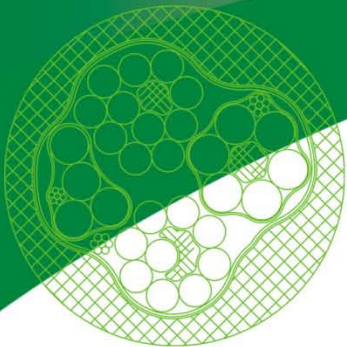


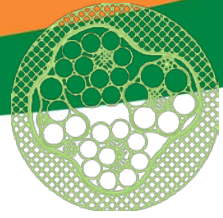
CABLE BASICS

Sizing and Selection
Standard vs. Custom



Presented by

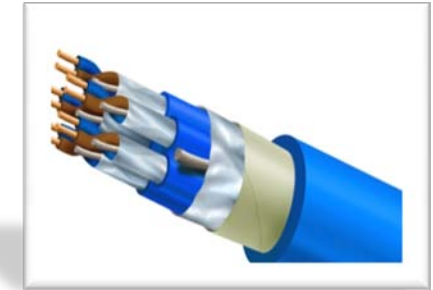
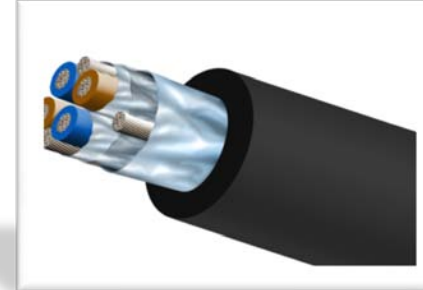
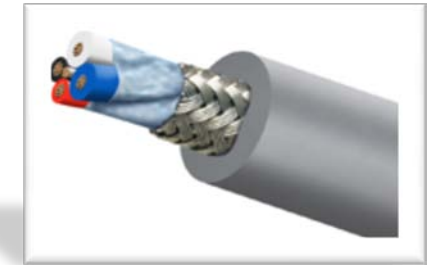
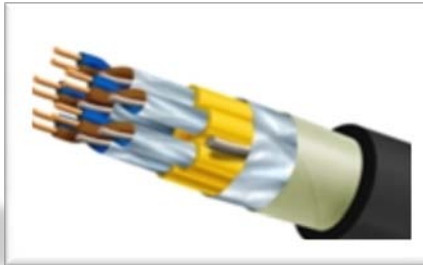
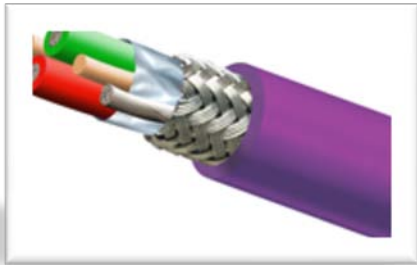
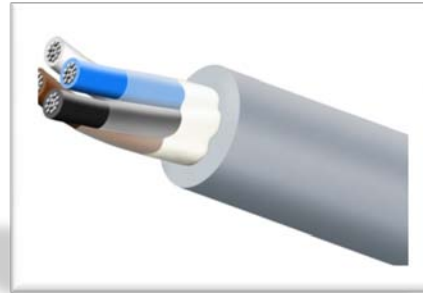
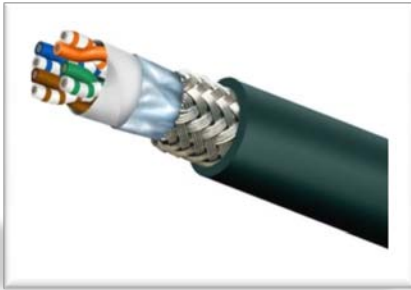




A cable
is a cable is
a cable – right ?

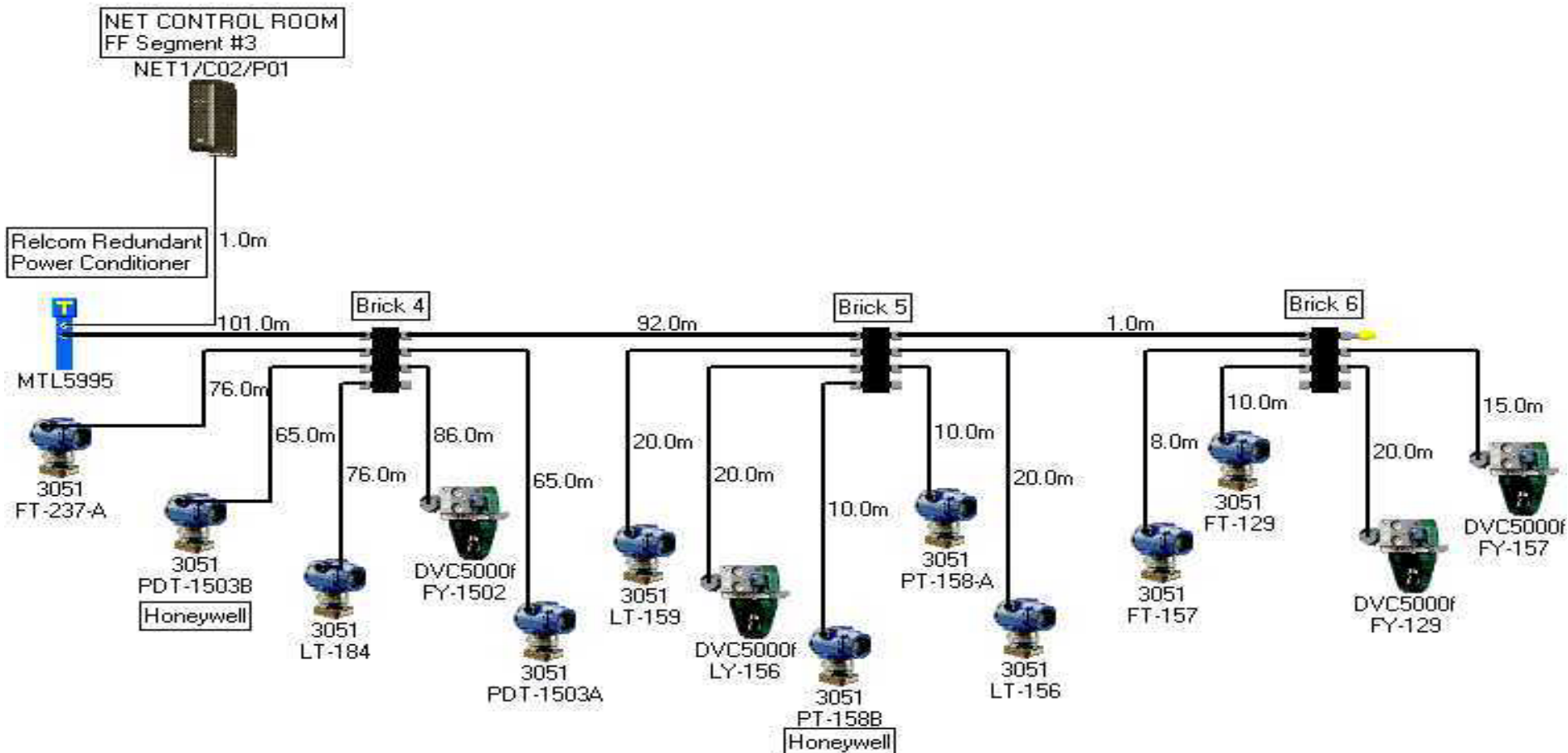


They all look sort of the same





They look the same on a schematic





Today's topics

- ▶ Cable basics
- ▶ Things to consider
- ▶ Choices available
- ▶ How to choose the best cable solution for *your* project



By the end of today's webinar you will

- ▶ Gain an awareness of how cable is manufactured
- ▶ Have a list of questions to ask when selecting cable
- ▶ Acquire knowledge about various materials available for cable construction
- ▶ Learn about some of the tests required for cable
- ▶ Have a better understanding of how to choose the best cable solution for *your* project



How is cable manufactured?

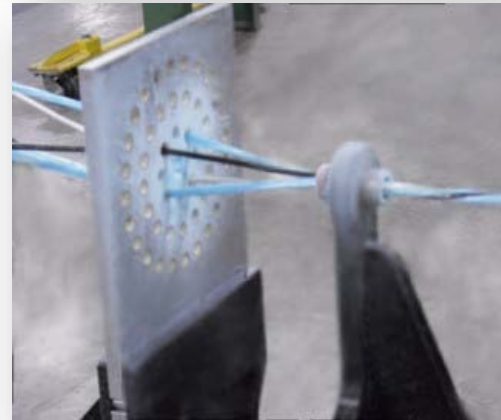
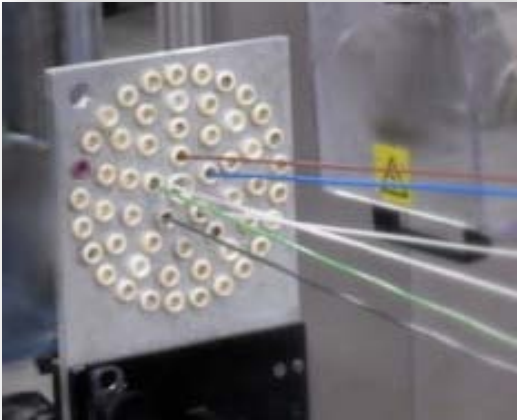


Step 1: Insulating the conductors



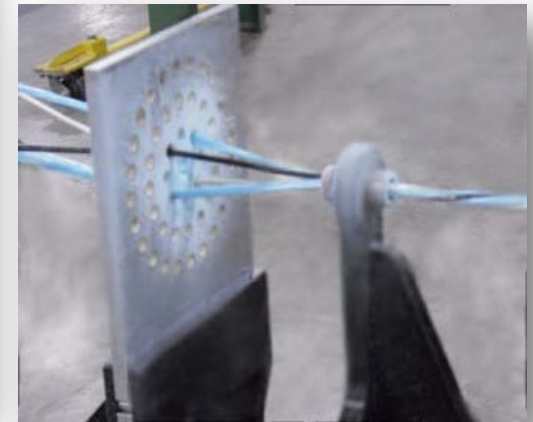


Step 2: Cabling



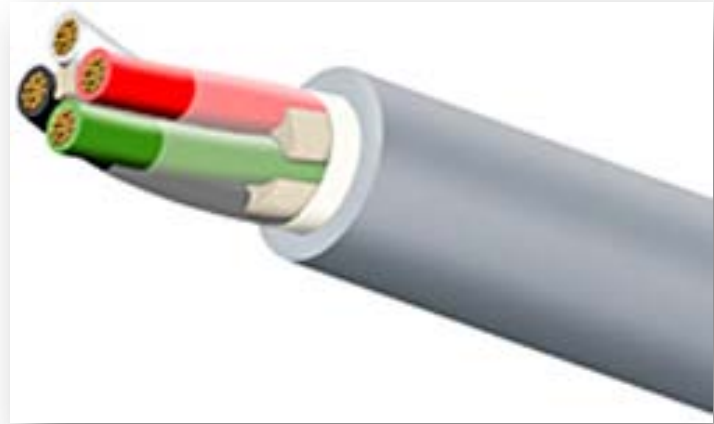
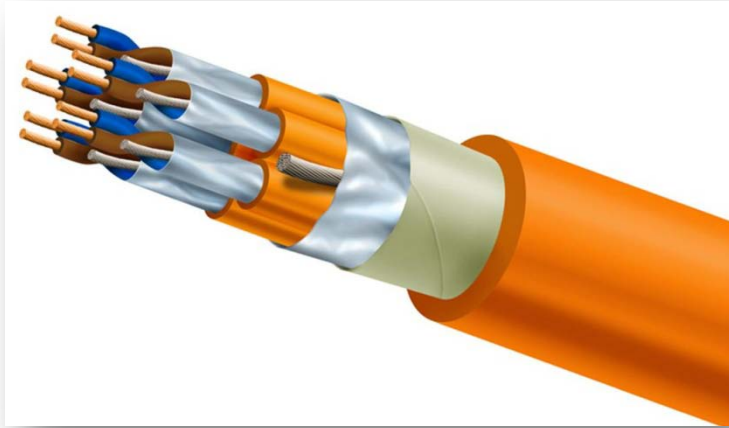


Step 3: Shielding, if required





Step 4: Jacketing





You have choices
in each of the
manufacturing steps



Choice influences and questions to ask

- ▶ Application: What is the cable's primary use?
 - ▶ Instrumentation and control
 - ▶ Power
 - ▶ Communication
 - ▶ Specific network or control system requirements

- ▶ Are there specific agency approvals required?
 - ▶ UL
 - ▶ CSA
 - ▶ CE
 - ▶ NFPA
 - ▶ SAE
 - ▶ IEC
 - ▶ VDE
 - ▶ FDA
 - ▶ ABS
 - ▶ IEEE
 - ▶ DNV
 - ▶ NEK 606
 - ▶ MSHA
 - ▶ USP
 - ▶ TUV



Agency approvals – examples

- ▶ UL-recognized appliance wiring material (AWM)
 - ▶ 30V to 1000V
- ▶ UL-listed
 - ▶ 600V to 2000V tray cable (TC)
 - ▶ 300V power-limited tray cable (PLTC)
 - ▶ 150V instrumentation tray cable (ITC)
 - ▶ Flex cord (power cord) 300V or 600V
- ▶ The approvals required help define materials choices



Electrical requirements

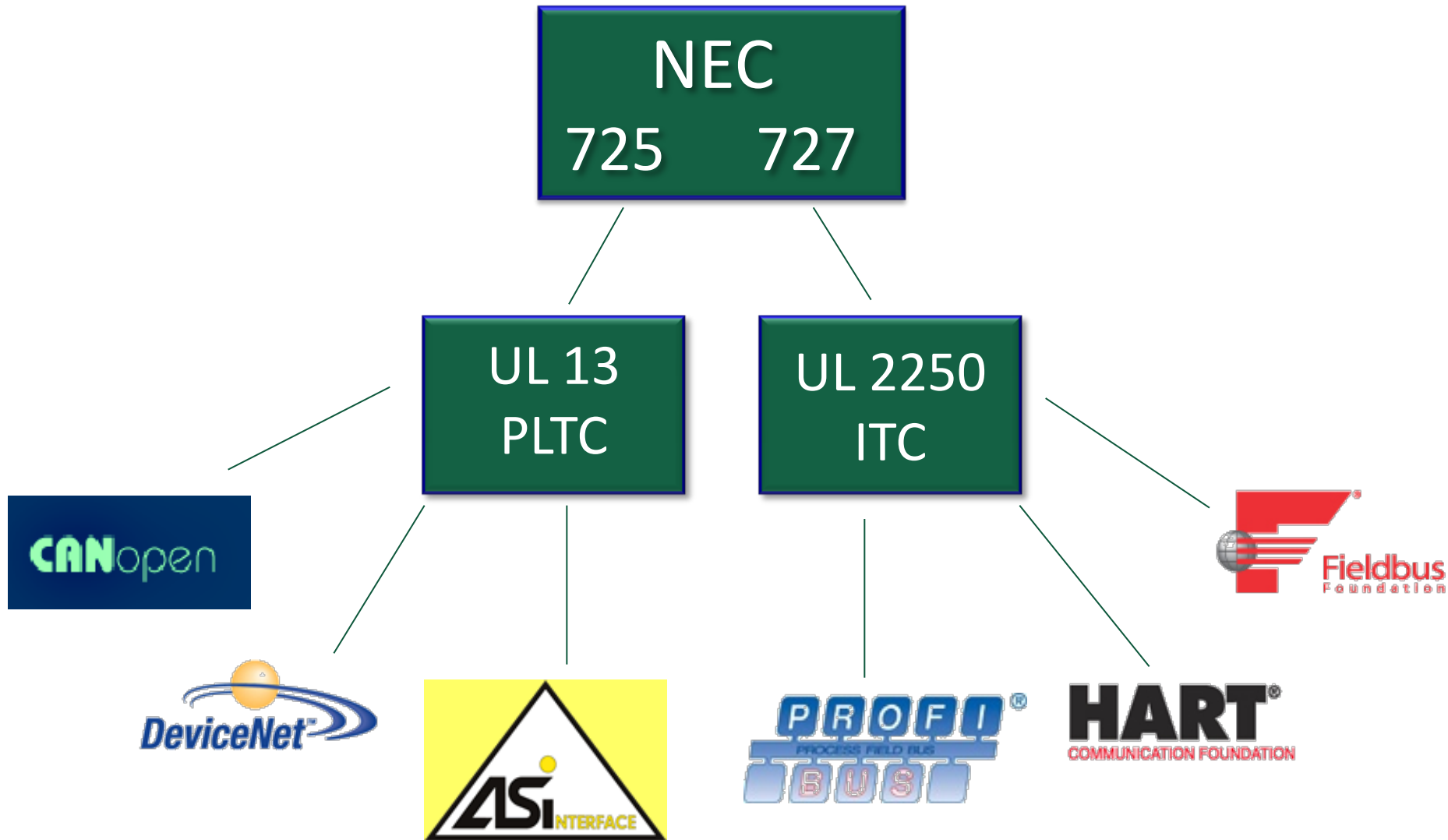
- ▶ Voltage and amperage
- ▶ Specified characteristic impedance
- ▶ Low or controlled capacitance
- ▶ Velocity of propagation
- ▶ Signal attenuation
- ▶ Audio or video specs
- ▶ Electromagnetic interference (EMI) or radio frequency interference (RFI) shielding requirements



Specify network protocol



NEC and UL work together





Questions to ask

- ▶ Stay with us here!
- ▶ At this point you may have the answers that apply to your project
- ▶ Let's review other considerations to give you questions you CAN ask and available options



Environment

- ▶ Temperature range – high and low
- ▶ Presence of water or other fluids
 - ▶ Occasional exposure, accidental after-splash and submersion
 - ▶ How long and at what temperatures
- ▶ Chemical exposure
 - ▶ Identify chemical(s) and concentrations
 - ▶ Liquid, solid or gas
 - ▶ For how long and at what temperatures
- ▶ Exposure to oils, fuels, solvents and more
- ▶ Wash-down or sterilization required



Environment

- ▶ Prolonged ultraviolet (UV) exposure
 - ▶ Sunlight
 - ▶ Weld flash
- ▶ Exposure to other contaminants
 - ▶ Dirt, dust and other contaminants
 - ▶ Bodily fluids (medical applications)
- ▶ Exposure (or potential) to flame
 - ▶ How much and how long
 - ▶ Hazardous-area classification



Physical characteristics

- ▶ Flexibility
- ▶ Flex-life
- ▶ Abrasion
 - ▶ How long and how often
- ▶ Dimensional requirements – size constraints
- ▶ Aesthetics
 - ▶ Look and feel
- ▶ How will the cable be assembled
 - ▶ Mold material types



WHEW !!!!!

- ▶ Seem complicated? It's really not
- ▶ Are you convinced that all cables are not alike?
- ▶ One size does not fit all
- ▶ A qualified cable design specialist can guide you through the details



Materials choices

- ▶ Conductor types
- ▶ Insulations
- ▶ Shielding options
- ▶ Jacketing options



Conductor types

- ▶ Copper stranding is the most common
- ▶ Bare copper
 - ▶ Looks like a shiny new penny
 - ▶ Cost-effective
 - ▶ Good for sonic welding
 - ▶ Up to 150°C
 - ▶ Pure electrical signal over long distances





Conductor types

▶ Tinned copper

- ▶ Looks like a shiny new dime
- ▶ Easier to solder than bare copper
- ▶ Corrosion-resistant
- ▶ Up to 150°C
- ▶ Fine stranding available
- ▶ Tinning adds some cost if your vendor doesn't buy in volume





Conductor types

- ▶ Silver-plated copper
 - ▶ Purer than copper
 - ▶ Dielectric clarity
 - ▶ Lower oxygen content
 - ▶ Up to 260°C
 - ▶ The audiophile's choice



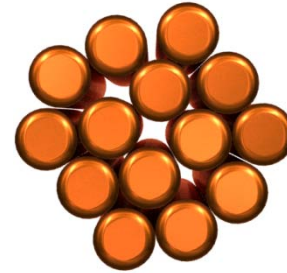
Conductor types

- ▶ Many alloys are available
 - ▶ Silver, nickel, cadmium and others
 - ▶ Select for toughness
 - ▶ Break strength
 - ▶ Flex-life
 - ▶ High-temperature
- ▶ Steel
 - ▶ Not a great dielectric unless coated
 - ▶ Strong with less stretch
 - ▶ Frequently used in military applications

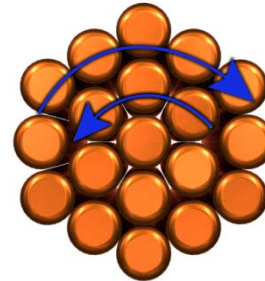


Conductor types

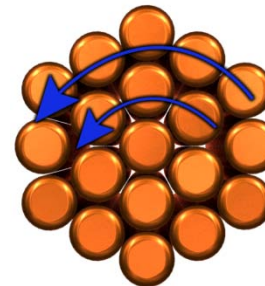
- ▶ Bunched is least expensive
- ▶ Concentric
- ▶ Semi-concentric
- ▶ Unilay
 - ▶ Tightly controlled electrical properties
 - ▶ Flex-life
 - ▶ Flexibility
- ▶ Rope-lay
 - ▶ Flex-life
 - ▶ Flexibility



Bunched



Concentric



Unilay



Insulations *(from least expensive to most)*

- ▶ Polyvinyl chloride (PVC) is most common
- ▶ Polyolefins: 80°C maximum temperature with very good electrical properties and low water absorption. Poor flame resistance can be overcome with jackets.
 - ▶ Polyethylene (PE)
 - ▶ Polypropylene (PP)
 - ▶ Foamed PE
- ▶ Cross-linked polyethylene (XLPE)
 - ▶ 105°C + maximum temperature
 - ▶ Very good electrical properties



Insulations

- ▶ Thermoplastic elastomers (TPE)
 - ▶ Broad category, but can have high temp ratings
 - ▶ Many different durometers (softness and flexibility)
 - ▶ Some are highly oil resistant

- ▶ Polypropylene (PP) and ethylene propylene diene monomer (EPDM) blends (Santoprene™)
 - ▶ Food grades and medical grades available
 - ▶ Resistant to wash-down and many chemicals

Santoprene is a trademark of Advanced Elastomer Systems, LP.



Insulations

- ▶ Polyester elastomer (Hytrel®)
 - ▶ -70°C to 105°C
 - ▶ Excellent cut and abrasion resistance
 - ▶ Reliable with thin walls
 - ▶ Poor dielectric
 - ▶ Low friction (high flex-life cables)
 - ▶ Less expensive than fluoropolymers



Hytrel is a registered trademark of DuPont.



Insulations

▶ Fluoropolymers

- ▶ Fluorinated ethylene propylene (FEP)
- ▶ Ethylene tetrafluoroethylene (ETFE)
 - ▶ Tefzel[®], Fluon[®] and Neoflon[™]
- ▶ Perfluoroalkoxy (PFA) polymer
- ▶ Ethylene chlorotrifluoroethylene (ECTFE)
 - ▶ Halar[®]

Tefzel is a registered trademark of DuPont, Fluon is a registered trademark of Asahi Glass Company, Neoflon is a trademark of Daikin Industries, Limited and Halar is a registered trademark of Solvay Polymers, Inc.



Insulations

▶ Fluoropolymers

- ▶ Cold temps -70°C or better
- ▶ Tefzel[®] 150°C to 200°C , FEP 150°C to 200°C , PFA to 260°C
- ▶ Excellent resistance to most chemicals
- ▶ Frequently the choice for clean room environments
- ▶ Fairly rigid material
- ▶ Low friction (flex-life)
- ▶ Abrasion resistant
- ▶ Highly flame retardant
- ▶ ETFE (Tefzel) does not emit toxic fumes when ignited (aerospace wire)
- ▶ Low dielectric constants

Tefzel is a registered trademark of DuPont.



Shielding options

- ▶ Multiple reasons to include shielding
 - ▶ Mechanical strength
 - ▶ Rodent or insect resistance
 - ▶ Electromagnetic compatibility (EMC)
- ▶ Shielding can be designed to protect components within the cable or the cable as a whole
- ▶ Foils, drains and braids are all options
- ▶ Shielding scheme can be adapted to your application





Tapes, wraps and fillers

- ▶ Clear or opaque Mylar[®] to bind core
- ▶ Paper wrap for jacket stripability
 - ▶ Used in place of rip cords
- ▶ PTFE or spun nylon tapes to improve flex-life
- ▶ Fillers may be used to keep cable round
 - ▶ Easier molding and sealing in glands
- ▶ Water-blocking tapes and fillers are available

Mylar is a registered trademark of DuPont.



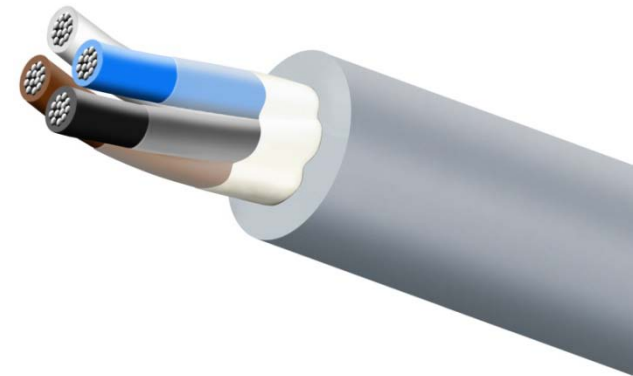
Jacketing – PVC

- ▶ Many grades available
- ▶ Temperature range -40°C to 105°C
- ▶ Durometers vary
- ▶ RoHS-compliant options
- ▶ Varying degrees of oil resistance
- ▶ Nonmigratory versions offered
- ▶ Ultraviolet (UV) stability varies
- ▶ Flame resistance varies widely
- ▶ Some pass severe crush and impact tests



Jacketing – TPE

- ▶ Thermoplastic elastomer (TPE)
- ▶ Temperature range -60°C to 105°C
 - ▶ Some remain flexible even in severe cold
- ▶ Durometers vary
- ▶ Can be highly oil resistant (Oil Res I & II)
- ▶ Often weather rated
- ▶ May have excellent flex-life properties
- ▶ Weld slag-resistant versions available
- ▶ Flame resistance varies widely
- ▶ Some pass severe crush and impact tests





Jacketing – TPU

- ▶ Thermoplastic polyurethane (TPU)
 - ▶ Polyether-based or
 - ▶ Polyester-based (poor in water)
- ▶ Various grades available
 - ▶ Some are alloys for cost-effectiveness
- ▶ Temperature range -60°C to 105°C
- ▶ Some have excellent cold-impact resistance
- ▶ Can be highly oil resistant (Oil Res I & II)
- ▶ Superior cut and abrasion resistance



Jacketing – TPU

- ▶ May have excellent flex-life properties
- ▶ Flame resistance varies widely
- ▶ Resistant to many chemicals
- ▶ Finishes vary from shiny to satin to matte
- ▶ Flame resistance varies from -0- to UL 1685
- ▶ Some pass severe crush and impact tests
- ▶ Excellent for coiling (retractile cords)



Jacketing – other options

- ▶ Polyethylenes
 - ▶ 80°C
- ▶ Polyester elastomer (Hytrel®)
 - ▶ Excellent for retractile cords
- ▶ Fluoropolymers
 - ▶ Excellent for higher temperatures
 - ▶ Rigid
 - ▶ Expensive
- ▶ New options such as low-smoke zero halogen (LSZH)

Hytrel is a registered trademark of DuPont.



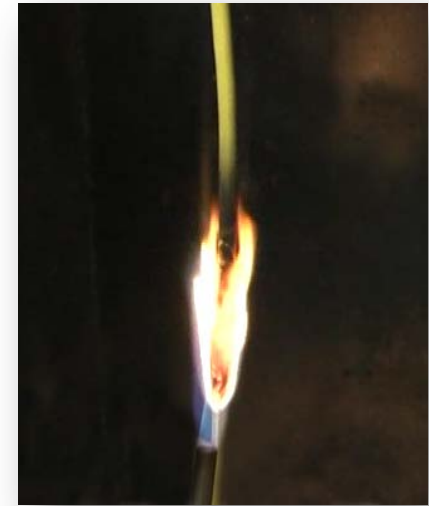
Testing and requirements

- ▶ Flame tests
- ▶ Ultraviolet (UV) tests
- ▶ Exposed-run (ER)



Flame tests

- ▶ Agency approvals require flame tests of various difficulty
- ▶ Recognized materials (AWM) may require as little as three one-minute bursts of flame from a turrill burner (internal wiring only)
- ▶ Listed cables, including tray cable (TC), instrument tray cable (ITC) and power-limited tray cable (PLTC) require UL 1685 or CSA FT4 flame testing





IEC 332-2 Cat A, UL 1685, IEEE 1202 and CSA FT4 Flame Test Comparisons

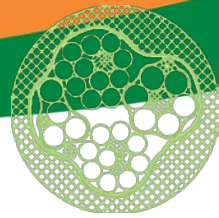
Test	IEC 332-3 Cat A	UL 1685 Vertical Tray	IEEE 1202/FT4
Flame BTU/Hr	70,000	70,000	70,000
Burner type	10-inch burner w 3 rows of holes, 81, 80 and 81 per row	10-inch ribbon burner	10-inch ribbon burner
How is the flame applied?	90 degrees perpendicular to sample	90 degrees perpendicular to sample	20 degrees up from the floor
Chamber height or length and sample location	11.5 feet, back of chamber nearly against the wall (potentially stricter than FT4)	8 feet, center of chamber	8 feet, center of chamber
Duration of flame	40 minutes	20 minutes	20 minutes
Acceptance criteria	Flame shall not propagate upward more than 8.2 feet (2.5 m)	Fails if flame propagates to the top of the cable tray	FT4 measures char length max 150 cm (50 inches) – IEEE measures melt/blistering
Sample footage determination	Determine sample volume per meter, IEC 60332-3-23 for further determination	Sample OD divided by 48 x 3	Dependent on OD, cables are bundled; refer to UL 13 or 444 procedure, similar to UL 1685



Ultraviolet (UV) resistance tests

- ▶ 720-hour xenon arc test
- ▶ Cable must retain at least 80 percent of the original tensile and elongation
- ▶ Not a guarantee of color fastness





Exposed-run (ER)

- ▶ 600V to 2000V tray cable, exposed-run (TC-ER), control and instrumentation tray cable, (CIC-TC)
- ▶ 300V power-limited tray cable (PLTC)
- ▶ 150V instrument tray cable (ITC)
 - ▶ Meet the same crush and impact tests of metal-clad cable, but without the metal
 - ▶ May be run exposed as long as protected and supported every 1.6 meters
 - ▶ This can be a significant cost savings over armored cable or use of conduit





Custom vs. standard

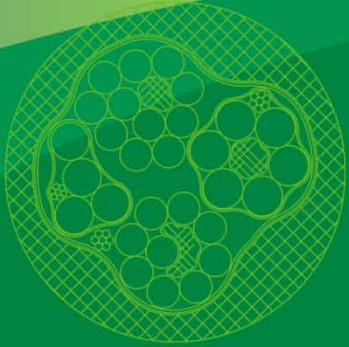
- ▶ Some off the shelf cables may meet your needs
 - ▶ Review the same questions to be certain you are specifying the correct cable for the job
- ▶ Custom cables are also an option
 - ▶ An experienced cable design specialist will ask the right questions and help specify a cable to meet your requirements
 - ▶ Why settle for an extra conductor or properties that don't fit what you really need
 - ▶ The exact custom cable you require may cost less than a standardized off the shelf cable



Custom vs. standard

- ▶ Custom cable:
 - ▶ Could save installation time and money
 - ▶ Can be color coded
 - ▶ Is available in composite configurations
- ▶ Be sure to ask!
 - ▶ You have choices. Consider your options.
 - ▶ This will ensure you receive the best cable solution for *your* project





CABLE BASICS

Thank you for joining us!

Have technical questions? Speak directly with one of our engineers



Steve Kedrowski

steven.kedrowski@northwire.com

Electrical Engineer • Program Manager
Government and Energy

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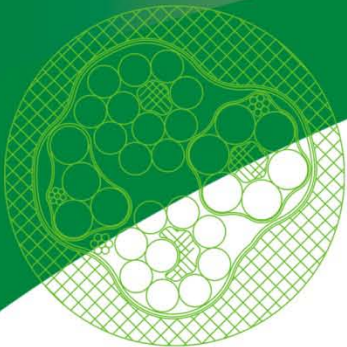
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