137	278.6	167	332.6
-12	10.4	18	64.4	48	118.4	78	172.4	108	226.4	138	280.4	168	334.4
-11	12.2	19	66.2	49	120.2	79	174.2	109	228.2	139	282.2	169	336.2

Conversion Formulas: ºF=9/5C+32 ºC=5/9(F-32)

DECIMAL EQUIVALENT TABLE

1/64	0.0156	11/32	0.34375	43/64	0.6719
1/32	0.03125	23/64	0.3594	11/16	0.6875
3/64	0.0469	3/8	0.3750	45/64	0.7031
1/16	0.0625	25/64	0.3906	23/32	0.71875
5/64	0.0781	13/32	0.40625	47/64	0.7344
3/32	0.09375	27/64	0.4219	3/4	0.7500
7/64	0.1094	7/16	0.4375	49/64	0.7656
1/8	0.1250	29/64	0.4531	5/32	0.78125
9/64	0.1406	15/32	0.46875	51/64	0.7969
5/32	0.15625	31/64	0.4844	13/16	0.8125
11/64	0.1719	1/2	0.5000	53/64	0.8281
3/16	0.1865	33/64	0.5156	27/32	0.84375
13/64	0.2031	17/32	0.53125	55/64	0.8594
7/32	0.21875	35/64	0.5469	7/8	0.8750
15/64	0.2344	9/16	0.5625	57/64	0.8906
1/4	0.2500	37/64	0.5781	29/32	0.90625
17/64	0.2656	19/32	0.59375	59/64	0.9219
9/32	0.28125	39/64	0.6094	15/16	0.9375
19/64	0.2969	5/8	0.6250	61/64	0.9531
5/16	0.3125	41/64	0.6406	31/32	0.96875
21/64	0.3281	21/32	0.65625	63/64	0.9844
				1	1.000

MAXIMUM CURRENT CAPACITY TABLE

WIRE GAUGE	MAXIMUM CURRENT RATINGS IN AMPERES PER:						
	MIL-W-50888 (ASG)***		NATIONAL ELECTRICAL CODE	UNDERWRITER'S LABORATORY		NAT'L BOARD OF FIRE UNDERWRITERS	500 CM ☆☆ PER AMP†
	CABLES GREATER THAN 15 COND.	SINGLE COND. IN FREE AIR		+60 C*	+80 C*		
30	.....	.....	.....	0.2	0.4	.....	0.20
28	.....	.....	.....	0.4	0.6	.....	0.32
26	.....	.....	.....	0.6	1.0	.....	0.51
24	.....	.....	.....	1.0	1.6	.....	0.81
22	5.0	.....	.....	1.6	2.5	.....	1.28
20	7.5	11.0	.....	2.5	4.0	3	2.04
18	10.0	16.0	6	4.0	6.0	5	3.24
16	13.0	22.0	10	6.0	10.0	7	5.16
14	17.0	32.0	20	10.0	16.0	15	8.22
12	23.0	41.0	30	16.0	26.0	20	13.05
10	33.0	55.0	35	.....	.....	25	20.80
8	46.0	73.0	50	.....	.....	35	33.00
6	60.0	101.0	70	.....	.....	50	52.60
4	80.0	135.0	90	.....	.....	70	83.40
2	100.0	181.0	125	.....	.....	90	132.80
1	125.0	211.0	150	.....	.....	100	167.50
0	150.0	245.0	200	.....	.....	125	212.00
00	175.0	283.0	225	.....	.....	150	266.00
000	200.0	328.0	275	.....	.....	175	336.00
0000	225.0	380.0	325	.....	.....	225	424.00

* Refers to insulation temperature rating

*** For 100ºC copper temp.

† Derated standard, Common to the wire & cable industry

☆☆ The abbreviation for circular mil

WIRE TABLES

COMMON STRANDING COMBINATIONS used to fabricate flexible wires

AWG	STRANDS	NOM. OD OF STRAND	APPROX. OD	CIRCULAR MIL AREA	WEIGHT LBS. PER 1000 FT	*MAXIMUM RESISTANCE OHMS PER 1000 FT
4/0	8512/36	.0050	.655	212800	761.6	.049
4/0	5320/34	.0063	.640	211470	634.0	.049
4/0	2109/30	.0100	.627	210900	672.5	.0576
4/0	427/23	.0226	.605	212342	663.1	.047
4/0	259/21	.0285	.606	209815		.055
3/0	1519/30	.0100	.574	152659	476.0	.061
3/0	4256/34	.0063	.555	169176	563.2	.061
3/0	1672/30	.0100	.495	168036	535.6	.0727
3/0	427/24	.0198	.536	167401	533.5	.059
3/0	259/22	.0253	.606	166381	526.4	.072
2/0	5292/36	.0050	.486	132300	480.0	.077
2/0	3332/34	.0063	.464	132447	424.6	.077
2/0	1330/30	.0100	.494	133665	435.0	.091
2/0	259/23	.0226	.414	132297	414.0	.090
2/0	133/20	.0320	.509	135926	419.0	.077
1/0	4214/35	.0050	.490	105350	382.7	.098
1/0	2646/34	.0063	.437	105178	335.0	.098
1/0	1045/30	.0100	.431	105022	350.0	.116
1/0	259/24	.0198	.422	104636	331.0	.113
1/0	133/21	.0285	.464	107743	342.4	.096
1	2107/34	.0063	.375	83753	266.0	.124
1	817/30	.0100	.382	81700	247.1	.149
1	259/25	.0179	.375	82983	262.5	.144
1	133/22	.0253	.365	85439	260.3	.121
2	2646/36	.0050	.379	66150	240.3	.157
2	665/30	.0100	.342	66832	205.5	.183
2	259/26	.0159	.325	65811	208.4	.186
2	133/23	.0226	.328	67736	209.7	.176
4	1666/36	.0050	.290	41650	130.7	.250
4	259/28	.0126	.261	41388	130.9	.200
4	133/25	.0179	.257	42613	133.0	.280
6	1050/36	.0050	.204	26250	84.0	.386
6	266/30	.0100	.210	26029	80.0	.453
6	133/27	.0142	.206	20628	80.4	.444
8	665/36	.0050	.166	16625	51.3	.620
8	133/29	.0113	.166	16851	52.9	.701
8	49/25	.0179	.166	16589	52.0	.67
10	105/30	.0100	.120	10552	32.5	1.15
10	49/27	.0142	.116	10445	32.6	1.21
10	37/26	.0159	.107	9402	29.0	1.26
12	165/34	.0063	.095	6549	19.8	1.58
12	65/30	.0100	.095	6533	20.8	1.85
12	19/25	.0179	.089	6088	18.8	1.92
12	7/20	.0320	.096	7168	21.6	1.45

AWG	STRANDS	NOM. OD OF STRAND	APPROX. OD	CIRCULAR MIL AREA	WEIGHT LBS. PER 1000 FT	*MAXIMUM RESISTANCE OHMS PER 1000 FT
14	105/34	.0063	.086	4173	13.0	2.49
14	41/30	.0100	.074	4121	12.7	2.94
14	19/27	.0142	.069	3829	11.9	3.05
16	105/36	.0050	.065	2625	8.1	3.99
16	65/34	.0063	.063	2584	8.0	4.02
16	26/30	.0100	.059	2613	8.0	4.59
16	19/29	.0113	.054	2426	7.5	4.82
16	7/24	.0201	.060	2628	8.6	3.70
18	65/36	.0050	.051	1625	5.0	6.40
18	41/34	.0063	.052	1629	5.0	6.37
18	19/30	.0100	.048	1608	4.9	6.22
18	16/30	.0100	.049	1608	4.9	6.60
18	7/26	.0159	.048	1770	5.5	6.54
20	41/36	.0050	.038	1025	3.2	10.02
20	26/34	.0063	.040	1033	3.2	10.05
20	19/32	.0080	.038	1201	3.7	9.76
20	10/30	.0100	.038	1005	3.1	11.80
20	7/28	.0126	.038	1119	3.5	10.40
22	26/36	.0050	.033	650	2.0	15.94
22	19/34	.0063	.030	754	2.3	15.90
22	7/30	.0100	.030	704	2.2	16.70
24	41/40	.0031	.0245	394	1.2	25.59
24	19/36	.0050	.024	475	1.5	25.40
24	10/34	.0063	.024	398	1.2	26.09
24	7/32	.0080	.024	448	1.4	23.30
26	19/38	.0040	.019	304	.92	40.10
26	10/36	.0050	.021	250	.77	41.48
26	7/34	.0063	.019	276	.85	42.60
28	19/40	.0031	.016	182	.563	67.70
28	7/36	.0050	.015	175	.539	68.20
30	19/42	.0025	.012	118	.359	87.30
30	7/38	.0040	.012	110	.340	108.00
32	19/44	.0020	.001	76	.230	136.40
32	7/40	.0031	.009	75	.213	182.00
34	7/42	.0025	.007	44	.132	237.00
36	7/44	.0020	.006	28	.085	371.00

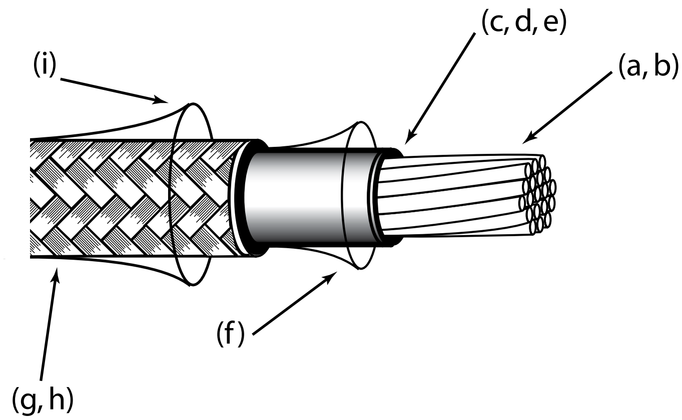
WIRE TABLES

SOLID ANNEALED COPPER WIRE

GAUGE NO.	DIAMETER in INCHES	*DIAMETER in MILS*	*DIAMETER in MM*	*AREA C MILS*	*AREA SQ. MM*	AREA SQ. INCHES	RESISTANCE Ohms/1000 Ft. @20ºC	WEIGHT Lb/1000 Ft.
0000	.4600	360.0	11.684	211600.	107.2200	.1661907	0.049	641.164
000	.4096	409.6	10.404	167772.	85.0120	.1317683	0.062	508.362
00	.3648	364.8	9.266	133079.	67.4326	.1045203	0.078	403.239
0	.3249	324.9	8.252	105560.	53.4884	.0829068	0.098	318.855
1	.2893	289.3	7.348	83694.	42.4089	.0657337	0.124	253.600
2	.2576	257.6	6.543	66358.	33.6242	.0521174	0.156	201.069
3	.2294	229.4	5.827	52624.	26.6653	.0413312	0.197	159.456
4	.2043	204.3	5.189	41738.	21.1493	.0327814	0.248	126.471
5	.1819	189.9	4.620	33088.	16.7658	.0259870	0.313	100.258
6	.1620	162.0	4.115	26244.	13.2981	.0206120	0.395	79.521
7	.1443	144.3	3.665	20822.	10.5510	.0163540	0.498	63.094
8	.1285	128.5	3.264	16512.	8.3669	.0129687	0.628	50.033
9	.1144	114.4	2.906	13087.	6.6315	.0102788	0.792	39.656
10	.1019	101.9	2.588	10384.	5.2615	.0081553	0.999	31.463
11	.0907	90.7	2.304	8226.	4.1685	.0064611	1.261	24.927
12	.0800	80.8	2.052	6529.	3.3081	.0051276	1.589	19.782
13	.0720	72.0	1.829	5184.	2.6268	.0040715	2.001	15.708
14	.0641	64.1	1.628	4109.	2.0820	.0032271	2.524	12.450
15	.0571	57.1	1.450	3260.	1.6521	.0025607	3.181	9.879
16	.0508	50.8	1.290	2581.	1.3076	.0020268	4.019	7.820
17	.0453	45.3	1.151	2052.	1.0398	.0016117	5.054	6.218
18	.0403	40.3	1.024	1624.	0.8229	.0012756	6.386	4.921
19	.0359	35.9	0.912	1289.	0.6531	.0010122	8.047	3.905
20	.0320	32.0	0.813	1024.	0.5189	.0008042	10.128	3.103
21	.0285	28.5	0.724	812.	0.4116	.0006379	12.768	2.461
22	.0253	25.3	0.643	640.	0.3243	.0005027	16.202	1.940
23	.0226	22.6	0.574	511.	0.2588	.0004012	20.305	1.548
24	.0201	20.1	0.511	404.	0.2047	.0003173	25.670	1.224
25	.0179	17.9	0.455	320.	0.1624	.0002517	32.368	0.971
26	.0159	15.9	0.404	253.	0.1281	.0001986	41.023	0.766
27	.0142	14.2	0.361	202.	0.1022	.0001584	51.433	0.611
28	.0126	12.6	0.320	159.	0.0804	.0001247	65.325	0.481
29	.0113	11.3	0.287	128.	0.0647	.0001003	81.220	0.387
30	.0100	10.0	0.254	100.	0.0507	.0000785	103.710	0.303
31	.0089	8.9	0.226	79.	0.0401	.0000622	130.930	0.224
32	.0080	8.0	0.203	64.	0.0324	.0000503	162.047	0.194
33	.0071	7.1	0.180	50.	0.0255	.0000396	205.733	0.153
34	.0063	6.3	0.160	40.	0.0201	.0000312	261.300	0.120
35	.0056	5.6	0.142	31.	0.0159	.0000246	330.708	0.095
36	.0050	5.0	0.127	25.	0.0127	.0000196	414.840	0.076
37	.0045	4.5	0.114	20.	1.0103	.0000159	512.148	0.061
38	.0040	4.0	0.102	16.	0.0081	.0000126	648.187	0.048
39	.0035	3.5	0.089	12.	0.0062	.0000096	846.612	0.037
40	.0031	3.1	0.079	10.	0.0049	.0000075	1079.188	0.029

HOW TO SPECIFY WIRE

IF NOT IDENTIFIED BY THE MANUFACTURER'S PART NUMBER
WIRE IS SPECIFIED BY THE FOLLOWING CHARACTERISTICS:



a. Gauge (awg)
b. Standing (bare or tinned) Number of strands
c. Type of primary insulation material. PVC, Polytetrafluoroethylene (PTFE), etc.
d. Thickness of primary insulation or working voltage for which the wire is to be used.
e. Color or coding of primary insulation**
f. Type and thickness of covering over primary insulation when required (i.e., nylon)
g. Type of shielding, braided or foil, if required
h. If braided, shield strand size, % of coverage, bare or tinned wire strands
i Overall jacket material, temperature range, thickness, color**, marking or coding

HOW NATIONAL WIRE PART NUMBERS ARE DERIVED

EXAMPLE

```
N C 1936U 9 - 0 - 2
                  └─ RED TRACER
              └───── BLACK TRACER
          └───────── INSULATION COLOR
    └─────────────── CATALOG NO.
```

BASIC COLOR CODE

0 - Black	5 - Green
1 - Brown	6 - Blue
2 - Red	7 - Violet (Purple)
3 - Orange	8 - Slate (Grey)
4 - Yellow	9 - White

N...............stands for National Wire and Cable Corporation.
C...............stands for Type "C" (as previously referred to in the spec).
1936..........means 19 strands of #36 copper which is equivalent to 24 gauge
U...............means "uncovered." That is, no jacket over the primary insulation.
902............refers to primary insulation base color and tracer colors as shown in the ..chart above. Tracers are numbered according to standard color code.

**Color limitation of tints is specified in MIL-STD-104, which comes supplied with a set of colored tabs for color comparison and identification.

TO ORDER RoHS COMPLIANT PRODUCTS: please add the letter "R" into the second position of the Part No.
EXAMPLE: Non-RoHS Part No NK1234 EXAMPLE: RoHS Part No NRK1234

Please refer to the National Wire Catalog for specific products that are RoHS available. The above instructions (always in green) will be listed on the applicable pages for the ordering process.

HOW TO SPECIFY PAIRS

WE RECOMMEND THE FOLLOWING FORMAT WHEN SPECIFYING TWISTED PAIRS AND TRIOS:

EXAMPLE

NB1934U - (2 A) - (0/2) - (0/4)

- (0/4) — Base color/stripe color
- (0/2) — Base color/stripe color
- A — Twisting code (see key below)
- 2 — No. of wires to be twisted (2 for pairs, etc.)
- NB1934U — Part No. for type of insulated wire

Part No. (see “How to Specify Wire”, Page 18)

KEY TO TWISTING CODE

A = SHORT TWINNER LAY
B = STANDARD TWINNER LAY
C = SHORT PLANETARY LAY
D = STANDARD PLANETRY LAY

THE “SHORT” LAY IS DEFINED AS EQUAL TO 5 X D X N AND THE “STANDARD” LAY IS DEFINED AS 10 X D X N WHERE D = CONDUCTOR DIAMETER, N = NO. OF CONDUCTORS

DIFFERENCES IN PAIR TWISTING

THE MOST COMMON COMMERCIAL PAIR-FORMING MACHINES ARE CALLED “TWINNERS.” THIS TYPE OF PAIR-FORMING IS THE LEAST EXPENSIVE WAY TO FROM TWISTED PAIRS. HOWEVER, PAIRS FORMED ON THIS TYPE OF EQUIPMENT HAVE BEEN KNOWN TO EXPERIENCE DEFORMATION OF THE STRANDED COPPER, STRAIN IN THE INSULATION AND POOR ELECTRICAL BALANCE.

THE SUPERIOR METHOD OF PAIR-FORMING IS BY USE OF A PLANETARY OR TUBULAR CABLING MACHINE IN SUCH A MANNER THAT NO RESIDUAL TWIST IS IMPARTED TO THE INDIVIDUAL WIRES FORMING THE TWISTED GROUP. THIS RESULTS IN BETTER ELECTRICAL BALANCE AND IMPROVES FLEXIBILITY.

NATIONAL IS EQUIPPED FOR ALL OF THE ABOVE DESCRIBED TECHNIQUES. CHOOSE THE METHOD BEST SUITED FOR YOUR PARTICULR APPLICATION.