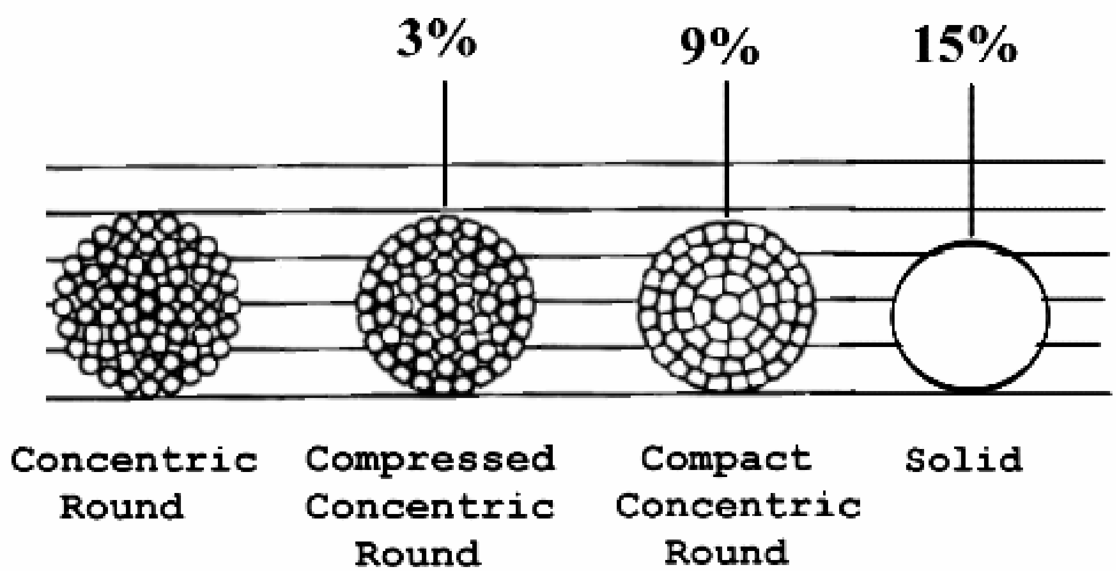
Wire Knowledge

Stranding Comparison



Conductor Coatings/Coverings

PURPOSE

- To facilitate stripping of components applied over the conductor
- To prevent compound fall-in
- Improve solderability
- Prevent Incompatibility Issues
- Provide electrostatic shielding for overlying insulation

TYPES

- Electroplate or Hot Dip Tin Alloy Metallic Coating
- Mylar (Opaque), Polyester or Paper Tape
- Extruded Semi-conducting Polymer Shield for MV Designs

Insulation Types

Thermoplastic

Definition: A classification for a solid insulation material that can be softened and made to flow by heating, extruded onto wire and quenched in cool water to make solid again. It can readily be softened and re-softened by repeated heating, but remains in a safely usable solid form when operated within its rated temperature limits.

Types	Normal Temperature Rating
▪ High Molecular Weight Polyethylene HMPE	75^{o}
▪ PolyVinyl Chloride (PVC)	60^{o}, 75^{o}, 90^{o}C
▪ Polypropylene	80^{o}
▪ Tefzel	150^{o}
▪ Teflon	150^{o} or 200^{o}C

Insulation Types

Thermoset

Definition: A classification for an insulation that is extruded onto wire and then, when subject to heat and pressure, undergoes a chemical change known as vulcanization, cross-linking or curing. The process fixes (sets) the physical properties of the material so that if it is again exposed to heat, the material will not melt, flow or drip.

Types	Normal Temperature Rating
▪ XLPE	90^oC
▪ XLPO (LSZH)	90^oC
▪ FR-EP	90^oC
▪ Silicone Rubber	125^oC
▪ Hypalon (Chlorosulfonated Polyethylene)	90^oC

Insulation Types

Thermoset (Cont.)

The preceding insulations are typically those used for low voltage applications (2000V or less). Listed below are insulations that are currently used in medium voltage (2001V and above) applications and high Integrity, low voltage cable designs.

Types	Normal Temperature Rating
▪ Cross-linked Polyethylene (XLPE)	105°C
▪ Ethylene-Propylene-Rubber (EPR)	105°C
▪ Ethylene Propylene Polymer (EPM)	105°C
▪ Ethylene Propylene Diene Polymer (EPDM	105°C
▪ Ethylene Alkene Co-Polymer (EAM)	105°C

Insulation Types

Thermoset (Cont.)

Thermoset insulations normally include a chemical catalyst additive such as sulfur or peroxide that provides the means for cross-linking of the material on the molecular level. Heat kicks off the cross-linking process and pressure is required to prevent bubbles/voids from forming due to out-gassing that occurs during the process. Following are processes typically used to make a material thermoset:

- Pressurized high temperature steam or Nitrogen cure (CV-Continuous Vulcanization)
- Lead or polymer mold - steam autoclave cure
- Moisture catalyst cure/cross-linking
- High energy electron beam cross-linking

Jackets

PURPOSE

- To protect the underlying cable core from mechanical, moisture and chemical damage during the installation and service life of the cable
- Enhance flame resistance
- Improve sunlight and electrical surface tracking resistance
- Facilitate installation
- Provide means for cable identification and grouping

Types of Jackets

Thermoplastic

▪ Polyvinyl Chloride	PVC
▪ Polyethylene	PE
▪ Nylon (Polyamide)	
▪ Chlorinated Polyethylene	CPE
▪ Thermoplastic Polyolefin	TPO

Thermoset

▪ Neoprene (Polychloroprene)	CR
▪ Hypalon (Chlorosulfonated Polyethylene)	CSPE, CP
▪ Nitrile / PVC (Blend of Nitrile Rubber & PVC)	NBR/PVC
▪ Chlorinated Polyethylene	CPE
▪ Cross-linked Polyolefin	XLPO

Single Conductor 600 Volt Cables

THW	THHN / THWN	XLP-XHHW	EPR HYPALON
Supply Problem	Stock	Stock	Stock
Lowest Cost	Low Cost-Circuit Sizes	Low Cost-Large Sizes	Highest Cost
75°C	90°C / 75°C	90°C	90°C / 75°C
Colors	Colors	Colors	Black Only
Larger OD	Small OD	Small OD	Larger OD
Fair Electricals	Fair Electricals	Good Electricals	Good Electricals
Good Moisture Res.	Good Moisture Res.	Excellent Moisture Res.	Excellent Moisture Res.
Pulls Easy	Pulls Easy	Pulls Easy	Pulls Harder
Good Flame Res.	Good Flame Res.	Poor Flame Res.	Good Flame Res.
Good Oil Res.	Good Oil Res.	Poor Oil Res.	Good Oil Res.
Good Chemical	Good Chemical	Good Chemical	Good Chemical
Poor Low Temp. -10°C(+14°)	Poor Low Tep. -10°C (+14°)	Excellent Low Temp.	Good Low Temp.

Single Conductor Assemblies

Tray Cable & Interlocked Armor

WHY USED:

- Lower installed cost system compared to pipe & wire
- Complete system installed at one time
- Accidental installation damage easily found and repaired when installed in tray
- Easier/cheaper to accommodate future changes in branch circuits/taps when installed in tray
- Same cable can be used in wide variety of installations – tray, duct, conduit, aerial or direct buried
- Jacket on UL Type TC (Tray Cable) and Armored (UL Type MC) provides mechanical, moisture and chemical protection during installation
- Greatly enhanced flame retardant system

Tray Cable & Interlocked Armor

Comparison

TRAY CABLE	INTERLOCKED CABLE
Lighter	More Rugged
Easier To Install	Better Flame
Lower Cost	

Color Coding / Phase Identification

- Color Coding Methods (8 total)
  - Method 1 – Full Colored Phase Conductors
  - Method 2 – Printed Numbers & Color (1-Black)
  - Method 4 – Black Phase Conductors With Printed Numbers (1-One)
- NEC Requirements
- ICEA Standard Color Coding Tables (7 total)
- Table E-2 for NEC Applications (ICEA S-73-532)

Tray Cable & Interlocked Armor

WHERE USED:

- In Industrial Establishments
- In Process Industries:
  - Petrochemical
  - Pulp & Paper
  - Chemical Plants
  - Automotive
  - Steel Mills
  - Cogeneration
  - Waste Water Treatment
- On Cable Tray Support Systems
- Some Usage In:
  - Conduit
  - Direct Burial
  - Underground Duct
  - Aerial – Messenger Supported

Medium Voltage Cable 2001 Volt Through 35kV

MEDIUM VOLTAGE CABLE: Cables having a voltage rating of 2001 volts and higher

CONSTRUCTION COMPARISON: BASIC CABLE

600V	**MV**
Conductor	Conductor
Insulation	Conductor Shield
Jacket (optional)	Insulation
	Insulation Shield (5kV-35kV)
	Jacket

DEFINITION OF SHIELDING:

Shielding of an electric power cable is the practice of confining the electric field of the cable within the insulation surrounding the conductor. It is accomplished by means of semiconducting conductor shield and, semiconducting insulation shield that is in combination with an overlying metallic shield

Medium Voltage Cable Conductor (Strand) Shield

PURPOSE

- To prelude excessive voltage stress on voids between conductor and insulation and eliminate voltage stress enhancing protrusions/ dimensional irregularities to provide a smooth electrode

TYPE

- Extruded semi-conducting material compatible with the insulation and the conductor and shall have allowable operating temperatures equal to or higher than those of the insulation

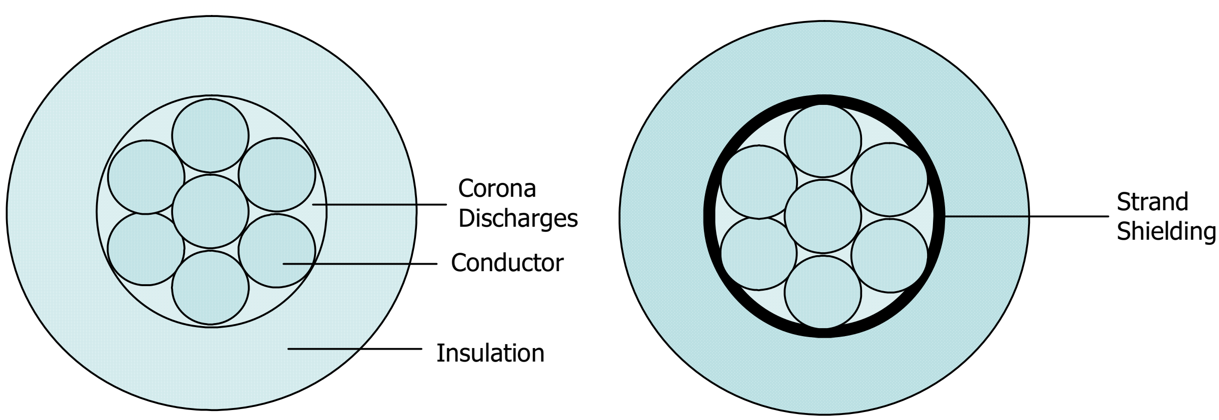
BASIC REQUIREMENTS

- Firmly bonded to the overlying insulation
- Easily removable from the conductor
- Chemically, physically and thermally compatible with conductor and insulation

Medium Voltage Cable

Conductor (Strand) Shielding

- The semi-conductive layer between conductor and insulation which compensates for air voids that exist between conductor and insulation.
- Air is a poor insulator, having a nominal dielectric strength of only 55 volts per mil, while most cable insulations have dielectric strengths over 700 volts/mil. Without strand shielding an electrical potential exists that will over-stress these air voids.
- As air breaks down or ionizes, it goes into corona (partial discharges). This forms ozone which chemically deteriorates cable insulations. The semi-conductive strand shielding eliminates this potential by simply "shorting out" the air.
- Modern cables are generally constructed with an extruded strand shield.



Medium Voltage Cable

Insulation Types

- Cross-linked Polyethylene (XLP)
  - Unfilled vs. Mineral Filled
  - Tree Retardant (TRXLPE)
- Ethylene – propylene – rubber (EPR)
  - EPDM, EPM and EAM
- XLP or EPR
  - Both are excellent solid dielectric
  - 105^{o}C rated for XLP
  - 105^{o}C rated for EPR

XLP	**EPR**
▪ Lower Cost	▪ More Flexible – Easier to Install
▪ Better Electricals	▪ Better Water Treeing Resistance (Electric Utility Application)
▪ Mechanically Tougher	▪ Better Flame Resistance
	▪ Increased Thermal Stability

Medium Voltage Cable

INSULATION

Insulation Level

100%	=	GROUND FAULT CLEARING TIME <= 1 MIN.
133%	=	GROUND FAULT CLEARING TIME <= 1 HR.
173%	=	GROUND FAULT CLEARING TIME INDEFINITE

Medium Voltage Cable

INSULATION

Cable Insulation Thickness Comparison Chart

Industry Standard	5kV-100%	5kV-133%	8kV-100%	15kV-100%	15kV-133%	25kV-100%	25kV-133%	35kV-100%
UL MV-105, ICEA S-93-639	.090″	.090″	.115″	.175″	.220″	.260″	.345″	.345
AEIC CS8 ICEA S-97-682	.090″	.115″	.115″	.175″	.220″	.260″	.345″	.345

Medium Voltage Cable

INSULATION SHIELD (NON-METALLIC)

PURPOSE

- To confine the electric field within the cable insulation
- To obtain symmetrical radial distribution of voltage stress within the solid dielectric (insulation)
- To reduce hazard of shock to personnel
- To eliminate damaging effects of varying electrical conductivity of installation environment
- To transfer cable insulation charging current to the metallic shield

Medium Voltage Cable

INSULATION SHIELD (METALLIC)

PURPOSE

- To safely carry the cable charging current off to a solid ground point
- To provide a substantial barrier for an increase in flame retardancy of the cable core
- To protect the cable core from mechanical damage, including rodent/termite attack (Bronze tape)
- To assist in carrying fault current (Not primary function and capability will depend on cross section/size of the metallic shield)

Medium Voltage Cable

INSULATION SHIELD (METALLIC)

TYPES

- Corrugated longitudinally applied copper wires
- Helically applied copper wires (drain wire/concentric neutral)
- Helically applied and overlapped copper tape
- Lateral serve, corrugated copper tape

Medium Voltage Cable

JACKETS

Thermoplastic

▪ Polyvinyl Chloride	PVC
▪ Linear Low Density Polyethylene	LLDPE
▪ Chlorinated Polyethylene	CPE
▪ Semiconducting Chlorinated Polyethylene	CPE
▪ Thermoplastic Polyolefin	TPO

Medium Voltage Cable

SHIELDED VS. NON-SHIELDED

Shielded Cable

- Most reliable, long-lived cable design
- Provides uniform stress distribution eliminating possibility of surface tracking and discharges
- Termination kits required
- Reduces shock hazard to personnel
- Protection provided for cables connected to overhead lines or otherwise subject to induced potentials

Non-Shielded Cable

- Less costly than shielded cable
- May be susceptible to surface discharges in wet, contaminated areas
- No termination kits required – lower cost installation
- Shock hazard to personnel does exist
- Convenient for terminating in motor terminal boxes where there is no room for stress cones on shielded cables
- **NOTE: NON-SHIELDED AVAILABLE IN ONLY 2.4kV, MAX**

Medium Voltage Cable

INSULATION COMPOUND COMPARISONS

INSULATION	Thermal Stability	Moisture Resistance	Ruggedness	Flexibility	Splicability	Oil Resistance	Chemical Res.	Flame Res.	Smoke Environment	Acid Gas Generation	Dissipation Factor	SIC	Dielectric Strength	Impulse Strength	Corona Resistance	Electrical Stability H20	Dielectric Losses	Cost
XLP	3	5	4	1	3	2	3	1	2	4	5	5	4	5	4	4	5	4
TR-XLP	3	5	4	1	3	2	3	1	2	4	4	5	4	5	4	4	4	3
EPR	5	4	3	3	4	2	4	3	3	4	3	4	3	4	5	5	3	2

Ratings:
5 = Exceptional
4 = Excellent
3 = Good
2 = Fair
1 = Poor

Medium Voltage Cable

JACKET COMPOUND COMPARISONS

JACKET MATERIAL	Physical Toughness	Heat Resistance	Flexibility	Moisture Resistance	Oil Resistance	Sunlight Resistance	Chemical Resistance	Low Temp. Properties	Flame Resistance	Smoke Emission Char	Acid Gas Emission	Coef Friction	Cost
PVC	3	2	3	3	3	3	4	2	3	2	1	3	5
LT-PVC	3	2	3	3	3	3	4	4	3	2	2	3	4
PE	3	1	2	5	1	4	4	4	4	1	5	5	5
CPE	4	4	1	3	4	4	4	3	3	3	2	5	3
HYP	3	4	4	4	4	4	4	3	4	2	2	2	2
POLYO	4	4	1	3	4	4	4	3	4	5	5	4	1

Ratings:

5 = Exceptional
4 = Excellent
3 = Good
2 = Fair
1 = Poor

All Products Flame Tests

- UL Horizontal Flame Test
- UL Vertical Flame Test
- VW-1 Vertical Wire Flame Test
- IEEE-383 & UL 70,000 BTU/HR Ribbon Burner Flame Test
  - UL-TC, For CT Use
  - UL-LS
- ICEA T-29-520 210,000 BTU/HR Ribbon Burner Flame Test
- IEEE-1202
- FT-4

Codes & Standards

▪ NEC	National Electrical Code
▪ UL	Underwriters Laboratories
▪ CSA	Canadian Standards Association
▪ ICEA	Insulated Cable Engineers Association
▪ NEMA	National Electrical Manufacturers Association
▪ AEIC	Association of Edison Illuminating Co's.
▪ ASTM	American Society for Testing & Materials
▪ IEEE	Institute of Electrical & Electronic Engineers