



Understanding North American Medium Voltage Cable Standards

November 27, 2025

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HOUSEKEEPING

- Questions can be asked at any time using the chat function on the webinar screen
- Any unanswered questions will be followed up through email
- This presentation, a recording of the webinar and a brief survey will be emailed to all registrants

Agenda

- 1 | Context
- 2 | North American Standards
- 3 | Basic Construction Requirements
- 4 | Physical/Mechanical Tests
- 5 | Electrical Tests
- 6 | Environmental/Chemical Resistance Tests
- 7 | Key Differences
- 8 | Decision Flow Chart

1. CONTEXT

Medium voltage (up to 46kV) cable standards exist to ensure safety, reliability, quality, performance and compatibility.

Requirements evolve over the years thanks to technological advancements, new scientific data, continuous improvement, and manufacturing/field experiences.

Safety

Reliability

Quality

Performance

Compatibility

1. CONTEXT

This presentation will review the **various design and testing requirements** in the main MV cable standards in North America.

We will also take a **deeper dive into** some of **design components** and finish with a **decision flowchart** to help determine what standard to specify a cable to.

Standards

CSA

CSA C68.5
CSA C68.10

ICEA

ICEA S-94-649
ICEA S-97-682
ICEA S-93-639
ICEA S-113-684

UL

UL 1072

Bonus: AEIC CS8 Specification (*Optional*)

Voltage range: Up to 46 kV



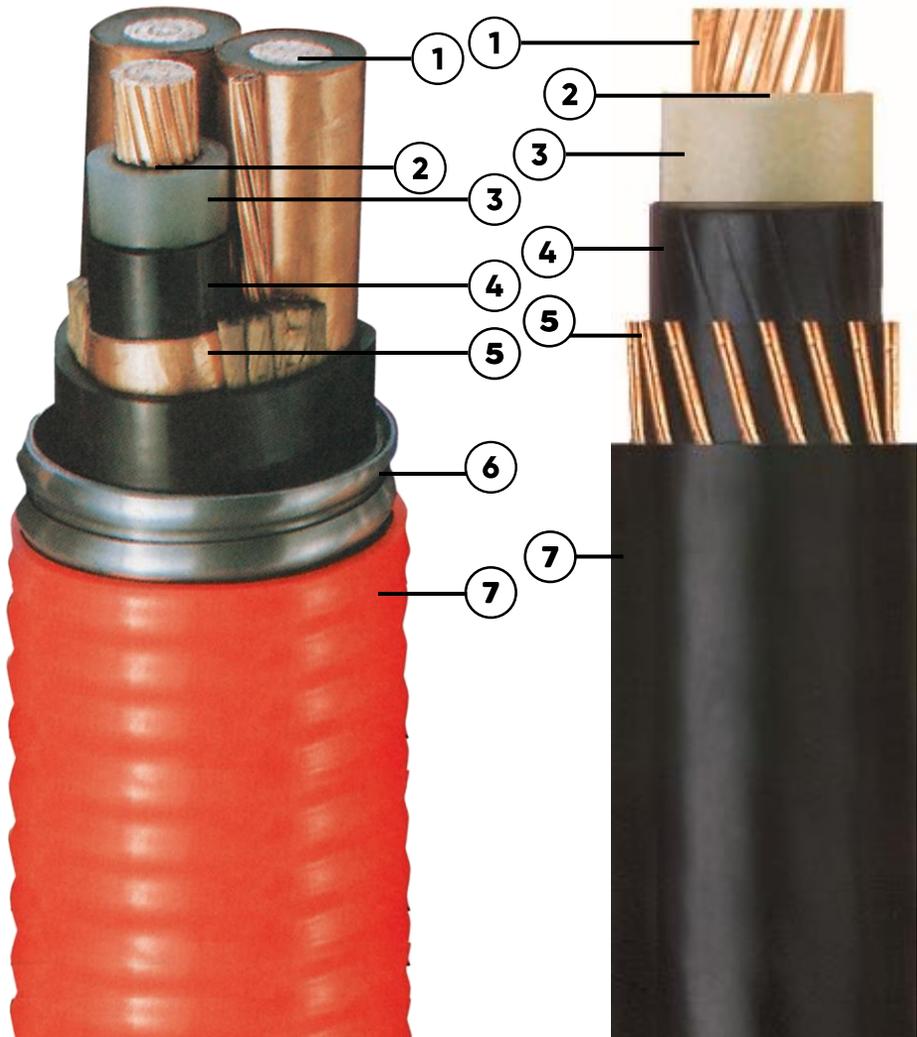
2. KEY NORTH AMERICAN STANDARDS

Standard	Voltage Range	Region	Scope	
CSA C68.5	15 – 46 kV <i><15kV possible</i>	Canada	Shielded power cables for use by electric utilities.	
CSA C68.10 (Type MV68.10)	5 – 46 kV	Canada	Shielded power cables for commercial / industrial installations within scope of the CE Code.	
ICEA S-94-649	5 – 46 kV	US / Canada	Concentric neutral cables for use by electric utilities.	
ICEA S-97-682	5 – 46 kV	US / Canada	Shielded power cables for use by electric utilities	
AEIC CS8	5 – 46 kV	US / Canada	Supplementary specification to ICEA S-94-649 and S-97-682	
ICEA S-113-684	5 – 46 kV	US / Canada	Shielded power cables with reduced diameters for use by electric utilities	
ICEA S-93-639 / ANSI/NEMA WC74	5 – 46 kV	US / Canada	Shielded power cables for commercial/industrial.	
UL 1072 (Types MV90/MV105)	2 – 35 kV	US	Shielded/Non-shielded cables for commercial/ industrial installations within scope of the NEC	

2. KEY NORTH AMERICAN STANDARDS

Standard	Typical Applications
CSA C68.5	Direct burial, installation in ducts in wet/dry locations, and exposure to sunlight
CSA C68.10 (Type MV68.10)	Indoor, outdoor, vertical, underground, aerial, or underwater installation. Suitable for cable tray if armoured (or unarmoured with TC rating)
ICEA S-94-649	Direct burial, installation in ducts in wet/dry locations, and exposure to sunlight.
ICEA S-97-682	Direct burial, installation in ducts in wet/dry locations, and exposure to sunlight.
AEIC CS8	Direct burial, installation in ducts in wet/dry locations, and exposure to sunlight.
ICEA S-113-684	Direct burial, installation in ducts in wet/dry locations, and exposure to sunlight.
ICEA S-93-639/ ANSI/NEMA WC74	Indoor, outdoor, vertical, underground or underwater installation. Suitable for cable tray if armoured (or unarmoured with TC rating)
UL 1072 (Types MV90/MV105)	Direct burial, cable trays, exposed to sunlight, and dry/wet locations.

3. CABLE COMPONENTS FUNCTION



#	Component	Function
①	Conductor	A wire or combination of wires designed to carry electric current. During installation, the conductor is typically a mechanical load-bearing component.
②	Conductor shield	A nonconducting or semi-conducting element in direct contact with the conductor acting as a stress control layer.
③	Insulation	Relied upon to electrically insulate the conductor and must be capable of withstanding the electrical stresses distributed across it when the conductor is energized.
④	Insulation shield	To confine the electric field to within the insulation and symmetrically distribute voltage stresses in the insulation.
⑤	Metallic shield	A non-magnetic metallic material serving as a current-carrying medium for charging and leakage currents while providing a solid ground plane. If large enough, it can also be used to carry neutral, unbalanced phase, and fault currents.
⑥	Armour	A metal sheath, tape, or wire providing mechanical protection.
⑦	Jacket	A covering that provides mechanical protection, chemical protection, sunlight resistance, moisture migration resistance, ion filtration, and corrosion resistance.

3. BASIC CONSTRUCTION REQUIREMENTS

Component	CSA C68.5	CSA C68.10	ICEA S-94-649	ICEA S-97-682	AEIC CS8	ICEA S-113-684	ICEA S-93-639	UL 1072
Conductor Type	Cu/Al/ Cu-Sn	Cu/Al/ Cu-Sn	Cu/Al/ Cu-Sn	Cu/Al/ Cu-Sn	Cu/Al/ Cu-Sn	Cu/Al/ Cu-Sn	Cu/Al/ Cu-Sn	Cu/Al/ Cu-Sn
Conductor Water-blocking	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional
Insulation Materials*	TRXLPE/ EPR	XLPE/ TRXLPE/ EPR	XLPE/ TRXLPE/ EAM/EPR	XLPE/ TRXLPE/ EAM/EPR	XLPE/ TRXLPE/ EPR	Thermoset material	XLPE/ TRXLPE/ EPR	XLPE/ EP/ DREP/ EPCV
Metallic Shielding	Concentric Neutral		Concentric Neutral		Concentric Neutral	Concentric Neutral		
	Tape(s)	Tape(s)		Tape(s)	Tape(s)	Tape(s)	Tape(s)	Tape(s)
		Tape + Wire					Tape + Wire	
		Wire Shield		Wire Shield	Wire Shield	Wire Shield	Wire Shield / Straps	Wire Shield / Straps
		Braid				Braid		Braid
	Lead Sheath	Lead Sheath		Lead Sheath	Metal Sheath	Metal Sheath	Metal Sheath	Metal Sheath
Metallic shield Water-blocking	Optional LWB	Optional LWB	Optional LWB	Optional LWB	Optional LWB or Radial	Optional LWB or Radial	None	None

*May be DISCHARGE-FREE (DF) or DISCHARGE-RESISTANT (DR) cable designs

3. BASIC CONSTRUCTION REQUIREMENTS

Component	CSA C68.5	CSA C68.10	ICEA S-94-649	ICEA S-97-682	AEIC CS8	ICEA S-113-684	ICEA S-93-639	UL 1072
Armour	None	Lead sheath	None	None	None	None	Lead sheath	Lead sheath
		Smooth aluminum sheath					Smooth aluminum sheath	Smooth aluminum sheath
		Flat steel tape					Flat steel tape	
		Continuously corrugated and welded metal sheath					Continuously corrugated and welded or extruded metal sheath	Continuously corrugated and welded or extruded metal sheath
		Interlocked metal tape					Interlocked metal tape	Interlocked metal tape
		Galvanized steel wire					Galvanized steel wire	
		Copper wire						
Jackets	LL/HDPE PVC PP XLPE SCPE Type I/II	CSPE-HD CPE-XL-HD CR-HD NBR/PVC-HD XLPE PVC L/LL/M/HDPE CPE-TP PP TPE LSHF	L/LL/M/HDPE SCPE Type I/II PVC CPE TPE PP XLPE	L/LL/M/HDPE SCPE Type I/II PVC CPE TPE PP XLPE	L/LL/M/HDPE SCPE Type I/II PVC CPE TPE PP XLPE	Materials not specified – performance based Filled or Unfilled Types: Standard Medium Duty Heavy Duty	CR-HD NBR/PVC-HD CSPE-HD CPE-XL-HD PVC CPE L/LL/M/HDPE LSHF	CP (i.e. CSPE) CPE NBR/PVC CR-HD PE PVC TPE XL (XLPE, XLPVC, XLEVA)
3 red stripes	Optional	-	Optional	Optional	Optional	Optional	-	- 10

3. BASIC CONSTRUCTION REQUIREMENTS

Metallic Shielding – A deeper dive

The primary function of a metallic shield is to provide electrical protection⁺

+

- 1. Metallic component of the insulation shield
- 2. Carries charging and leakage currents
- 3. Provides a solid ground plane
- 4. If large enough, can carry neutral currents, unbalanced phase currents, and fault currents

Concentric Neutral

Types

Round wires
Flat straps

Materials

Copper
Tin-coated copper



Tape

Types

Helical
Corrugated and Longitudinal

Materials

Copper
Tin-coated copper*



Wire

Types

Helical
Corrugated and Longitudinal

Materials

Copper
Tin-coated copper



Braid

Types

Wrapped metal wires

Materials

Copper
Tin-coated copper

Metal Sheath

Types

Smooth
Welded & Corrugated
Extruded & Corrugated

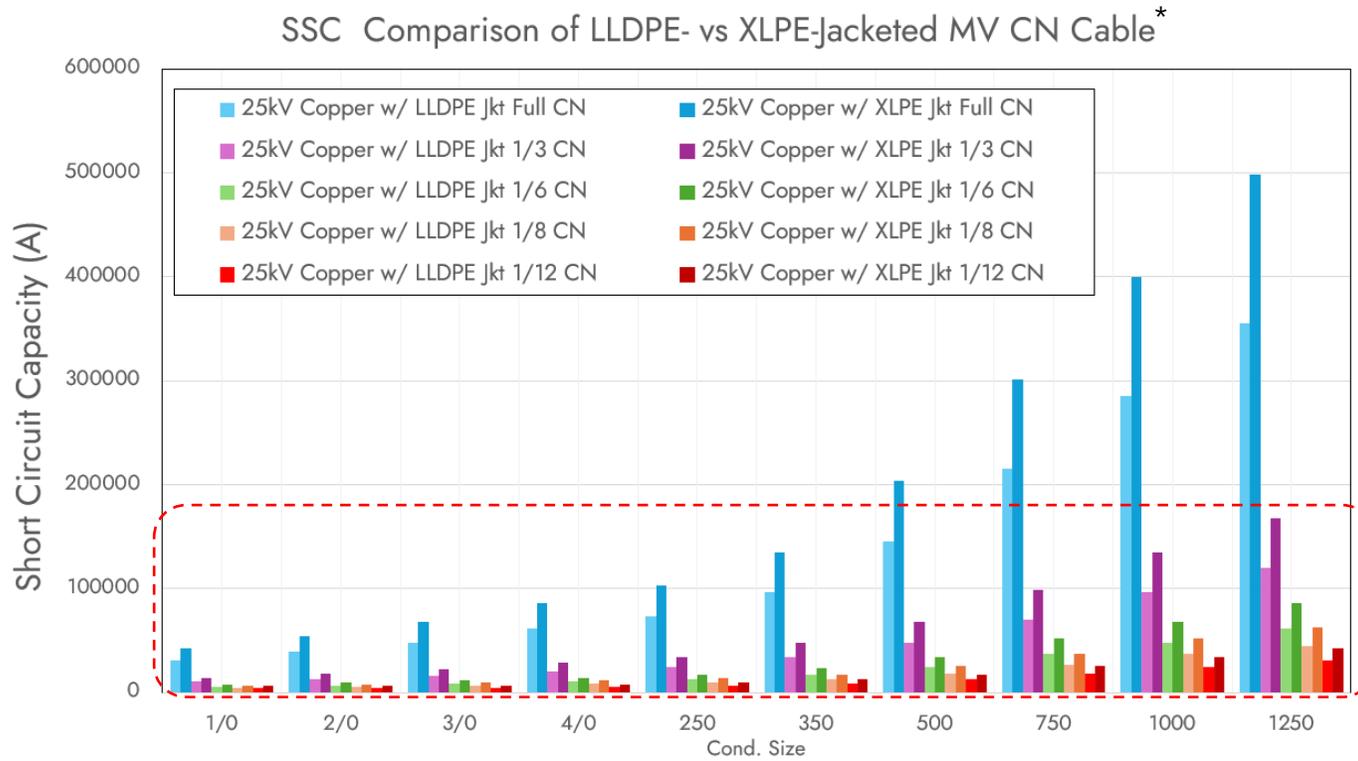
Materials

Aluminum
Aluminum alloy
Lead**
Copper***
Bronze***

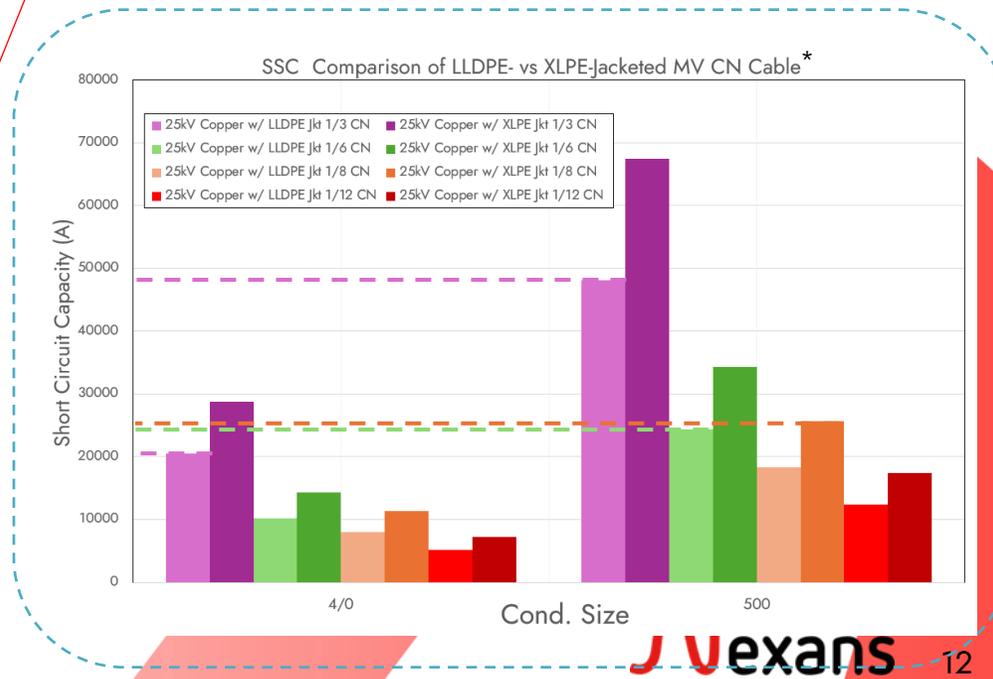
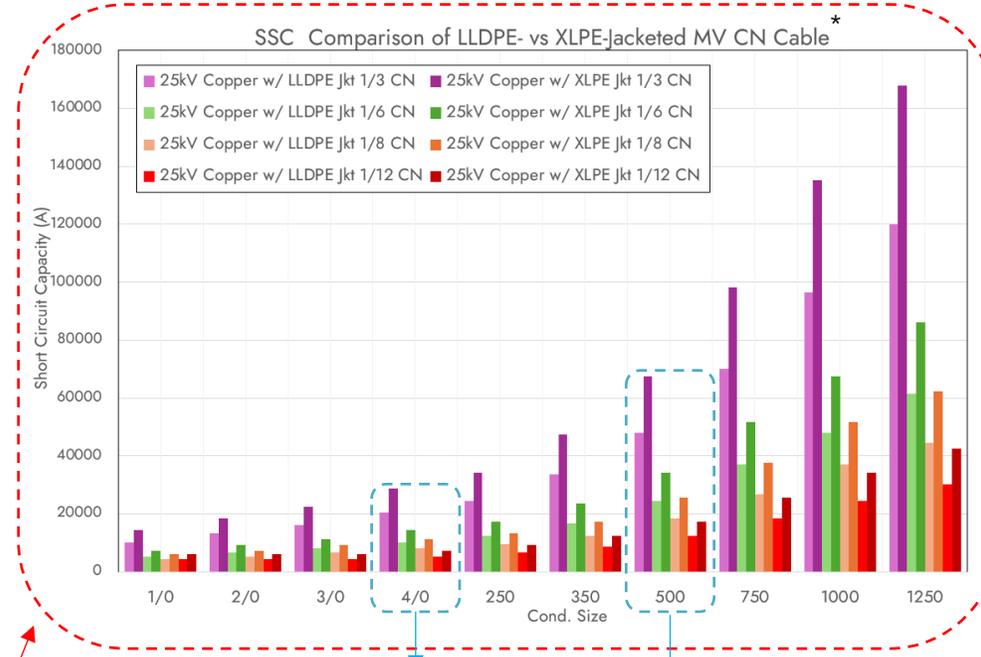
*helical tape only **extruded and smooth only ***welded and corrugated only

3. BASIC CONSTRUCTION REQUIREMENTS

Metallic Shielding – A deeper dive (CN)



Understanding the relationship between conductor and concentric neutral size, jacket material types, and fault-clearing requirements **can help reduce cost** while maintaining performance and compliance.



*short circuit duration of 3 cycles. Adiabatic heat generation assumed (i.e. conservative)

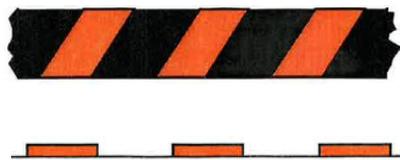
3. BASIC CONSTRUCTION REQUIREMENTS

Metallic Shielding – A deeper dive (Copper Tape)

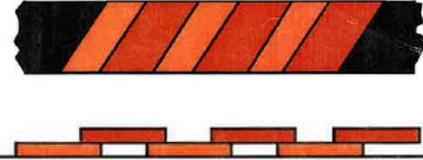
Various methods of application

Helical

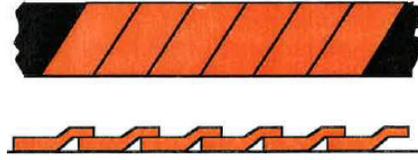
1 Tape w/ Gap



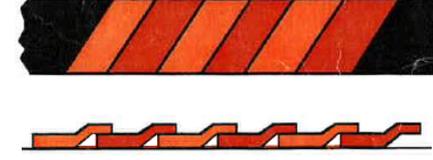
2 Tapes Gap over Gap



1 Tape w/ Overlap



2 Tapes Intercalated



2 Tapes Double Start



Longitudinal +
Corrugated



Requirements for copper tape metallic shielding include quality of application, thicknesses, corrugation lay factor, and % overlap/gap.

3. BASIC CONSTRUCTION REQUIREMENTS

Armours – A deeper dive

The primary function of an armour is to provide mechanical protection. In *certain* instances, it may serve as the nonmagnetic metal component of the insulation shield.

Metal Sheath

Types

Extruded smooth
Extruded corrugated

Materials

Aluminum
Lead

Wire

Types

Round

Materials

Galvanized steel

Tape

Types

Flat
Welded & Corrugated
Interlocked

Materials

Steel
Aluminum
Copper
Bronze
Other non-magnetic materials:
Brass, Cupro-nickel, Zinc



Flat steel tape



Interlocked tape

Welded and Corrugated Tape



Galv steel wire

3. BASIC CONSTRUCTION REQUIREMENTS

Jackets – A deeper dive

A jacket consists of a nonconducting or semi-conducting material compatible with all cable components with which it is in contact. The following are the most common types:

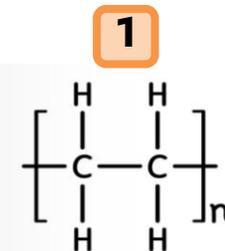
Thermoplastic

LDPE	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
MDPE	Medium-Density Polyethylene
HDPE	High-Density Polyethylene
PVC	Polyvinyl Chloride
PP	Polypropylene
CPE-TP	Chlorinated Polyethylene, Thermoplastic
TPE	Thermoplastic Elastomer
SCPE	Semi-conducting Polyethylene
LSHF	Limited-Smoke Halogen Free

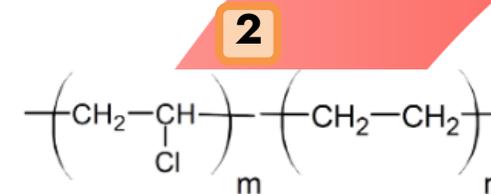
A jacket is optional for concentric neutral cables.

Thermoset

LSHF	Limited-Smoke Halogen Free
CSPE	Chlorosulfonated Polyethylene (Hypalon)
CPE-XL	Chlorinated Polyethylene, Thermoset
CR	Neoprene
NBR/PVC	Nitrile-butadiene/Polyvinyl Chloride
XLPE	Cross-linked Polyethylene

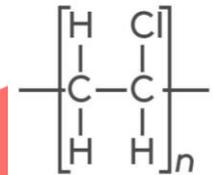


What compound is this?



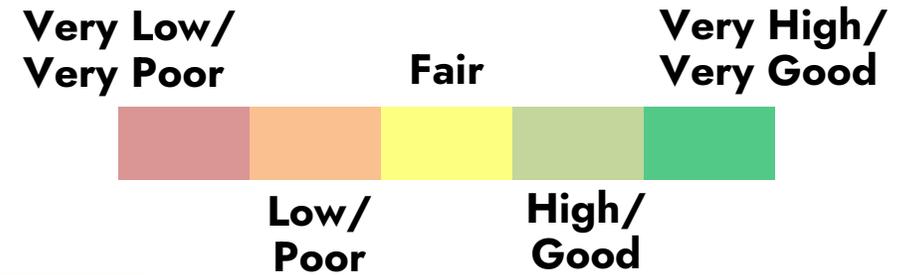
What compound is this?

3



What compound is this?

3. BASIC CONSTRUCTION REQUIREMENTS



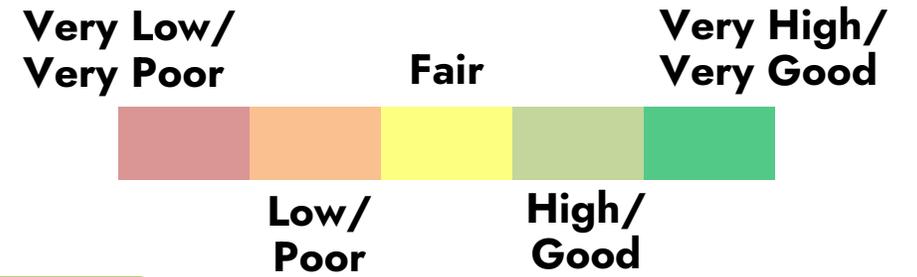
Jackets – A deeper dive

Thermoplastic materials*

Property	LDPE	LLDPE	MDPE	HDPE	PVC	PP	CPE-TP	TPE	SCPE	LSHF
Operating Temperature	High/Good	High/Good	High/Good	High/Good	Very High/Very Good	Very High/Very Good	High/Good	Very High/Very Good	High/Good	High/Good
Low Temperature	Very High/Very Good	Very High/Very Good	Very High/Very Good	Very High/Very Good	High/Good	Very High/Very Good	High/Good	Very High/Very Good	High/Good	High/Good
Abrasion	High/Good	High/Good	High/Good	Very High/Very Good	High/Good	High/Good	Very High/Very Good	High/Good	High/Good	High/Good
Toughness	High/Good	High/Good	High/Good	Very High/Very Good	High/Good	High/Good	Very High/Very Good	High/Good	High/Good	High/Good
Flexibility	Low/Poor	Low/Poor	Low/Poor	Very Low/Very Poor	Very High/Very Good	High/Good	High/Good	Very High/Very Good	High/Good	High/Good
Weather/UV Resistance	High/Good									
Chemical Resistance	High/Good	High/Good	High/Good	High/Good	Very High/Very Good	Very High/Very Good	Very High/Very Good	High/Good	High/Good	High/Good
Water Resistance	High/Good									
Flame Retardance	Low/Poor	Low/Poor	Low/Poor	Low/Poor	High/Good	High/Good	Very High/Very Good	Very High/Very Good	High/Good	Very High/Very Good
Fire Resistance	Low/Poor	Low/Poor	Low/Poor	Low/Poor	High/Good	Low/Poor	High/Good	High/Good	High/Good	High/Good
Toxicity (when burning)	Very High/Very Good	Low/Poor	Very High/Very Good	Low/Poor						
Relative \$	Very Low/Very Poor	Very Low/Very Poor	Low/Poor	Low/Poor	Very Low/Very Poor	Very Low/Very Poor	High/Good	High/Good	High/Good	Very High/Very Good

*Materials assumed to be in base form (i.e. no additives, etc.)

3. BASIC CONSTRUCTION REQUIREMENTS



Jackets – A deeper dive

Thermoset materials*

Property	CSPE	CPE-XL	CR	NBR/PVC	XLPE	LSHF
Operating Temperature	High/Good	High/Good	High/Good	High/Good	High/Good	High/Good
Low Temperature	High/Good	High/Good	High/Good	Low/Poor	High/Good	High/Good
Abrasion	High/Good	High/Good	High/Good	High/Good	High/Good	High/Good
Toughness	High/Good	High/Good	High/Good	High/Good	High/Good	High/Good
Flexibility	High/Good	Fair	High/Good	Low/Poor	Low/Poor	High/Good
Weather/UV Resistance	High/Good	High/Good	High/Good	Fair	High/Good	High/Good
Chemical Resistance	High/Good	High/Good	High/Good	High/Good	High/Good	High/Good
Water Resistance	High/Good	High/Good	High/Good	High/Good	High/Good	High/Good
Flame Retardance	High/Good	High/Good	Fair	High/Good	Fair	High/Good
Fire Resistance	High/Good	High/Good	Fair	Low/Poor	Low/Poor	Fair
Toxicity (when burning)	Fair	Fair	Fair	Fair	Low/Poor	Low/Poor
Relative \$	High/Good	Fair	Fair	Low/Poor	Fair	High/Good

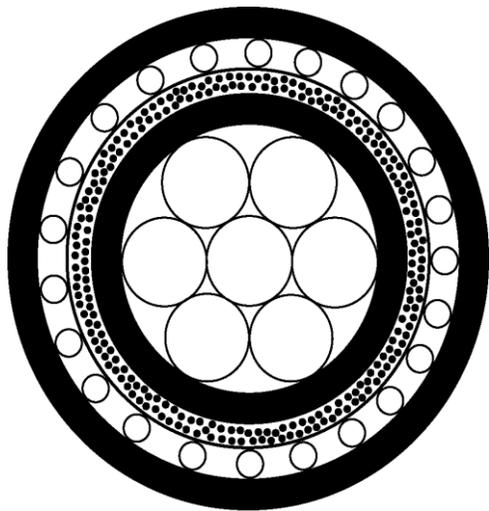
*Materials assumed to be in base form (i.e. no additives, etc.)

3. BASIC CONSTRUCTION REQUIREMENTS

Jackets – A deeper dive

Application Method

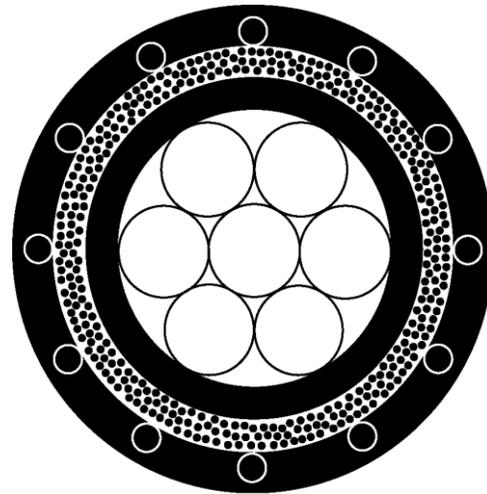
Overlaying



A separator tape is typically applied over the metallic shield to prevent fall-in.

More flexible

Encapsulating



Jacket material is extruded to fill void spaces around metallic shield

Less flexible

3 Red Stripes

An optional feature

Notes:

1. When provided, the three stripes shall be extruded into the jacket to a specified depth.
2. The stripe material must be durable and compatible.
3. The total width cannot exceed 50% of the outer circumference of the jacket.
4. The stripes must be sunlight resistant



4 - 6. TESTING REQUIREMENTS

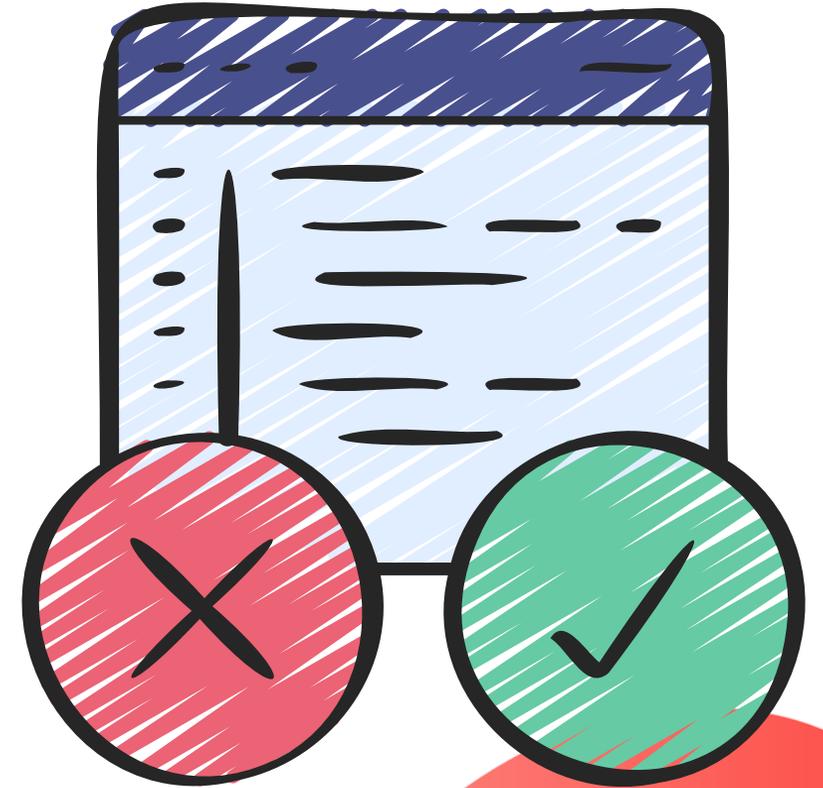
Medium voltage cables undergo rigorous production and qualification testing to ensure performance, safety and compliance.

The type of tests include:

1. Physical/Mechanical Tests
2. Electrical Tests
3. Environmental/Chemical Resistance Tests

The following are some of the common tests required by medium voltage cable standards in North America.

For more specific details and requirements for these types of tests, please consult the relevant standard.



4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS – 1 OF 3

Physical/Mechanical Test*	CSA C68.5	CSA C68.10	ICEA S-94-649	ICEA S-97-682	AEIC CS8	ICEA S-113-684	ICEA S-93-639	UL 1072
Dimensional measurements	✓	✓	✓	✓	✓	✓	✓	✓
Aged/unaged Tensile & Elongation	✓	✓	✓	✓	✓	✓	✓	✓
Air oven aging	✓	✓	✓	✓	✓	✓	✓	✓
Voids, protrusions, convolutions, contaminants & irregularities	✓	✓	✓	✓	✓	✓	✗	✗
Wafer boil	✓	✓	✓	✓	✓	✓	✓	✗
Hot creep/set	✓	✓	✓	✓	✓	✓	✓	✓
Shrinkback (XLPE/TRXLPE only)	✓	✓	✓	✓	✓	✓	✗	✗
Insulation eccentricity	✓	✓	✓	✓	✓	✓	✗	✗
Indent (under concentric neutral)	✓	✗	✓	✗	✓	✗	✗	✗
Removability/Adhesion (insulation shield)	✓	✓	✓	✓	✓	✓	✓	✓
Corrugation lay factor	✗	✗	✗	✓	✓	✓	✗	✗

*DF and DR cable designs may have slightly different testing requirements.

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS – 2 OF 3

Physical/Mechanical Test*	CSA C68.5	CSA C68.10	ICEA S-94-649	ICEA S-97-682	AEIC CS8	ICEA S-113-684	ICEA S-93-639	UL 1072
Deformation	✓	✓	✓	✓	✓	✓	✓	✓ (insul + jkt)
Cold impact	✓ (-25, -40, -45, -50)	✓ (-25, -40, -45, -50)	✗	✗	✗	✗	✗	✓ (-40)
Cold bend + PD	✓	✓	✗	✗	✗	✗	✗	✗
Cold bend	✗	✗	✓ (jacket)	✓ (jacket)	✓ (jacket)	✓ (jacket)	✓	✓ (-35)
Tightness of jacket (PE overlay)	✗	✓	✗	✓	✓	✓	✓	✗
Heat shock	✓	✓ (PVC)	✓ (PVC)	✓ (PVC)	✓ (PVC)	✓ (PVC)	✓	✓ (PVC /TPE)
Water in conductor / under jacket	✓	✓	✓	✓	✓	✓	✓	✗
Longitudinal water penetration (optional)	✓	✓	✓	✓	✓	✓	✓ (conductor)	✗
Flexibility of armour	✗	✓	✗	✗	✗	✗	✓	✓
Tightness of armour	✗	✗	✗	✗	✗	✗	✗	✓
Tension of interlocked armour	✗	✗	✗	✗	✗	✗	✗	✓
Zinc Coating (galv steel armor)	✗	✓	✗	✗	✗	✗	✓	✓
Compatibility of optional WB components	✓	✓	✓	✓	✓	✓	✓	✓ (SB only)

*DF and DR cable designs may have slightly different testing requirements.

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS – 3 OF 3

Physical/Mechanical Test*	CSA C68.5	CSA C68.10	ICEA S-94-649	ICEA S-97-682	AEIC CS8	ICEA S-113-684	ICEA S-93-639	UL 1072
Connectability (for blocked strand conductor)	✓ (optional)	✗	✗	✗	✗	✗	✗	✗
Brittleness	✓	✓	✓	✓	✓	✓	✓	✓
Thermomechanical qualification	✓	✗	✓ (optional)	✓ (optional)	✓ (opt.)	✓ (optional)	✗	✗
Duct pulling	✗	✗	✗	✗	✗	✓	✗	✗
Durability of ink	✗	✗	✗	✗	✗	✗	✗	✓
Tree Count Test (for engineering info only)	✗	✗	✗	✗	✓	✗	✗	✗

*DF and DR cable designs may have slightly different testing requirements.

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

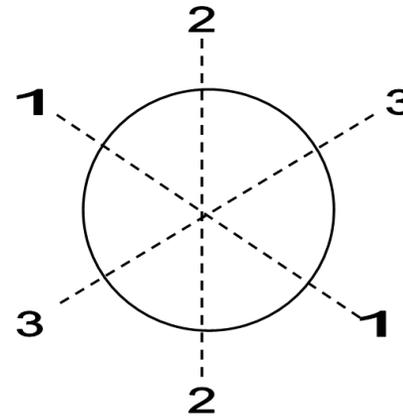
Dimensional Measurements

Purpose

Measure key dimensions such as thicknesses, diameters, areas and weights.

Importance

Ensure compliance
Maintain performance and clearances
Process control and consistency



Diameter measurement using micrometer method



Scale



Insulation thickness measurements

Conductor diameter measurement using caliper

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Aged/unaged Tensile & Elongation

Purpose

Evaluate material strength and flexibility before and after thermal aging

Importance

Assess long-term durability
Confirm insulation and jacket material stability
Identify material degradation



"dog-bone" prep



Universal testing machine

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Voids, protrusions, convolutions, contaminants & irregularities

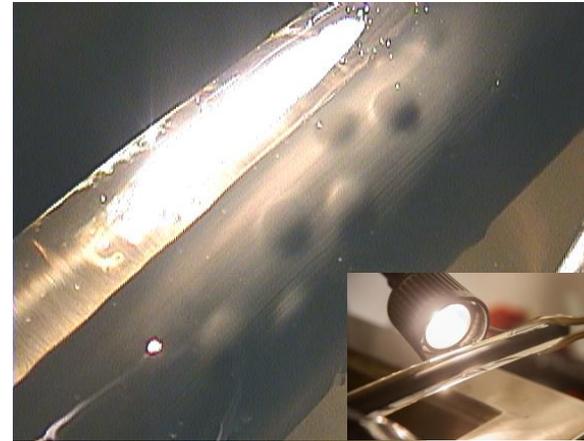
Purpose

Detect physical defects and irregularities within insulation.

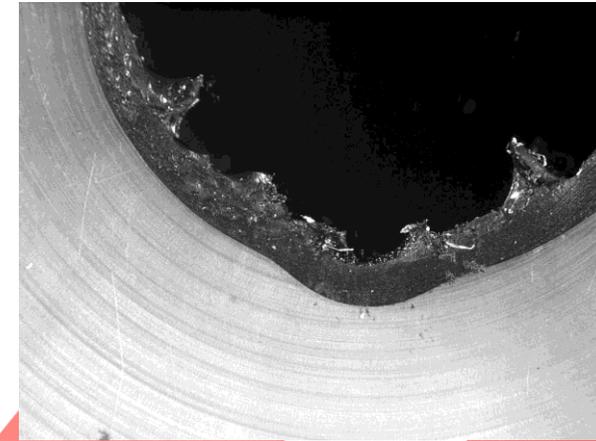
Importance

Prevent partial discharge and insulation failure
Verify material purity and extrusion quality

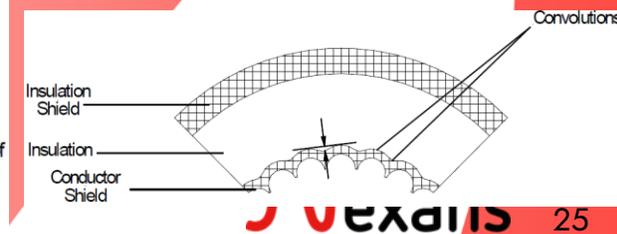
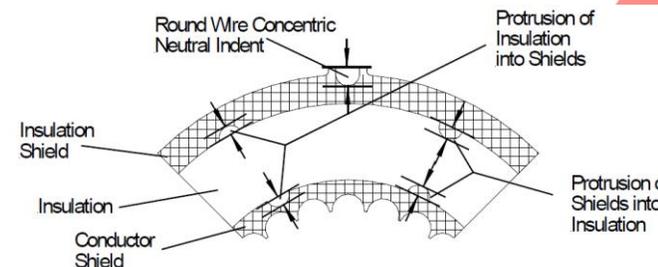
AKA: “Amber, agglomerate, gel, contaminant, protrusion, convolution, and void test



Internal irregularity test – using hot oil bath



Wafer showing protrusion



4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Wafer boil

Purpose

Check if thermoset conductor shield and insulation shield dissolve/crack after extrusion.

Importance

Ensure effective crosslinking



Wafers are immersed in a boiling solvent for 5 hours and then removed and examined for shield/insulation interface continuity.



Wafer boil test setup

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Hot creep/set

Purpose

Measure the relative degree of crosslinking of polymeric insulations.

Importance

Validate thermal stability
Ensure performance

Consists of an elongation test in an oven, followed by a hot creep set test



"dog-bone" specimen in oven attached to supporting apparatus with weight

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Shrinkback (XLPE/TR-XLPE only)

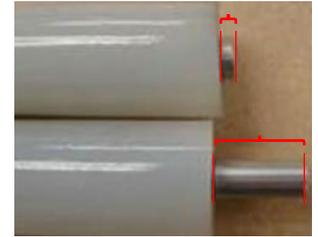
Purpose

Evaluate conductor protrusion beyond insulation after extrusion.

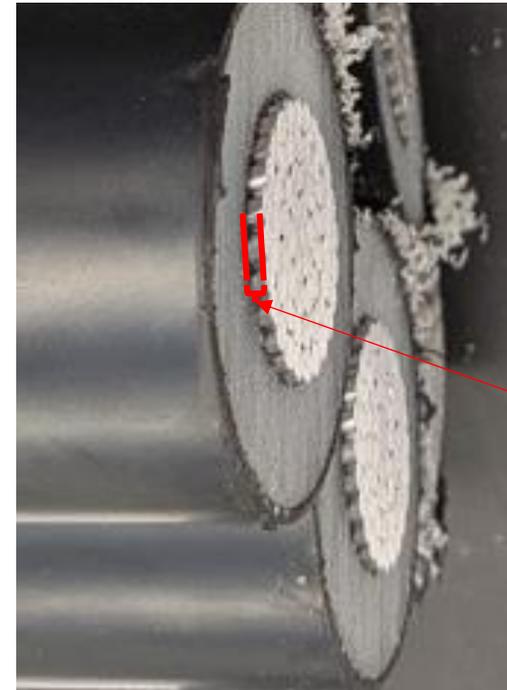
Importance

Detect internal stresses from extrusion or curing
Prevent installation issues
Ensure splicing/termination reliability

Shrinkback



A cable sample undergoes a cycle of heating/cooling before shrinkback is measured



shrinkback

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

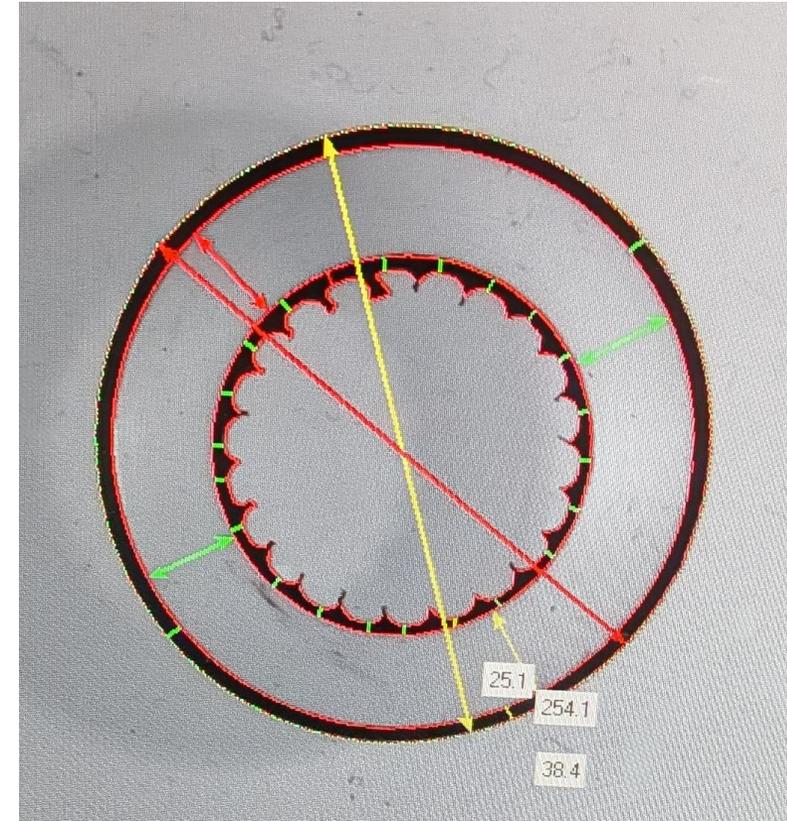
Insulation eccentricity

Purpose

Measure uniformity of insulation thicknesses around the conductor

Importance

Reduce stress points leading to PD
Maintain dielectric strength



Optical device for eccentricity measurements

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

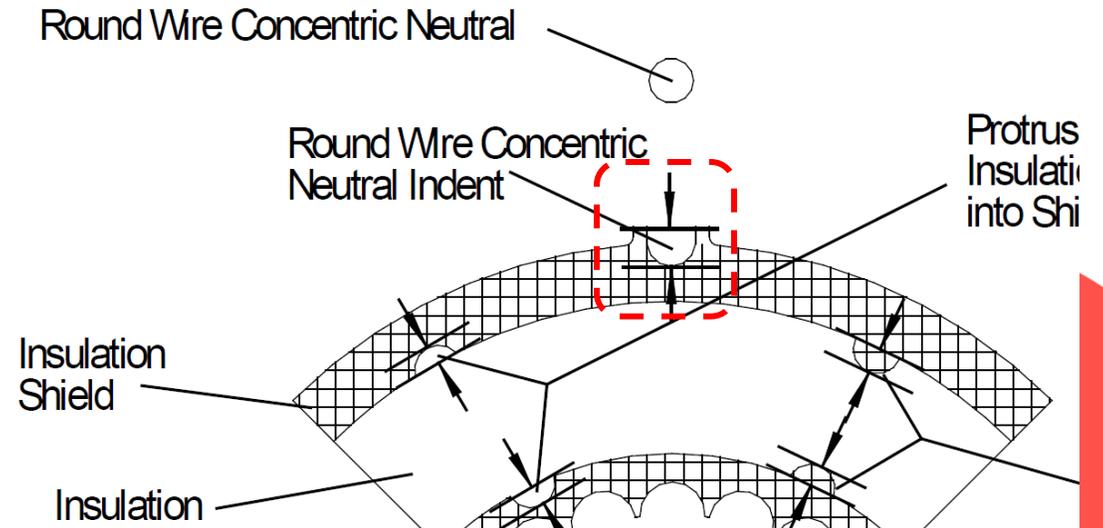
Indent (under concentric neutral)

Purpose

Check insulation shield's resistance to deformation caused by concentric neutral wires.

Importance

Prevent localized thinning
Ensure long-term reliability
Validate curing



4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Removability/Adhesion (insulation shield)

Purpose

Assess the bond between the insulation and insulation shield.

Importance

Ensure clean stripping during installation
Prevent tearing
Confirm material compatibility

The insulation shield must be readily removable, and the required tension must be within the limits specified in the relevant standard.



Poor strippability results



Good strippability results

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Corrugation lay factor

Purpose

Evaluate lay pattern and uniformity of corrugated tape.

Importance

Maintain dimensional consistency
Support flexibility & crush resistance

Corrugation should produce a lay factor not less than 115% on the cable after jacketing

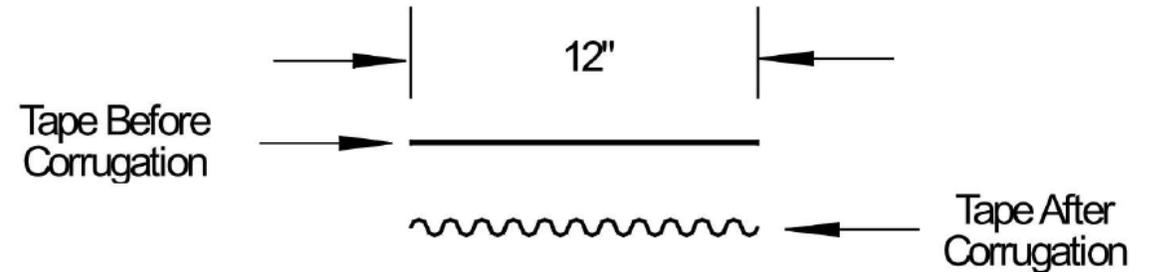


Figure 6-1
Corrugation Lay Factor

$$CLF = W_{AC} \div W_{BC}$$

Where:

CLF = Corrugation Lay Factor

W_{AC} = Weight of tape after corrugation

W_{BC} = Weight of tape prior to corrugation



4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Deformation

Purpose

Assess material deformation under mechanical load

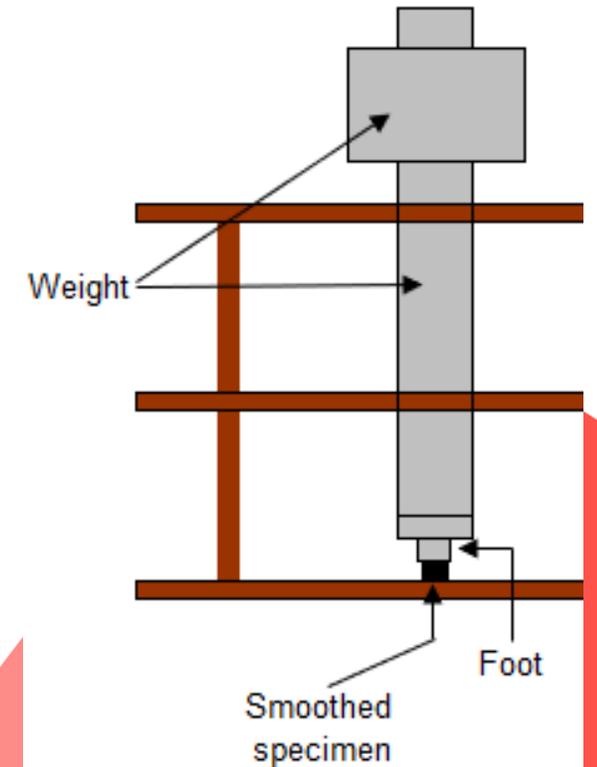
Importance

Ensure insulation or jacket resists crushing
Validate durability
Confirm material strength

% deformation is calculated using initial and final thickness after testing under a specified load



Deformation test set up in oven



Deformation test set up in oven

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Cold impact

Purpose

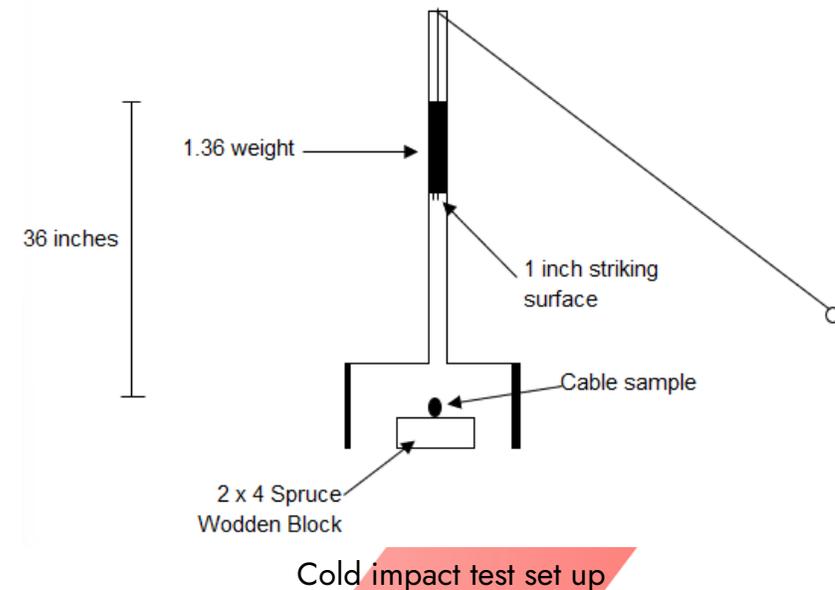
Test resistance to impact at low temperatures.

Importance

Ensure mechanical toughness in cold climates
Prevents cracking or rupture during installation

10 finished cable samples are conditioned at the specified cold temperature rating for a specified time.

Passing criteria: Not more than 2 out of 10 specimens tested can show cracks or rupture when subjected to an impact of 12 J.



Example cold chamber

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Cold bend + PD

Purpose

Evaluate bending performance at low temperatures and checks for partial discharge

Importance

Confirm cable performance in cold climate installations
Reduce risk of field failures

3 cable samples are conditioned at a specified cold temperature and time before being bent 180° around a mandrel of a given diameter.

Passing criteria: no visible cracks on any sample and samples must pass a partial discharge test (CSA).



Example cold chamber for conditioning cable samples



Example tool for performing bend test (reel or mandrel)

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Heat shock

Purpose

Evaluate material stability under sudden temperature changes

Importance

Ensure insulation/jacket will not crack
Support installation in harsh environments

A sample is wound tightly around a mandrel of a certain diameter, held firmly in place, and subjected to a specified temperature and time.

Passing criteria: no visible cracks or ruptures in the jacket

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Longitudinal water penetration (optional)

Purpose

Determine effectiveness of non-metallic water-blocking components in cable.

Importance

Prevent corrosion & electrical failure
Ensure manufacturing quality

Procedures defined in:
ICEA T-34-664 (LWB under jacket)
ICEA T-31-610 (Conductor)



Prepared sample (3 ft)

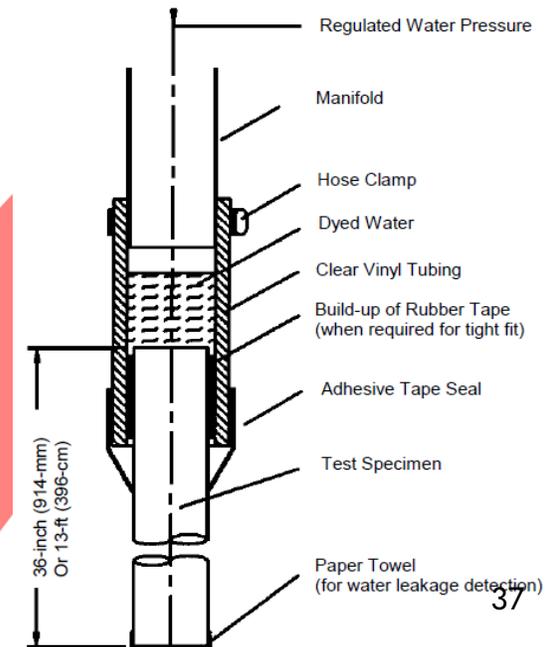


A passing result

Pressure gauge
(reading 5 psi)



Typical test equipment and setup



4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Zinc coating (galvanized steel armour)

Purpose

Verify adhesion and quality of zinc coating on steel armour

Importance

Corrosion resistance
Serve life in wet/corrosive environments



Galvanized steel wire

The zinc coating must remain adherent when the wire is wrapped around a cylindrical mandrel of a specified diameter at a specified rate.

The zinc coating shall not flake nor be removable from the wire by rubbing with the fingers.

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

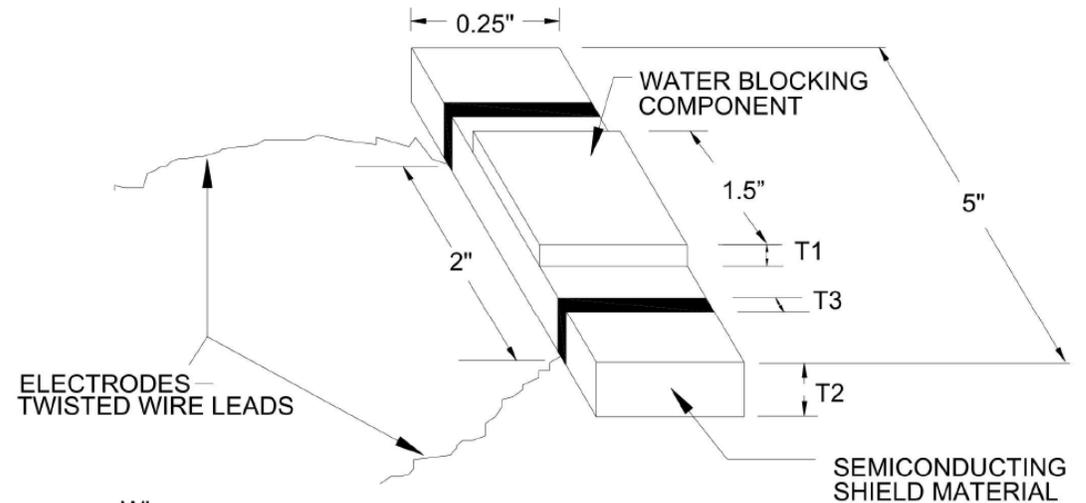
Compatibility of optional water-blocking components

Purpose

Ensure water blocking powders, tapes, yarns, or gels are compatible with the materials they come into contact with.

Importance

Ensure long-term stability and reliability of water-blocking components



Where:

- T1 = Water Blocking Component to be minimum 0.010" thick or single layer, as applicable
- T2 = Semiconducting shield material to be 0.050" thick
- T3 = Band of Silver Conductive Paint to be 0.125" wide

Typical test specimen preparation

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS



Connectability (for blocked strand conductor)

Purpose

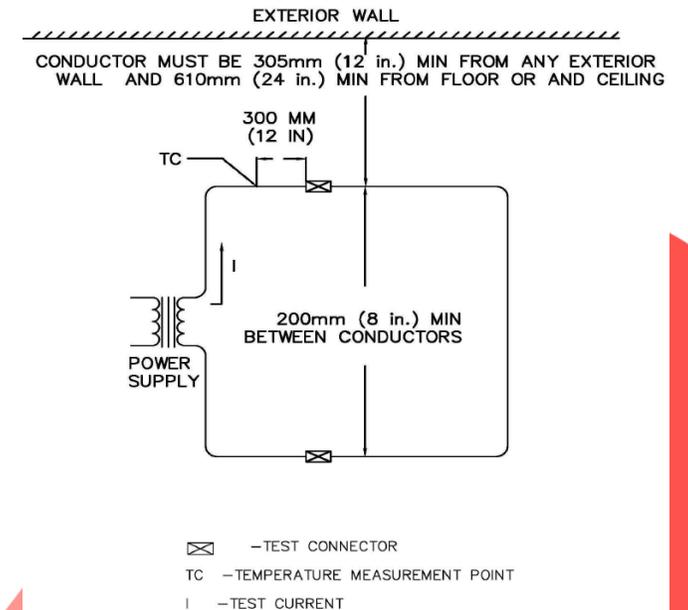
Ensure no deterioration in connection performance between blocked conductor and connector.

Importance

Maintain resistance and temperature stability between a water-blocked conductor and a connector.

Procedure defined in
ANSI C119.4

Purpose of this test is to give reasonable assurance to the user that connectors will perform in a satisfactory manner



Example test set up

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Brittleness

Purpose

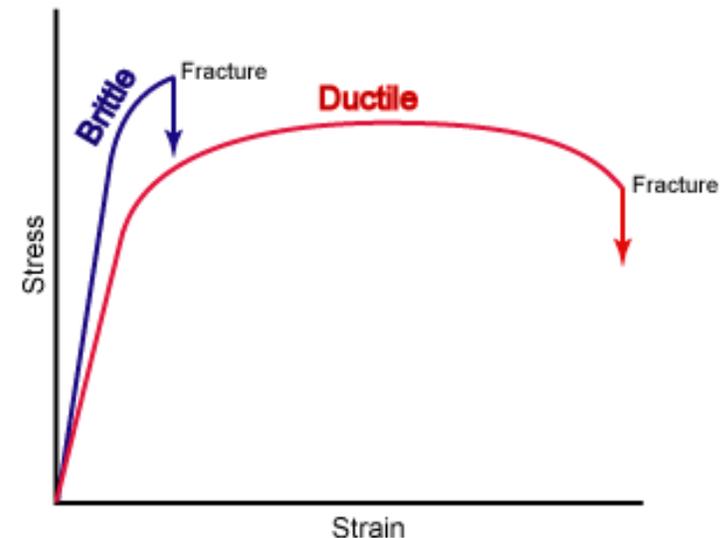
Measure material resistance to cracking when subject to impact or bending

Importance

Ensure cold weather performance
Prevent insulation/jacket failure
Confirm material formulation consistency

Test method defined in
ASTM D746

Brittleness testing determines the lowest temperature at which a material does not exhibit brittle failure



4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Thermomechanical qualification

Purpose

Evaluate mechanical and thermal stress on complete cable

Importance

Ensure performance under load cycles
Confirm robustness of construction

Tests include:

1. Heat cycling
2. PD tests before/after heat cycling
3. Tan δ before/after heat cycling
4. Jacket Examination
5. Component dimensions before/after heat cycling

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Duct pulling

Purpose

Test cable's ability to withstand pulling forces during installation

Importance

Prevent damage during conduit pulls
Support safe installation practices

Test method defined in
ICEA S-113-684

If a cable uses a jacket material and/or thicknesses that are not covered by ICEA standards, a purchaser may request a duct pulling qualification test.

This test is conducted to establish that the cable design will not be damaged when pulled through a conduit in a way that generally represents pulling conditions in service

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Durability of ink

Purpose

Ensure printed marking resists abrasion, solvents, and environmental exposure.

Importance

Maintain identification readability
Supports traceability over service life



A specimen is taken from a finished cable and conditioned in an air oven and rubbed repeatedly with a felt-faced weight

4. PHYSICAL/MECHANICAL TESTING REQUIREMENTS

Tree count test (for engineering information only)

Purpose

To count the number, size, and type of water/electrical trees during core material qualification.

Importance

Understand the relationship between tree growth under accelerated aging conditions and cable performance.

What is treeing?

Electrochemical degradation initiated by a combination of electric field, moisture and ionic impurities.

Types

Vented



Grow from shield interfaces

Bowtie



Grow from water-filled voids or contaminants

5. ELECTRICAL TESTING REQUIREMENTS

Electrical Test*	CSA C68.5	CSA C68.10	ICEA S-94-649	ICEA S-97-682	AEIC CS8	ICEA S-113-684	ICEA S-93-639	UL 1072
DC resistance	✓	✓	✓	✓	✓	✓	✓	✓
Volume resistivity	✓	✓	✓	✓	✓	✓	✓	✓
Insulation resistance	✓	✓	✓	✓	✓	✓	✓	✓
Spark test (non-conducting jacket)	✓	✓	✓	✓	✓	✓	✓	✓
Radial resistivity (for semicon jacket/covering only)	✓	✓	✓	✓	✓	✓	✗	✗
AC withstand	✓	✓	✓	✓	✓	✓	✓	✓
Partial discharge (PD)	✓	✓	✓	✓	✓	✓	✓	✓
CV extrusion qualification	✓(monthly)	✓	✓(monthly)	✓(monthly)	✓(monthly)	✓(monthly)	✗	✗
High Voltage Time Test (HVTT)	✓	✗	✓	✓	✓	✓	✗	✗
Hot impulse	✓	✗	✓	✓	✓	✓	✗	✗
Accelerated Water Tree Test (AWTT)	✓	✗	✓	✓	✓	✓	✗	✗
Dielectric constant & dissip/power factor	✓	✓	✓	✓	✓	✓	✓	✓
Resistance stability	✓	✓	✓	✓	✓	✓	✗	✗
Dry electrical test	✓	✓	✓	✓	✓	✓	✓	✓
Dissipation factor characterization	✓	✓	✓	✓	✓	✓	✗	✗
Accelerated water absorption	✗	✓	✓	✓	✓	✓	✓	✓

*DF and DR cable designs may have slightly different testing requirements. For example, DR cables do not need to undergo a PD test.

5. ELECTRICAL TESTING REQUIREMENTS

DC resistance

Purpose

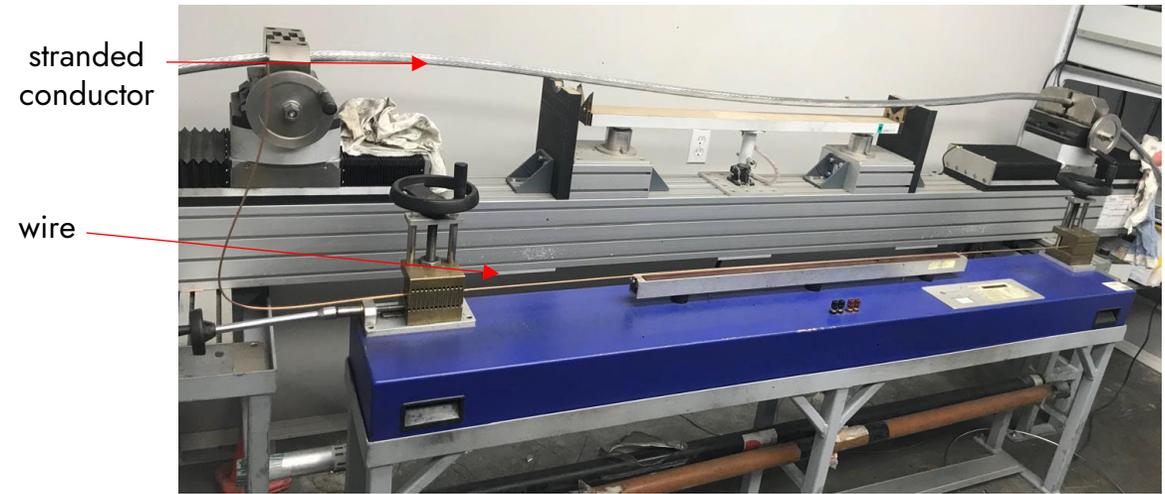
Measure conductor resistance at a specified temperature

Importance

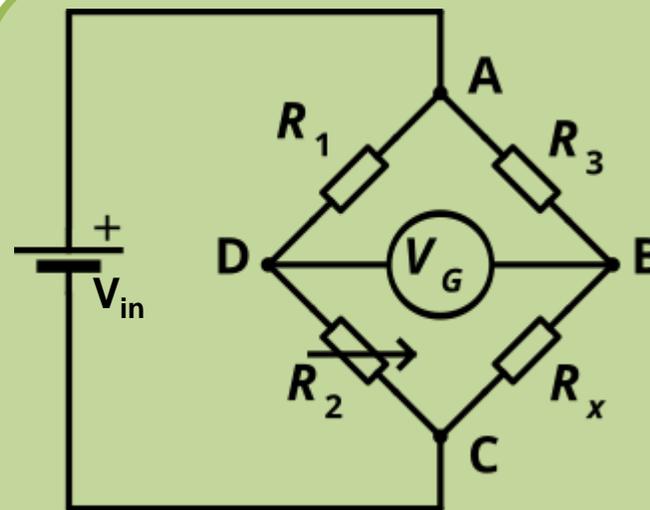
Confirm conductor size/integrity
Ensure compliance with conductivity requirements
Ampacity



Megger tester



Resistance bridge



Wheatstone bridge circuit

V_{in} = DC voltage source
 V_g = voltmeter
 R_1 and R_3 = known resistance
 R_2 = variable resistance
 R_x = unknown resistance

5. ELECTRICAL TESTING REQUIREMENTS

Volume resistivity / Resistance Stability

Test method defined in ICEA T-25-425

Purpose

Determine the stability of a semi-con insulation material's resistivity* throughout its volume

*Calculated from longitudinal resistance

Importance

Verify material purity and insulation quality
Prevent leakage current
Ensure long-term performance

Conductor shield

$$\rho = \frac{0.4R(D^2 - d^2)}{1000L}$$

ρ = volume resistivity (Ωm)
 R = measured resistance (Ω)
 D = diameter over conductor stress control layer, mm
 d = diameter over conductor, mm
 L = distance between potential electrodes, mm



Insulation shield

$$\rho = \frac{0.8R(D^2 - d^2)}{1000L}$$

ρ = volume resistivity (Ωm)
 R = measured resistance (Ω)
 D = diameter over insulation shield layer, mm
 d = diameter over insulation, mm
 L = distance between potential electrodes, mm



5. ELECTRICAL TESTING REQUIREMENTS

Insulation resistance

Purpose

Measure resistance between the conductor and insulation

Importance

Confirm integrity of insulation
Ensure reliable electrical performance



multimeter



Megger tester

Test methods defined in:

**ANSI/ICEA T-27-581 / NEMA
WC23053**

and

**CSA C22.2 No. 2556 /
UL 2556 / NMX-J-556-ANCE**

5. ELECTRICAL TESTING REQUIREMENTS

Spark test (non-conducting jacket)

Purpose

Detect defects in jacket.

Importance

Ensure jacket continuity
Prevent exposure of internal cable components
Quality control during extrusion

Also known as “Jacket Integrity Test”



Spark tester (open)

Semi-conducting jackets may only be inspected using optical devices and/or visually.

5. ELECTRICAL TESTING REQUIREMENTS

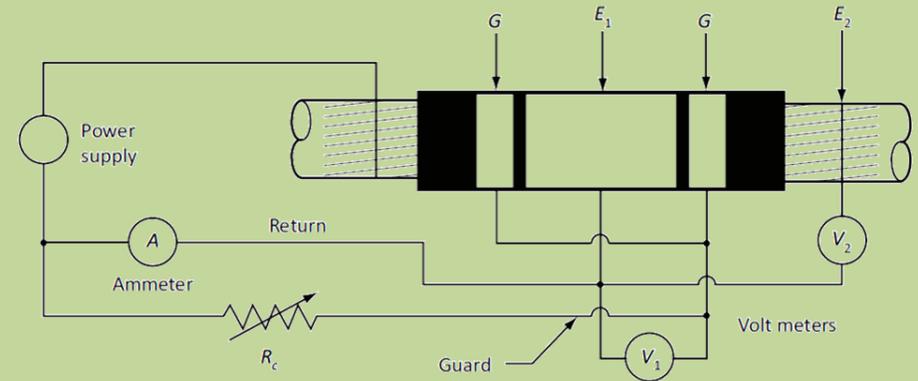
Radial resistivity (for semicon jacket/covering only)

Purpose

Measure resistance* across the thickness of semi-conducting covering/jackets.

Importance

Ensure proper shielding performance
Control electrical stress distribution



Legend:

- E₁ = measuring electrode, conducting paint on the surface of the jacket
- E₂ = measuring electrode, metallic tape shield, lead sheath, or wires tied together
- G = guard electrode, conducting paint on the surface of the jacket

Circuit for radial resistivity measurement



Example specimen

5. ELECTRICAL TESTING REQUIREMENTS

AC withstand

Purpose

Apply high AC voltage to verify insulation integrity

Importance

Detect insulation defects
Confirm cable can handle overvoltage events

AC withstand test procedures and voltages are specified in the relevant standard



AC withstand test set up

5. ELECTRICAL TESTING REQUIREMENTS

Partial discharge (PD)

Purpose

Detect microscopic electrical discharges within the insulation

Importance

Identify voids, defects, or contamination
Prevent long-term insulation degradation

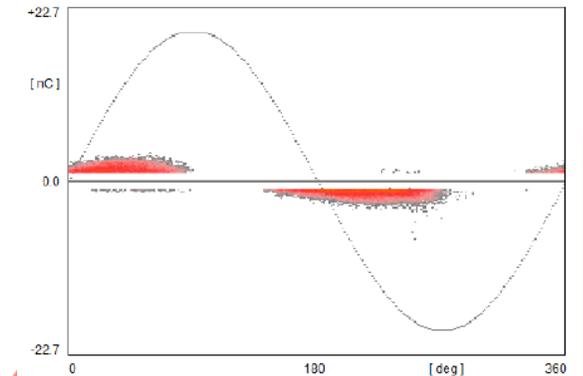
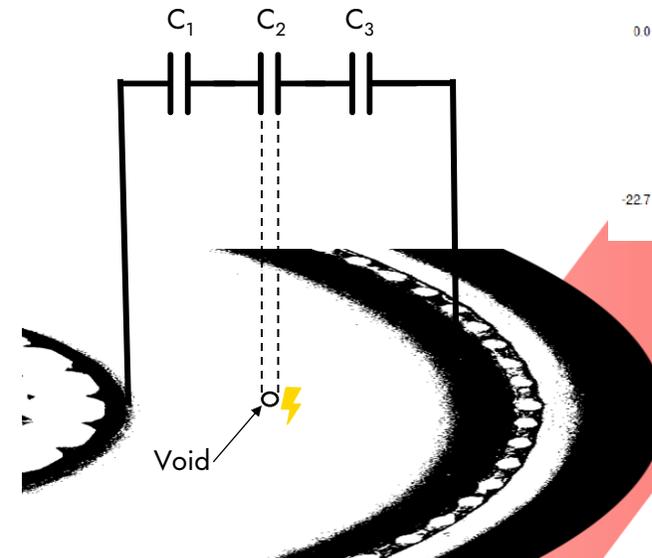
What is partial discharge?

A localized electrical discharge that occurs under high voltage stress. Partial discharge level shall not exceed **5 pC** at the specified AC test voltage.

Types

Internal PD (within the insulation)
Surface PD (tracking across the insulation)
Corona PD (from an electrode into gas)

Example



If $V_{\text{withstand}}$ of C₂ < applied field & $V_{\text{withstand}}$ of C₁/C₃ > applied field, PD occurs

5. ELECTRICAL TESTING REQUIREMENTS

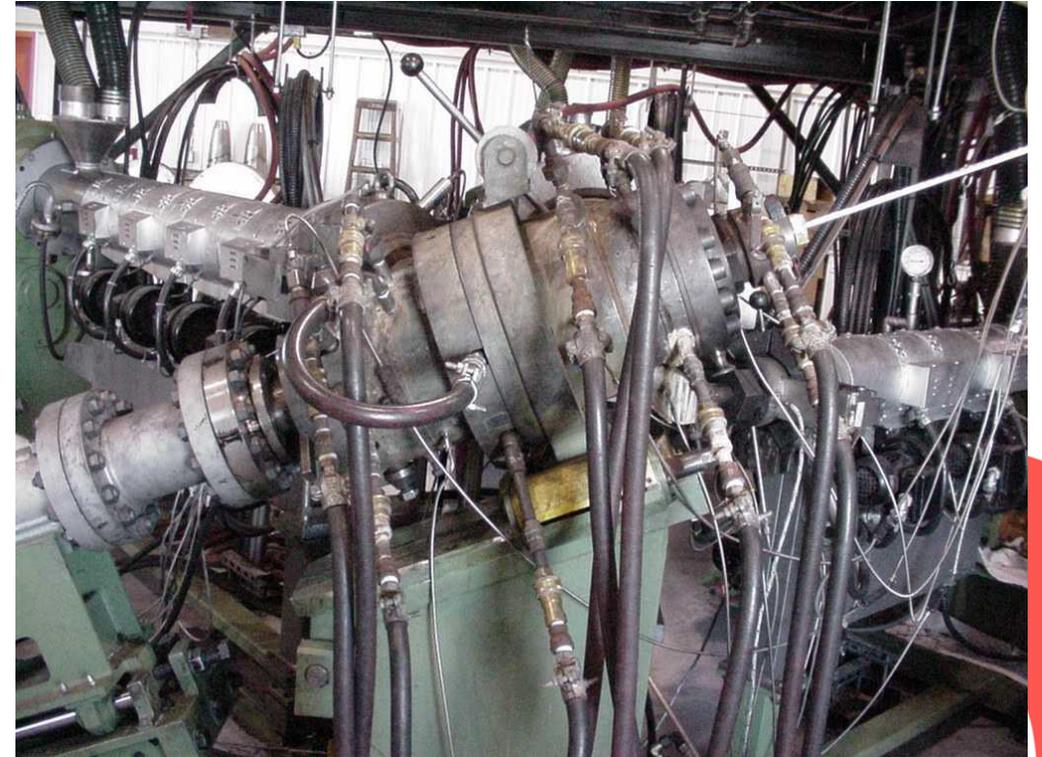
CV extrusion qualification

Purpose

Validate performance and control of the continuous vulcanization (CV) extrusion process

Importance

Ensure consistent insulation curing
Reduce risk of defects



CV extrusion triple head

5. ELECTRICAL TESTING REQUIREMENTS

Accelerated Water Tree Test (AWTT)

Purpose

Accelerate formation of water trees in insulation to evaluate water-tree resistance

Importance

Predict long-term aging in wet environments
Support qualification

This test is a key part of cable core qualification.

Samples are aged for 120*, 180, and 360 days and then go through HVTT / physical measurements.

*Only a 120-day test is required for cable core *manufacturing* qualification.

5. ELECTRICAL TESTING REQUIREMENTS

Dielectric constant and dissipation/power factor

Purpose

Measure insulation permittivity and energy loss under AC stress

Importance

Indicate dielectric quality
Predict thermal and elec efficiency
Higher values signal aging or contamination

What is dielectric constant?

A measure of how well a material can store electrical energy when subjected to an electric field (aka *relative permittivity*)

Dissipation factor (TanDelta)

Electrical measurement of energy loss.
Ratio: resistive current to capacitive current

Power factor (SinDelta)

Electrical measurement of energy loss.
Ratio: real power to apparent power

5. ELECTRICAL TESTING REQUIREMENTS

Dry electrical

Purpose

Apply high AC voltage in dry conditions to check insulation integrity

Importance

Identify insulation defects
Confirm production quality
Support qualification

This test is a key part of cable qualification.

Samples of cable are current loaded at their emergency temperature rating for a minimum of 3 weeks while **capacitance and dissipation factor** are measured and monitored.

After current loading test is complete, PD level is measured and reported.

5. ELECTRICAL TESTING REQUIREMENTS

Dissipation factor characterization

Purpose

Characterize the insulation energy-loss behaviour at both room and elevated temperatures.

Importance

Predict insulation aging
Assess contamination or moisture
Support qualification and advanced diagnosis

Dissipation factor (TanDelta)

Electrical measurement of energy loss.
Ratio: resistive current to capacitive current

Notes

A lower dissipation factor indicates better insulation quality and lower heat generation

A higher or increasing dissipation factor indicates degradation, moisture ingress, contamination, or aging

6. ENVIRONMENTAL/CHEMICAL TESTING REQUIREMENTS

Environmental/Chemical Test*	CSA C68.5	CSA C68.10	ICEA S-94-649	ICEA S-97-682	AEIC CS8	ICEA S-113-684	ICEA S-93-639	UL 1072
Weather/UV resistance (720h/1000h UV)	✓ (1000h)	✓ (1000h)	✓ (Mandatory: PVC, CPE, TPE Optional: others) (720h)	✓ (Mandatory: PVC, CPE, TPE Optional: others) (720h)	✓ (Mandatory: PVC, CPE, TPE Optional: others) (720h)	✓ (720h)	✓ (720h)	✓ Optional (720h)
Carbon black content (jacket)	✓	✓	✓	✓	✓	✓	✗	✗
Absorption coefficient	✗	✗	✓	✓	✓	✓	✓	✗
Environmental stress cracking	✓	✓	✓	✓	✓	✓	✓	✓
Oil resistance / immersion	✓ (PVC)	✓	✓ (PVC, CPE + TPE)	✓ (PVC, CPE + TPE)	✓ (PVC, CPE + TPE)	✓ (PVC, CPE + TPE)	✓	✓
Flame – vertical (optional)	✓	✓	✗	✗	✗	✓	✓	✓
Limited smoke (optional)	✗	✓	✗	✗	✗	✓	✓	✓
Acid gas evolution (HAL-FREE only)	✗	✓	✗	✗	✗	✓	✓	✗
Halogen content (HAL-FREE only)	✗	✓	✗	✗	✗	✓	✓	✗

*DF and DR cable designs may have slightly different testing requirements.

6. ENVIRONMENTAL/CHEMICAL TESTING REQUIREMENTS

Weather/UV resistance

Purpose

Evaluate jacket material resistance to UV exposure and weathering

Importance

Prevent cracking and fading outdoors
Ensure long-term stability in sunlight and harsh conditions



Carbon black content

Measure percentage of carbon black in jacket compound

Ensure adequate UV protection
Maintain jacket strength and durability
Prevent premature aging and surface cracking

6. ENVIRONMENTAL/CHEMICAL TESTING REQUIREMENTS

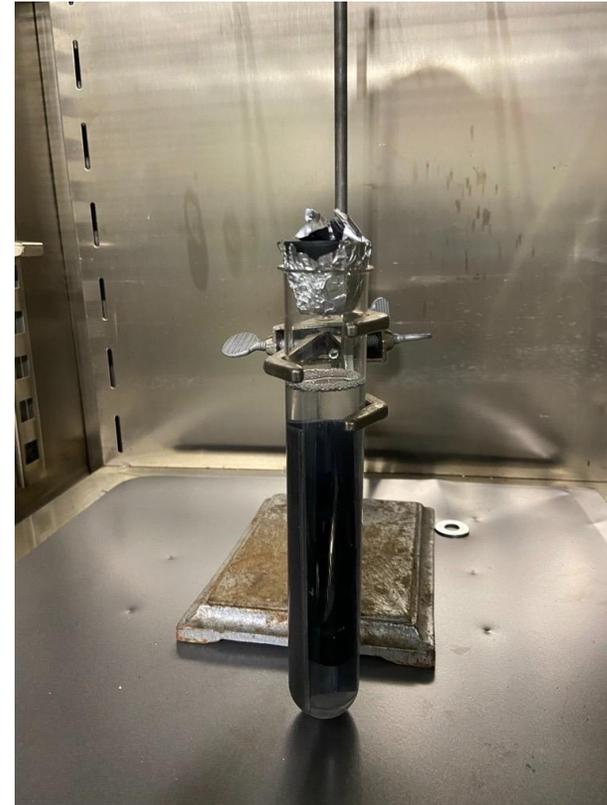
Environmental stress cracking

Purpose

Assess material resistance to cracking under mechanical stress and chemical exposure

Importance

Prevent jacket failure in demanding environments
Support qualification



ESC test set up



6. ENVIRONMENTAL/CHEMICAL TESTING REQUIREMENTS

Oil resistance/immersion

Purpose

Measure material resistance to swelling, softening, or degradation when exposed to oils.

Importance

Ensure performance in environments exposed to oil
Prevent jacket breakdown

Test specimens are immersed in IRM 902 oil at a specified temperature for a specified time.

Then, tensile and elongation properties are measured and compared with original properties.



oil

6. ENVIRONMENTAL/CHEMICAL TESTING REQUIREMENTS

Flame – Vertical (optional)

Purpose

Evaluate cable's flame propagation performance

Importance

Ensure compliance with safety/building codes
Reduce risk of flame spread

FT1 / VW1

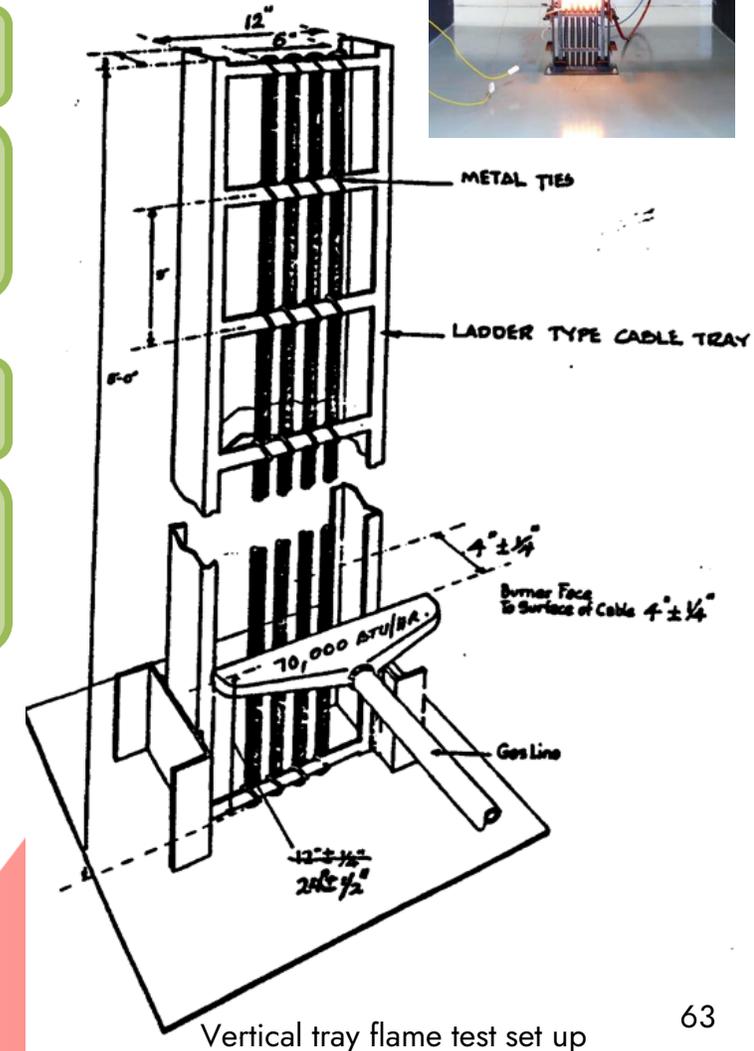
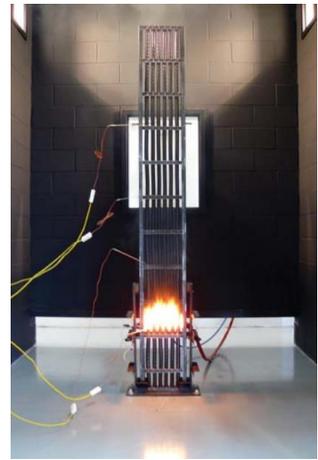
Vertical flame test
Heat input: 1700 BTU/h

FT4/IEEE 1202/UL1685

Vertical *tray* flame test
Heat input: 70,000 BTU/h

ICEA T-30-520

Vertical *tray* flame test
Heat input: 70,000 BTU/h



Vertical tray flame test set up

6. ENVIRONMENTAL/CHEMICAL TESTING REQUIREMENTS

Limited smoke (optional)

Purpose

Determine smoke generation during combustion

Importance

Enhance visibility and safety in a fire
Critical for tunnels, transit systems,
and high-traffic areas

Cables with a **limited smoke (ST1)** designation have a low smoke release rate (SRR).

Test methods (UL/CSA 2556)

Method 1 – Vertical tray

Duration: 20 mins
Smoke release: 95 m²
Peak release rate: 0.25 m²/s

Method 2 – FT4

Duration: 20 mins
Smoke release: 150 m²
Peak release rate: 0.40 m²/s

$$SRR = \frac{(OD \times M_1)}{0.4064}$$

where

SRR = smoke release rate, m²/s

OD = optical density

M₁ = volumetric flow rate, m³/s, in the exhaust duct, referred to 298K

0.4064 = path length in the duct, m

6. ENVIRONMENTAL/CHEMICAL TESTING REQUIREMENTS

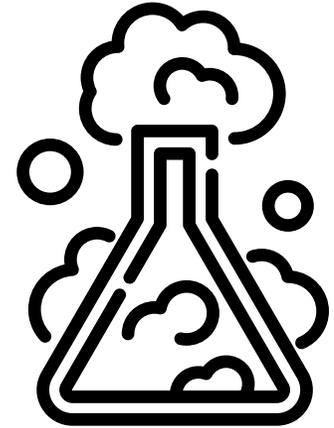
Acid gas evolution (HAL-FREE only)

Purpose

Measure acidic or corrosive gas released when halogen-free materials burn

Importance

Ensure safe air quality during fires
Prevent damage to equipment



This test determines the amount of acid gas byproducts that have evolved during combustion, expressed as hydrogen chloride %.

6. ENVIRONMENTAL/CHEMICAL TESTING REQUIREMENTS

Halogen content (HAL-FREE only)

Purpose

Confirm material contains minimal or no halogens

Importance

Ensure compliance
Reduce toxic gas emissions during a fire

Periodic Table of the Elements

Number	Symbol	Name	Mass
1	H	Hydrogen	1.008
2	He	Helium	4.003
3	Li	Lithium	6.941
4	Be	Beryllium	9.012
5	B	Boron	10.811
6	C	Carbon	12.011
7	N	Nitrogen	14.007
8	O	Oxygen	15.999
9	F	Fluorine	18.998
10	Ne	Neon	20.180
11	Na	Sodium	22.990
12	Mg	Magnesium	24.305
13	Al	Aluminum	26.982
14	Si	Silicon	28.086
15	P	Phosphorus	30.974
16	S	Sulfur	32.066
17	Cl	Chlorine	35.453
18	Ar	Argon	39.948
19	K	Potassium	39.098
20	Ca	Calcium	40.078
21	Sc	Scandium	44.956
22	Ti	Titanium	47.867
23	V	Vanadium	50.942
24	Cr	Chromium	51.996
25	Mn	Manganese	54.938
26	Fe	Iron	55.845
27	Co	Cobalt	58.933
28	Ni	Nickel	58.693
29	Cu	Copper	63.546
30	Zn	Zinc	65.38
31	Ga	Gallium	69.723
32	Ge	Germanium	72.631
33	As	Arsenic	74.922
34	Se	Selenium	78.971
35	Br	Bromine	79.904
36	Kr	Krypton	83.798
37	Rb	Rubidium	85.468
38	Sr	Strontium	87.62
39	Y	Yttrium	88.906
40	Zr	Zirconium	91.224
41	Nb	Niobium	92.906
42	Mo	Molybdenum	95.95
43	Tc	Technetium	98.907
44	Ru	Ruthenium	101.07
45	Rh	Rhodium	102.906
46	Pd	Palladium	106.42
47	Ag	Silver	107.868
48	Cd	Cadmium	112.414
49	In	Indium	114.818
50	Sn	Tin	118.710
51	Sb	Antimony	121.760
52	Te	Tellurium	127.6
53	I	Iodine	126.904
54	Xe	Xenon	131.293
55	Cs	Cesium	132.905
56	Ba	Barium	137.328
57-71			
72	Hf	Hafnium	178.49
73	Ta	Tantalum	180.948
74	W	Tungsten	183.84
75	Re	Rhenium	186.207
76	Os	Osmium	190.23
77	Ir	Iridium	192.22
78	Pt	Platinum	195.085
79	Au	Gold	196.967
80	Hg	Mercury	200.592
81	Tl	Thallium	204.383
82	Pb	Lead	207.2
83	Bi	Bismuth	208.980
84	Po	Polonium	[209]
85	At	Astatine	[210]
86	Rn	Radon	[222]
87	Fr	Francium	[223]
88	Ra	Radium	[226]
89-103			
104	Rf	Rutherfordium	[261]
105	Db	Dubnium	[262]
106	Sg	Seaborgium	[266]
107	Bh	Berkelium	[267]
108	Hs	Hassium	[270]
109	Mt	Moscovium	[278]
110	Ds	Darmstadtium	[285]
111	Rg	Roentgenium	[288]
112	Cn	Copernicium	[285]
113	Nh	Nihonium	[286]
114	Fl	Flerovium	[289]
115	Mc	Moscovium	[288]
116	Lv	Livermorium	[293]
117	Ts	Tennessine	[294]
118	Og	Oganesson	[294]

Why are halogens used?

They are typically very flame resistant. When burning, these materials will:

1. Smoke heavily, limiting fresh air from reaching ignited material
2. Form a char barrier, temporarily protecting unburnt material

Why go halogen-free?

While flame resistant, halogen-containing materials will eventually burn. Halogenated FRs can have a high toxicity risk.

Measuring halogen content

Halogen content is determined using x-ray fluorescence or by chemical composition analysis of ingredients used.
Each non-metallic component must have < 0.2% total halogen

7. KEY DIFFERENCES

CSA C68.5 vs C68.10

C68.5 is for utility use with concentric neutral and AWTT requirements
C68.10 is for industrial use

CSA C68.10 vs UL 1072

UL 1072 is for industrial use under the scope of the NEC
CSA C68.10 is for industrial use under the scope of the CE Code

ICEA vs AEIC CS8

AEIC CS8 Specification builds on existing ICEA utility cable standards with additional requirements including:

1. Tree Count Test after AWTT
2. Modified hot creep/set limits
3. Reduced de-gassing times
4. CTR reporting requirements

CSA vs ICEA

CSA standards typically adapt **ICEA** requirements with Canadian-specific reqt's like:

1. Cold Bend w/ PD
2. 1000 Hr UV Test
3. Mandatory Thermomechanical test

UL vs ICEA

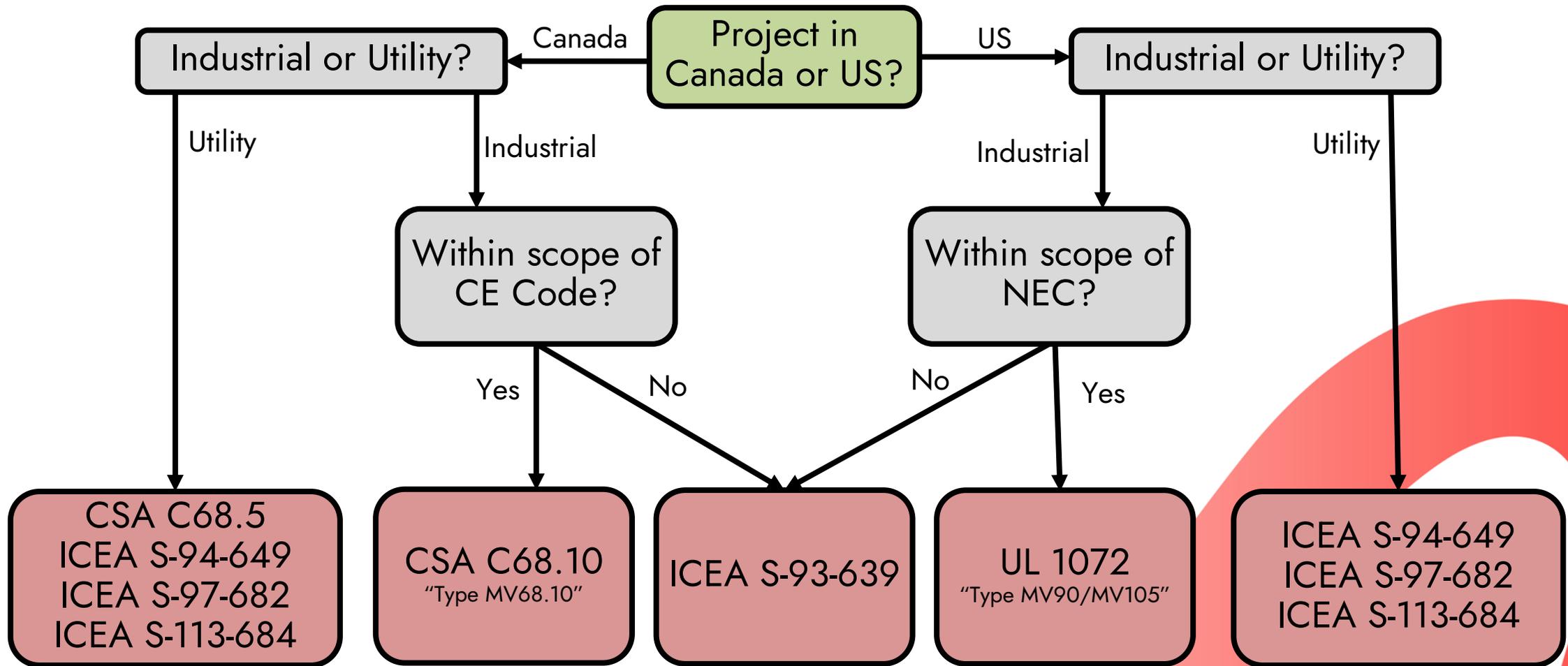
ICEA focuses on construction and material properties, whereas **UL** is more focused on NEC compliance and product marking

ICEA S-113-684

Unlike 649, 682, and 639, **ICEA S-113-684** is a performance-based standard permitting significant reduction of cable diameters, if so qualified.

8. DECISION FLOWCHART

The following flowchart may help determine what standard to specify a cable to.



Note: Some applications may require compliance with multiple standards. Cables can be evaluated to multiple standards⁶⁸

Q&A

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