Medium Voltage Cable Constructability Overview Presentation

Dec 1, 2020 IEEE Southern AB Chapter Meeting

Introduction

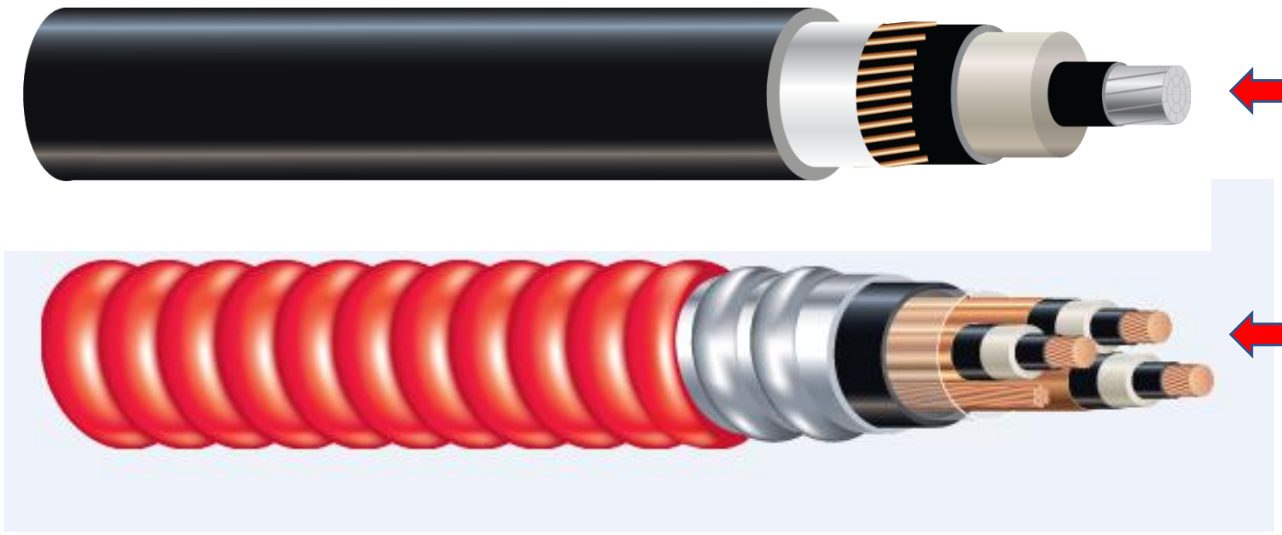
Blair Sackney, BSc. Eng.

Major Project & Engineering Support

- 19 years wire & cable experience, major industrial projects
- BSc. Eng. (University of Alberta)
- Employer – Texcan, Surrey BC – Wire and Cable distributor
- Previous employers – Cable manufacturers – in Application Engineering and Sales roles
  - Southwire
  - Shawflex
  - Alcan Cable
- IEEE activity
  - ESTMP presentations
  - PCIC Vancouver Volunteer 2019
  - Presentations at IEEE Chapter meetings in Calgary, Edmonton, and Fort McMurray
- Regular cable technical newsletters

Agenda

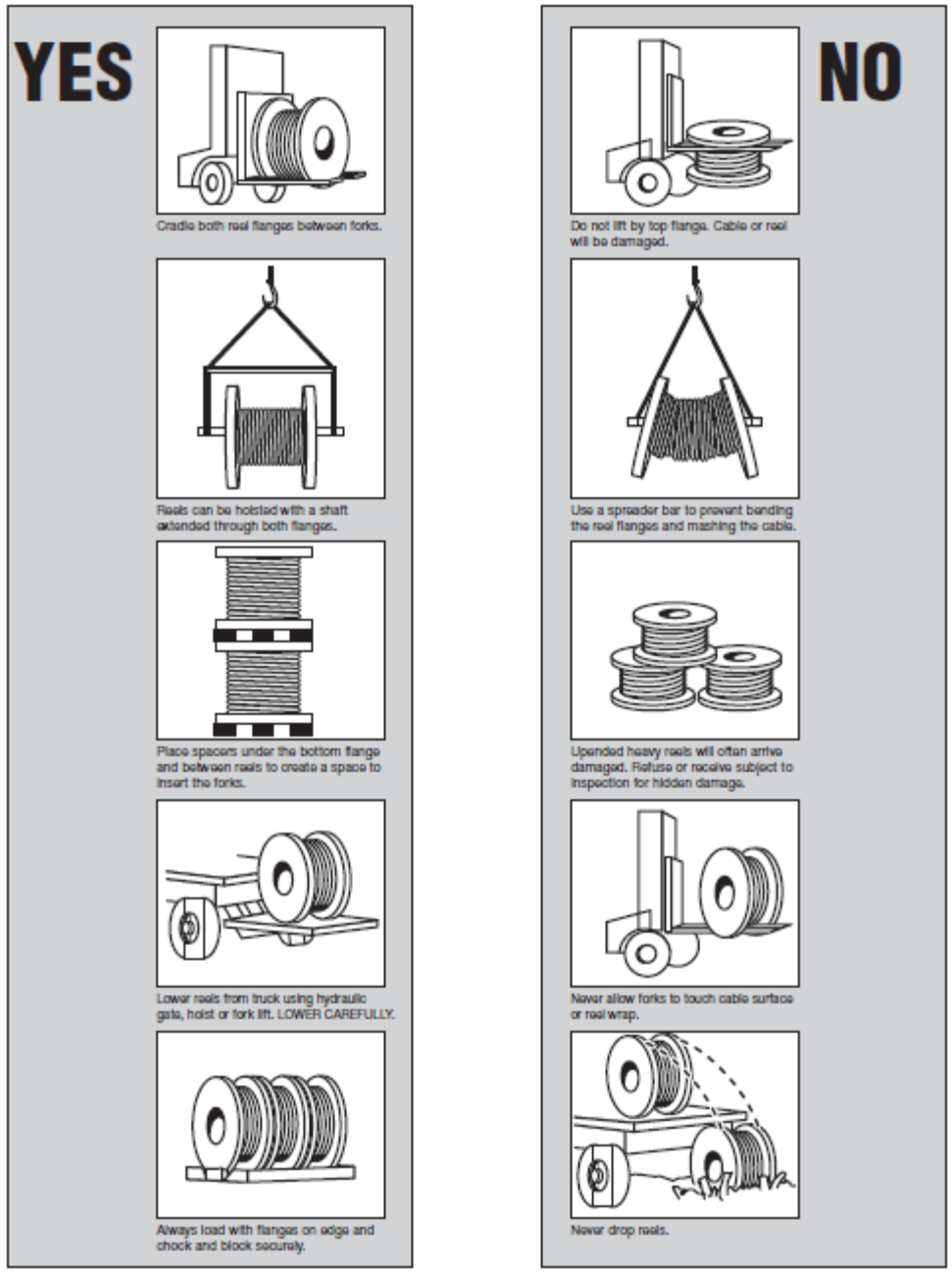
- Medium voltage cable handling
- Cable pull calculations & pull plans
- Cable routing best practices
- Large cable installations
- Site acceptance and maintenance testing



UD Cable

HVTECK

Cable Handling



End Caps

- End caps are installed on cables shipped from the manufacturers and distributors to jobsite to prevent water entry into the cable
- If an end cap is removed a new end cap must be installed.
- Both heat shrink and cold shrink end caps are available. Inexpensive items.

End Caps

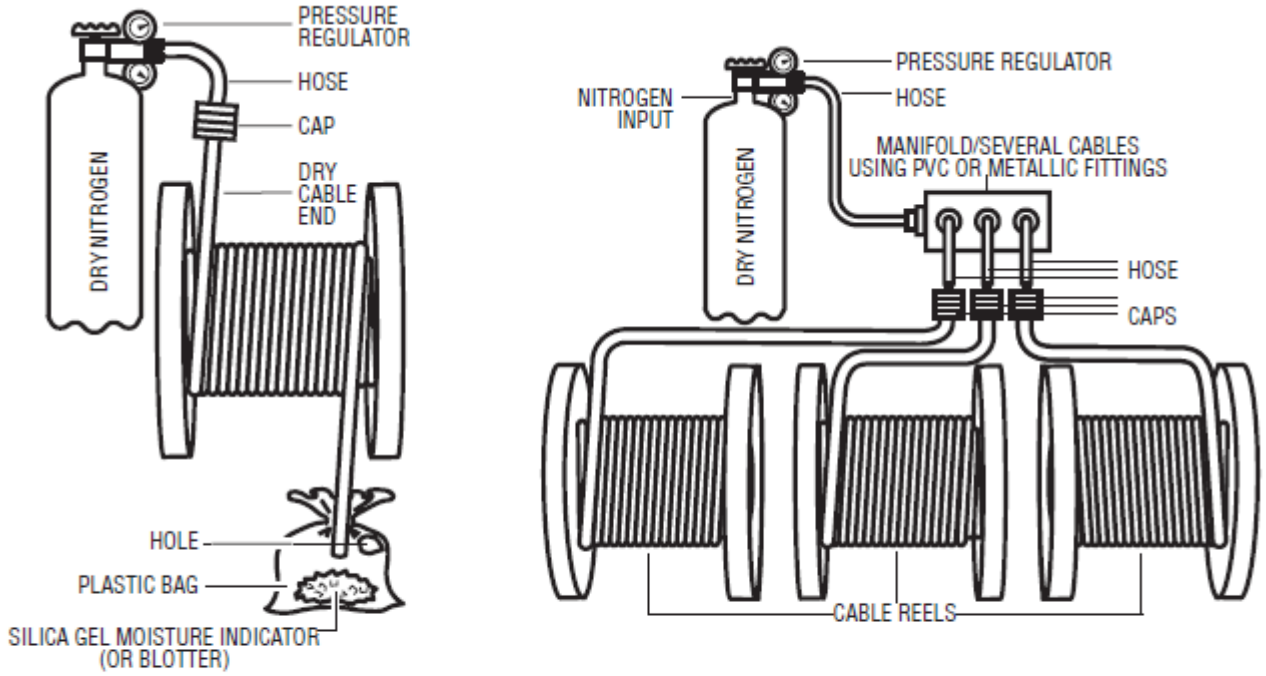


Fig. 7.3 Setup for Purging Water from Strand or Shield

Receiving / Storage

- Upon receipt inspect reels for damage to the reels or cable
- Cable can be stored inside or outside.
- If stored outside the reels need to sit on a hard surface so the reel flanges don’t sink into the soil. Preferably in a well drained area
- Colored cable jackets will fade in sunlight. Some colors or manufacturers product fade more than others.
- Some cables are not sunlight resistant and should only be stored indoors

Low Temperature Handling

-Main CSA tests

-Cold Bend Test (easy to pass)

Bend around a 12 x OD mandrel

-Cold Impact Test (harder to pass)

Drop weight from height – 8/10 to pass

-Typical testing options -25C, -40C, -45C, -50C

Low Temperature Handling

-Installation handling temperatures left to cable manufacturer to state

-Beware of -40C installation claims

-Rule of thumb

- **25C Min installation temp** for Thermoset insulations (EPR/XLPE) passing both -40C cold bend and impact test
- **10C Min installation temp** for Thermoplastic insulation (PVC) or thermosets that pass both -25C cold bend and impact tests

-There is no minimum temperature once the cable is installed. The cable can sit installed in the elements or stored on reels in a Canadian winter with no issue as long as the cable isn't mechanically disturbed.

Min Bend Radius

-CE Code 12-614 min bend radius is 6 x OD for armored cables

-CE Code 12-614 (3)(C) allows you to use manufacturer's numbers

-CE Code Table 15 is for High Voltage applications

-Tape Shielded Cable (ie. 5-35KV HVTECK)

-CE Code > 12 times cable OD or 12 times conductor OD

-NEC > 7 times cable OD or 12 times conductor OD

-12 times the OD of large cables can result in very large cable trays.

-Table 15 in my view is an old table that needs updating to line up with NEC and 12-614. Many of the cable manufacturers have bend radius numbers on their spec sheets in line with the NEC and can provide a letter for your inspection deviation that their cables are designed to be bent according to their spec sheet numbers.

Min Bend Radius

Table 15

Bending radii — High-voltage cable

(See Rules 34-400 and 36-102.)

Note: *Click the image below to view it at full size.*

Type of cable	Cable diameter multiplying factor (see Note)		
	Up to and including 25 mm diameter	Over 25 mm diameter and up to and including 50 mm diameter	Over 50 mm diameter
Lead covered	10	12	12
Corrugated aluminum-sheathed	10	12	12
Smooth aluminum-sheathed	12	15	18
Tape shielded	12	12	12
Flat tape armoured	12	12	12
Wire armoured	12	12	12
Non-shielded	7	7	7
Wire shielded	7	7	7
Portable power cables 5 kV and less	6	6	6
Portable power cables over 5 kV	8	8	8

Note: *The bending radius is the radius measured at the innermost surface. It equals the overall diameter of the cable multiplied by the appropriate number shown in Columns 2, 3, and 4.*

Cable Handling Main Constraints

Cable Minimum Bend Radius

-Separate armor, crush insulation / jacket, flattened armor, jacket stretching

-this is a common issue - standard sheaves are often too small.

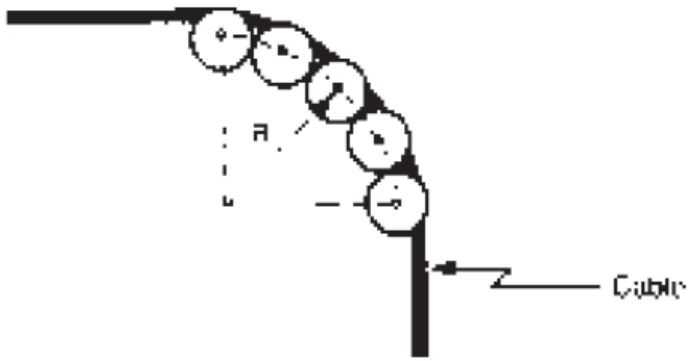
-use compound roller sheaves / sheave assemblies but be careful

they are installed correctly (in line with the pull)

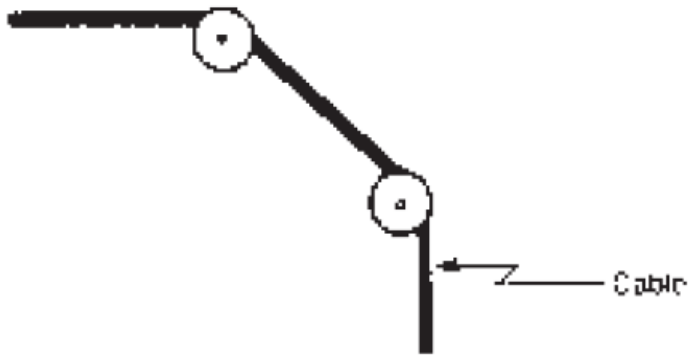
Cable Handling Main Constraints

Cable Minimum Bend Radius

Careful to ensure the set up of compound or multiple sheaves are set up correctly or the bend radius may be significantly less than expected.



Proper set up



Improper set up
Radius is now the
small sheave radius

Cable Handling Main Constraints

Cable Minimum Bend Radius

Standard largest sheave is 24” OD > only 12” Radius

For example: at 7 x min bend radius for most armored cables 1.7” OD is the largest cable that can go around a 24” OD sheave

3c-1/0 Teck90 1KV = 1.68”

Cable Handling Main Constraints

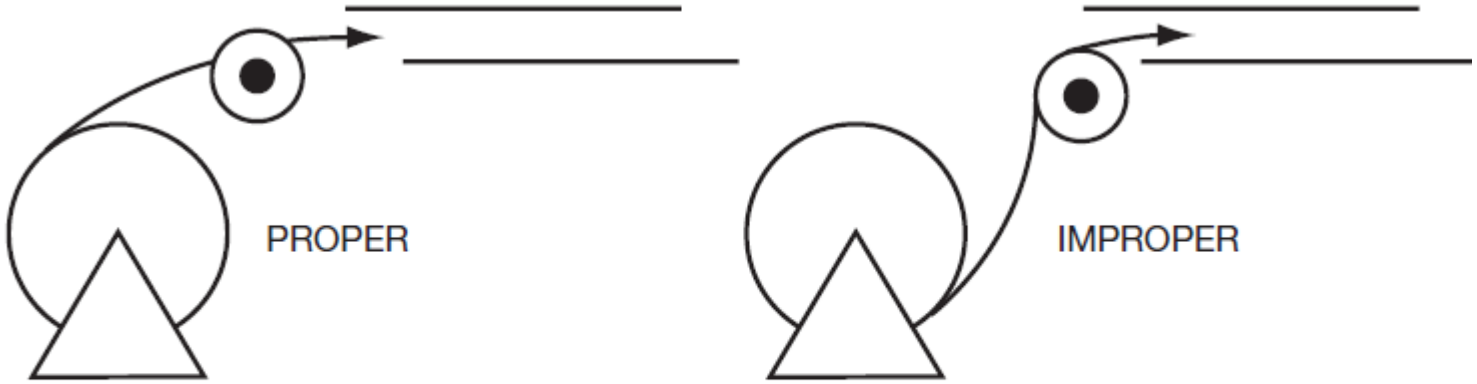


Fig. 3.2.2.1 **Fig. 3.2.2.2**

The feed-in setup should unreel the cable with a natural curvature (Fig. 3.2.2.1) as opposed to a reverse “S” curvature (Fig. 3.2.2.2)

Cable Pull Calculations

-Cable pull calculations should be done on any long large cable pulls or any pulls with more than 2 x 90° bends

-Constraints

-minimum bend radius

-maximum pulling tension

-sidewall bearing pressure

-Pulling calculations are directional. Ensure you indicate to field which direction the pull calc is based upon.

Maximum Pulling Tension

-This is not very often an issue for power cables.

-Usually the Kallems Grip or tugger are the limitation on big cables

-Max pulling tension is based upon the gauge size, metal type, and # of conductors only.

-Cable type, jacket types, shields, etc… have no effect on max pulling tension

Tmax single conductor = S (allowable stress) x Conductor area (in circular mils)

S = 0.8 copper

S = 0.6 8000 series aluminum

Tmax multi conductor = # Conductors x S x Cond Area x 0.8

Side Wall Bearing Pressure

This is the radial force on the cable around bends

SWBP is typically the main pulling constraint

To reduce pull tensions / SWBP

-**increase bend radius - This is the key factor to reduce SWBP**

-recalculate the pull in the opposite direction

-reduce number of bends

-reduce run lengths

-straighten runs

-have a good lube program, clean out conduits before pulling cables

-add manholes (careful to have sheaves lined up properly in manholes and correctly sized)

-yale grips / pull off tray and feed back in (careful not to overbend cable)

Cable Pull Calculations

-Can find equations in all the main cable manufacturers websites and do them by hand

-Most electrical network modelling softwares have pull calc modules

-Free softwares on line

-Southwire pull calculator https://www.southwire.com/calculator-simpull

-Greenlee https://www.greenlee.com/us/en/pulling-calculator

-Polywater https://www.polywater.com/pull-planner/

-Pull calculations are more an art than a science. Too many assumptions and field details to model accurately.

Tutorial link (36 minutes):
https://www.youtube.com/embed/GCTYGnLVA6c

For more information, go to Southwire.com

Enter wire info in purple areas that will go into the raceway	# of wires	Wire Type	Wire Size	Wire OD	Wire Wt/ ft.
Phase Wires	3	SIMpull CU XHHW	2 500	0.927	1.63
Neutral Wire		SIMpull CU THHN	1	0.000	0.00
Ground Wire	1	SIMpull CU XHHW	3 11	0.337	0.18
Total Cables	4	Sets	Reel Size (D X W)	Feet	Gross Wt.
		1	N7 (30" X 20")	0	30

Equipment GW (NEC 250.122) w/o VD considerations to OCD	1600 amps	CU 4/0 CU
		AL 350 AL

Enter raceway info in purple areas			
Raceway Typ	PVC Sch 40 or HDPE		
Raceway Siz	4	Min Conduit 3 in. Per NEC	
Conduit ID	3.998	Maxis Size Grip	Min size conduit using 4 grips & jacket
% Conduit Fill	16.839%	C	3 1/2

Enter Voltage Drop Info in purple areas	SIMpull CU XHHW	
	Single Phase	Three Phase
Amperage @ load (one set)	380	380
System Voltage	120	480
Circuit Length	262.4	262.4
Voltage Drop % (NEC Tbl 9)	7.5%	1.6%
Volts at Load	111.03	472.23
Power Factor for Voltage Drop Is:	0.60	

Cable Pull Calculated Values		
Maximum Pulling Force (lb.)	9,937	
Max Sidewall Pres. (lb.)	1000	
Jam Probability	4.31	Very Small

Phase Wire Ampacity Considerations			
Insulation Withstand Limit (a)	4 cycles / .0667		139,199
Adjust for Ambient Temp	26-30C (78-86F)	2	430
Adjust for # of Current Carrying Conductors	1-3		430
Max Allowable Ampacity for this Scenario 2017 NEC 310.15 (B) (16)			380

Phase Wire Attributes	
Attributes can change based on wire type, size and Mfg	
Acceptable Megohm Readings	50 M'ohms - infinity
Dielectric Constant	See catalog sheet
Max Oper Temp for Dry Use	90 C
Max Oper Temp for Wet Use	90 C
Min Bend Radius (in.)	3.708
Min Installation Temp	-40C (-40F)
Vertically Support every	50 ft.
Riser MC Requires No Vertical Supports	
Sunlight Resistant	yes all colors
CT Rated	Yes
UL	44, 1581, 1685
NEMA	WC 70
RoHS Compliant	no
75 C Ampacity 310.15(B)(16)	380
90 C ampacity 310.15(B)(16)	430
Coefficient Of Friction	**0.16**
Compressed Soft CU Class B	Stranding

Copy this url address to get Southwire's most current calc =

SIMpull Cable Pull Calculator for 600V 5.13

Yellow areas = you have the ability to change data.
Purple areas = input required.

262.4' of 3/C 500 SIMpull CU XHHW and 1/C 3 SIMpull CU XHHW
4" PVC Sch 40 or HDPE

Total wt./ ft	5.082
Configuration	COMPLEX
Wt.correction factor	1.40
COF	0.25
Incoming tension	25

Maximum Pulling Force (lb.) 9,937
Max Sidewall Pres. (lb.) 1,000
Jam Probability Very Small

COF 0.25
Recommended
SIMpull CU XHHW
No Lube Required
Colored wires

Feeder:
Origin:
Destination:

	Straight Section			Bend Section						
Wire pull / Segment	Angle (Slope)	Wire is being pulled ...	Segment Length ft.	Bend Type	Up, Down, N/A	Degree of elbow	Radius (in.)	continuous tension (lbs.)	sidewall pressure (lbs.)	Begin new pull in this segment
1	90	Down	16.4	VCUP	Down	45	36	1	0	
2	90	Down	4	VCUP	Down	45	UBR # 1	1	1	
3		HZTL	230	VCUP	UP	45	36	540	134	
4	90	UP	4	VCDN	UP	45	UBR # 1	738	388	
5	90	UP	8			90	Std	779	410	
6								0	0	
7								0	0	
8								0	0	
9								0	0	
10								0	0	
11								0	0	
12								0	0	
13								0	0	
14								0	0	
15								0	0	
16								0	0	
17								0	0	
18				Call Southwire if you neeed additional segments				0	0	
		Total Length	262.4							

Notes:

Southwire recommended wire pulling equipment.

1. Southwire factory installed SIMpull Heads for pre-cut paralleled reels
2. Minumum size cable puller and a 9/16 SIMpull Rope.

Maxis 3K has a maximum pulling force of 3,000 lb. and pulls Continuous Tensions up to 1,500lb. Use a 9/16" SIMpull Rope.

Maxis 6K has a maximum pulling force of 6,000 lb. and pulls Continuous Tensions up to 3,500lb. Use a 9/16" SIMpull Rope.

Maxis XD 10K has a maximum pulling force of 10,000 lb. and pulls Continuous Tensions up to 7,000lb. Use a 9/16" SIMpull Rope.

http://www.southwiretools.com/

Conduit system is assumed to be clean and free of debris.

Southwire Engineering conservative Coefficient Of Friction (COF)
.35 for regular THHN THWN, XHHW and USE; all requiring lube as recommended
.16 for SIMpull XHHW that requires no lube
.14 for SIMpull THHN THWN that requires no lube

Determines Unique Bend Radius	
Degree of bend	0
Distance of bend (Ft.)	0
Bend Radius (Ft.) Is =	0

Note: Rollers or sheaves are found in drop down of "Radius (in.)" Example; a 12" diameter roller is 6" RR" (radius roller)

Unique Bend Radius	enter as FEET	Unique Bend Degree	Enter as Degree	Unique Angle (Slope)	Enter as degree(s)
UBR # 1 =	1.3		0	Angle # 1 =	0
UBR # 2 =	0.0		0	Angle # 2 =	0
UBR # 3 =	0.0		0	Angle # 3 =	0
UBR # 4 =	0.0		0	Angle # 4 =	0

Coefficient of Friction

-Coefficient of friction assumption will have a large effect on your final pull calculation.

-Below is a table of conservation numbers that should work for both new and existing installations (assuming the conduits have been cleaned.

-More aggressive numbers can be used based upon your knowledge of the pull. Such as if the installation is new, the contractor is very experienced in proper job set up, and there is a good lubrication program in place. Myself if I'm comfortable with all the above have used 0.25. Manufacturers of no lube cables have used 0.15 for new installations with no lube cables.

-However it is best to be conservative if you're not familiar with the job details.

Table from Southwire Installation Manual

TYPICAL COEFFICIENTS OF DYNAMIC FRICTION (μ)
ADEQUATE CABLE LUBRICATION DURING PULL (A)

	Type of Conduit (B)			
Cable Exterior	M	PVC	FIB	ASB
PVC- Polyvinyl Chloride	0.4	0.35	0.5	0.5
PE- Low Density HMW Polyethylene	0.35	0.35	0.5	0.5
PO- SOLONON™ (Polyolefin)	0.35	0.35	0.5	0.5
CSPE- Hypalon® (Chlorosulfonated Polyethylene)	0.5	0.5	0.7	0.6
XLPE- Cross-Linked PE	0.35	0.35	0.5	0.5
Nylon	0.4	0.35	0.5	0.5
CPE- Chlorinated PE	0.5	0.5	0.7	0.6

(A) These represent conservative values for use in lieu of more exact information.[4]
(B) Conduit Codes:
M = metallic, steel or aluminum
PVC = polyvinyl chloride, thin wall or heavy schedule 40
FIB = fiber conduit—Orangeburg or Nocrete
ASB = asbestos cement—Transite or Korduct

Assist Pulls

YaleGrip

Synthetic Pulling & Stopping Grips

YaleGrips install easily on varying diameters.

Size the grip by anticipated loads, not by the cable size it fits. When the anticipated load needs to be spread over a wider surface area, a six-leg grip is suggested. Please call or email for a quotation.

YaleGrips are made from a Technora® Aramid fiber flat braid and are assembled in a 4-leg configuration extending from a reinforcing, securing eye. The eye is covered entirely with an extra layer of braid, which is saturated with Maxijacket urethane, an abrasion-resistant coating for extended life.

YaleGrips are used as pulling and stopping grips for electrical-line construction work above and below ground, for deployment and retrieval of a variety of cables, as marine stoppers on hawsers and for temporary or permanent strain relief. YaleGrips are applied quickly over a wide range of cable diameters without specialized tools. They are noncorrosive, have good dielectric properties and are compact and lightweight. Installed, the grip remains flexible and does less damage to mating surfaces than other types of grips.

YaleGrips are far stronger than wire mesh grips and do not form dangerous "fishhooks," as do wire mesh grips, making them safer to handle.

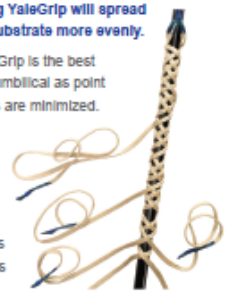
YaleGrips may be used for temporary or permanent eyes, both in midspan or on the end.

Options include urethaning the entire grip, which extends the grip's life, especially useful in active towing applications. We call this the "marine treatment." We also can make a grip with extended tails to accommodate larger cables. Hardware can be added to the eye, such as stainless thimbles, which enhances performance.

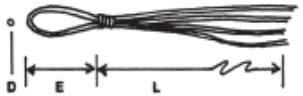
To view an install, visit: www.yalecordage.com/yalegrips

The optional 6-leg YaleGrip will spread the load on the substrate more evenly.

The 6-legged YaleGrip is the best way to handle an umbilical as point compression loads are minimized.



The 6-leg grip has the same tensile rating as the 4-leg model but spreads the compressive forces more evenly across the surface. The 6-leg and the 4-leg are both available with our optional Maxijacket marine coating.



Larger-sized cables may be accommodated by lengthening tail dimension ("L"). Please call or email for a quotation.

YaleGrips are available in all sizes shown below, each of which is color coded for easy identification. Each grip additionally carries a serialized tag for tracking purposes.

Specifications

Material Size		Part Number	Minimum Cable Diameter		Maximum Cable Diameter		Average Break Strength		Maximum Working Load (5:1)		Tail Length		Eye Size		Color
Inches	(mm)		Inches	(mm)	Inches	(mm)	Lbs	Kg	Lbs	Kg	Feet	M	Inches	(cm)	
7/16	(11)	944504T	3/16	(5)	1/2	(13)	6,000	2,722	1,200	544	4.5	1.4	6	(15)	Red
9/16	(14)	944505T	1/4	(6)	3/4	(18)	12,000	5,443	2,400	1,089	5.5	1.7	6	(15)	Blue
11/16	(17)	944506T	3/8	(10)	7/8	(22)	18,000	8,165	3,600	1,633	6.5	2.0	6	(15)	Green
7/8	(22)	944507T	1/2	(13)	1	(25)	30,000	13,608	6,000	2,722	8	2.4	8	(20)	Orange
1	(25)	944508T	5/8	(16)	1-1/8	(29)	48,000	21,773	9,600	4,355	10	3.0	8	(20)	Yellow
1-1/4	(32)	944509T	7/8	(22)	1-3/4	(44)	72,000	32,659	14,400	6,532	16	4.9	12	(30)	Black
1-1/2	(38)	944510T	1-1/8	(29)	3	(76)	120,000	54,432	24,000	10,886	22	6.7	16	(41)	Red
1-3/4	(44)	944511T	1-3/8	(35)	3-1/2	(89)	180,000	81,648	36,000	16,330	28	8.5	18	(46)	Blue
2	(51)	944512T	2	(51)	4	(102)	290,000	131,544	58,000	26,309	34	10.3	18	(46)	Green
2-1/4	(57)	944513T	3-1/4	(83)	5	(127)	365,000	165,564	73,000	33,113	40	12.2	20	(51)	Orange
2-1/2	(64)	944514T	4	(102)	6	(152)	450,000	204,120	90,000	40,824	52	15.8	24	(61)	Yellow

77 Industrial Park Road, Saco, ME 04072 • 207-282-3396 • www.yalecordage.com

YALE CORDAGE
Performance. Passion. Possibilities.

Manholes / Pull Boxes

-Pull boxes can be designed into the runs to allow for pulling points if required.

-Size them to allow the contractor to maintain bending radius when coming out of the manhole.

Large Cable Installations

Trend has been towards very large OD Medium Voltage cables (over 4” OD) and very long runs.

Challenge: Results in very large reels of very difficult to install cables with more risk of cable handling damage

-jobsite might not be able to handle the reel size

-Cable length can be limited by maximum reel size resulting in splices

-Might lead to “improvised field solutions”

-personnel and equipment safety

Solution: Consider single conductor or paralleled cables

-lower handling costs

-reduced cable damage risk

-longer splice free runs

-May use more tray space, but “free air” ampacity gains may be achieved if conductor spacing is maintained, reducing cable gauge sizes

Factory Acceptance Test -CTR

CABLE DESCRIPTION: 1/C 500 KCMIL CU 115 EPR CPE JKT 5KV133% 8KV100% CT

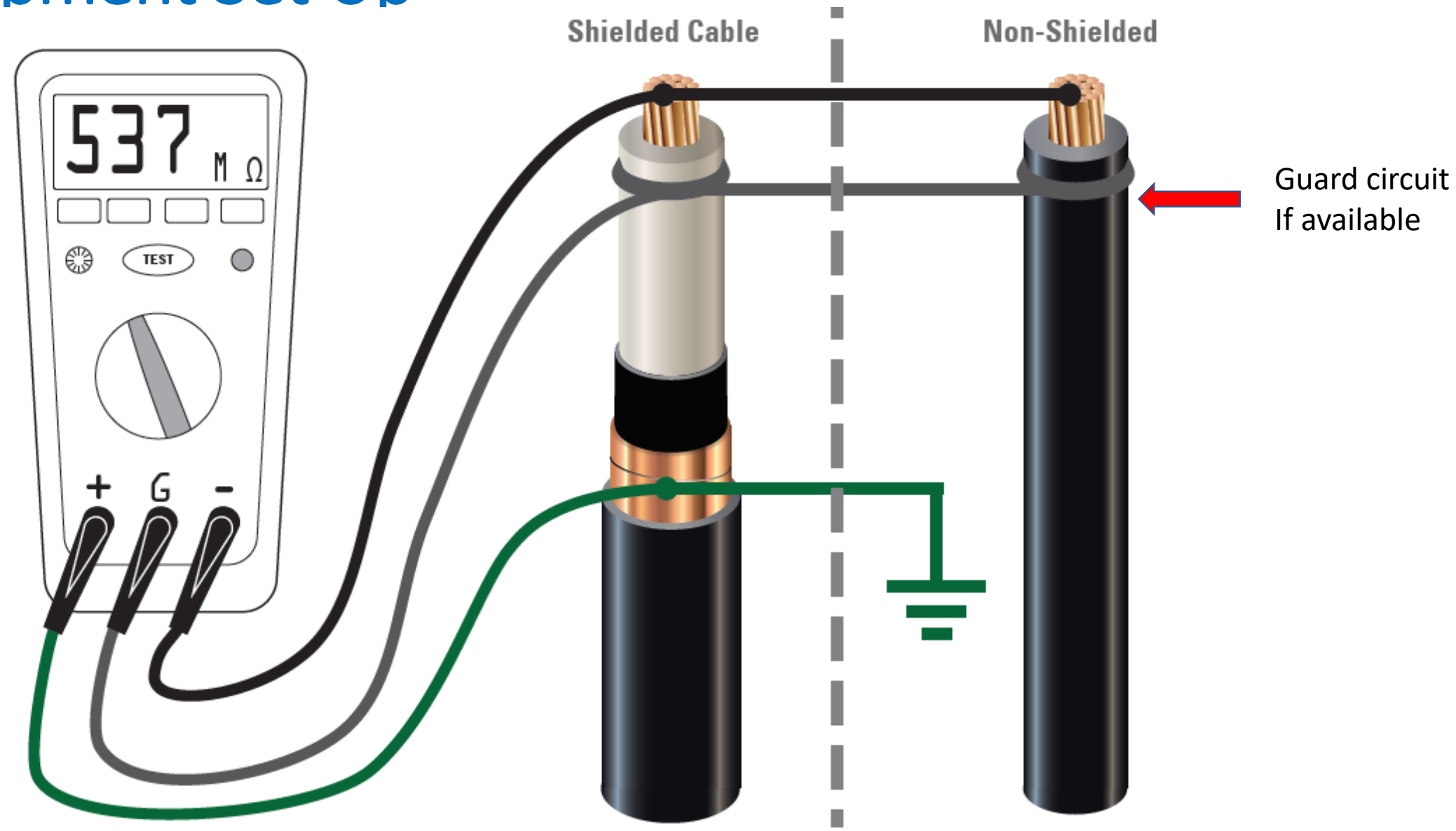
HV Test Tag No		104182	102538	102540	102541	102542	
Section No. Test		44	68	69	70	71	
Master Length		2,900	3,200	3,050	3,034	3,100	
Certification Lot		118044	118068	118069	118070	118071	
Shipout Reel No.		110058	110059	110060	110061	110062	
Shipout Length (FEET)		2,100	2,100	2,100	1,900	1,900	
	SPECIFICATION						
CONDUCTOR							
MIN Diameter (INCH)	0.774	0.776	0.776	0.776	0.776	0.776	
CONDUCTOR SHIELD							
MIN Thickness (INCH)	0.016	0.023	0.023	0.023	0.023	0.023	
INSULATION							
MIN Diameter (INCH)	1.035	1.050	1.050	1.050	1.050	1.050	
MIN Thickness (INCH)	0.110	0.117	0.117	0.117	0.117	0.117	
INSULATION SHIELD							
MIN Diameter (INCH)	1.085	1.150	1.140	1.140	1.140	1.140	
MIN Thickness (INCH)	0.032	0.036	0.036	0.036	0.036	0.036	
METALLIC SHIELD							
MIN Thickness (INCH)	1.104	1.140	1.140	1.140	1.140	1.140	
NOM Tape Overlap	22.5%	25%	25%	25%	25%	25%	
JACKET							
NOM Diameter (INCH)	1.244	1.400	1.370	1.365	1.380	1.340	
MIN Thickness (INCH)	0.070	0.082	0.082	0.082	0.082	0.082	
ELECTRICAL TESTING							
AC Withstand Time (Minutes)	5	5	5	5	5	5	
AC Withstand Voltage (kV)	23	23	23	23	23	23	
MAX Partial Discharge (pC)	5	2	1	1	1	1	
MIN Insulation Resistance (Meg Ohms/1000ft)	3450	19395	20064	20398	19023	19437	
MAX Conductor Resistance (Ohms/1000ft)	0.0220	0.0216	0.0216	0.0216	0.0216	0.0216	

SPECIFICATIONS ICEA S-93-639
NEMA PUB. NO. WC-74
UL STANDARD 1072

Testing Overview

- Ensure all safety protocols are followed.
- Start with a Continuity and Megger Test (insulation resistance)
  - Refer to NETA 100.1 for test information
- DC Hipot test equipment is widely available, low input power, inexpensive, and easy to use
  - Refer to IEEE 400.1 for test information
  - DC testing might not be effective in detecting certain types of insulation defects
  - IEEE 400 doesn’t recommend DC Hipot tests for aged / underground extruded cables
- VLF withstand testing is much more common now and recommended for field testing of aged or underground cables
  - Refer to IEEE 400.2 for test information
  - Typically 0.1 Hz
  - Can also do a Tan Delta test giving you information you can trend over time.

Equipment Set Up



Megger Testing Results

- Good cable should test out similar to below
- Resistance values will increase over time due to capacitive and insulation charging
- As charging becomes more complete the resistance readings will level out.
- Test time depends upon cable length – 10 minutes is typically sufficient.

Cable Voltage Rating	Minimum Test Voltage	Minimum Insulation Resistance
Volts	Volts, DC	MΩ•1000 ft.
300	500	25
600	1,000	50
1,000	1,000	50
2,000	1,000	100
2,400	1,000	500
5,000	2,500	1,500
8,000	2,500	1,500
15,000	2,500	5,000
25,000	5,000	10,000
28,000	5,000	15,000
35,000	5,000	20,000

DC Installation – Hi Pot Testing

- DC installation testing is accomplished by employing high voltage, low current dc power to the cable. Installation testing is important in that it provides assurance that no damage has occurred during installation or in handling after leaving the factory. If the cable is installed by a contractor, the test can serve as an acceptance test and assure the owner that the cable has not been damaged and should perform satisfactorily.

Recommended dc Test Voltages for Shielded Power Cable Systems From 5 - 35KV

System Voltage KV Phase to Phase	Accceptance Test Voltage (KV dc, Cond-gnd)	Maintenance Test Voltage (KV dc, Cond-gnd)
5	28	23
8	36	29
15	56	46
25	75	61
28	85	68
35	100	75

Acceptance test voltage duration is normally 15 minutes. Maintenance test voltage duration is normally not less than 5 minutes or more than 15 minutes

DC Field Withstand Testing Voltages & Duration 15KV 133% Insulation Level

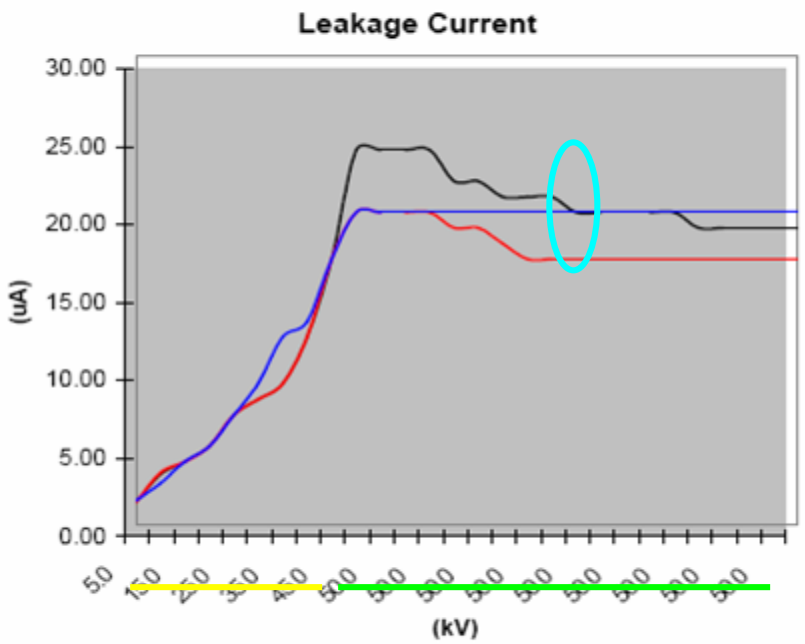
TABLE I
DC FIELD TEST VOLTAGES AND TEST DURATION (15-KV 133% INSULATION LEVEL)

Standard	Insulation	Acceptance	Maintenance
IEEE 400	EPR/XLP	56 kV / 15 Min.	46 kV 5-15 Min.
IEEE 576	EPR/XLP	65 kV / 15 Min.	
ICEA S-68-516	EPR	65 kV / 15 Min.	
ICEA S-66-524	XLP	65 kV / 15 Min.	
ICEA S-94-649	EPR/XLP	64 kV / 15 Min.	20 kV 5 Min.
AEIC CS6-96	EPR	64 kV / 5 Min.	51 kV 5 Min.
AEIC CS5-94	XLP	64 kV / 5 Min.	20 kV 5 Min.

High Potential Test Report

LEAKAGE CURRENT (uA)					
Time	kV	A	B	C	N
DC Voltage Buildup	5.0	1.40	1.40	1.50	
	10.0	3.20	3.30	2.60	
	15.0	4.00	4.00	4.00	
	20.0	5.00	5.00	5.00	
	25.0	7.00	7.00	7.00	
	30.0	8.00	8.00	9.00	
	35.0	9.00	9.00	12.00	
	40.0	12.00	12.00	13.00	
	45.0	17.00	17.00	17.00	
	50.0	24.00	20.00	20.00	
15 sec	50.0	24.00	20.00	20.00	
30 sec	50.0	24.00	20.00	20.00	
45 sec	50.0	24.00	20.00	20.00	
1 min	50.0	22.00	19.00	20.00	
2 min	50.0	22.00	19.00	20.00	
3 min	50.0	21.00	18.00	20.00	
4 min	50.0	21.00	17.00	20.00	
5 min	50.0	21.00	17.00	20.00	
6 min	50.0	20.00	17.00	20.00	
7 min	50.0	20.00	17.00	20.00	
8 min	50.0	20.00	17.00	20.00	
9 min	50.0	20.00	17.00	20.00	
10 min	50.0	20.00	17.00	20.00	
11 min	50.0	19.00	17.00	20.00	
12 min	50.0	19.00	17.00	20.00	
13 min	50.0	19.00	17.00	20.00	
14 min	50.0	19.00	17.00	20.00	
15 min	50.0	19.00	17.00	20.00	

INSULATION RESISTANCE (MEGOHMS)		
	PRE	POST
A-GND	MΩ	MΩ
B-GND	MΩ	MΩ
C-GND	MΩ	MΩ
NEU-GND	MΩ	MΩ



COMMENTS AND REMARKS:

IEEE 400.2 VLF Testing

also recommended to retest with VLF-TD, VLF-DTD, VLF-TDTS, or VLF-PD after repair to assess the workmanship of the repair. Monitoring cannot be used to reduce the testing time for retests as the cable system has already been shown to be potentially weak by the prior failure.

Table 3—VLF withstand test voltages for sinusoidal and cosine-rectangular waveforms (see Note 1)

Waveform	Cable system rating (phase to phase) [kV]	Installation (phase to ground)		Acceptance (phase to ground)		Maintenance[2] (phase to ground) (see Note 2)	
		[kV rms]	[kV peak]	[kV rms]	[kV peak]	[kV rms]	[kV peak]
Sinusoidal	5	9	13	10	14	7	10
	8	11	16	13	18	10	14
	15	19	27	21	30	16	22
	20	24 (Note 3)	34 (Note 3)	26	37	20	28
	25	29 (Note 3)	41 (Note 3)	32	45	24 (Note 3)	34 (Note 3)
	28	32	45	36 (Note 3)	51 (Note 3)	27	38
	30	34	48	38	54	29 (Note 3)	41 (Note 3)
	35	39	55	44	62	33	47
	46	51	72	57	81	43	61
	69	75	106	84	119	63	89
Cosine-Rectangular	5	13	13	14	14	10	10
	8	16	16	18	18	14	14
	15	27	27	30	30	22	22
	20	34	34	37	37	28	28
	25	41	41	45	45	34	34
	28	45	45	51	51	38	38
	30	48	48	54	54	41	41
	35	55	55	62	62	47	47
	46	72	72	81	81	61	61
	69	106	106	119	119	89	89

15 to 30 minute duration

What to do when you see an anomaly?

- If a cable does not pass the test it may still be good.
- Dirty cable end and high humidity can have significant effects on tests
  - Ensure the cable ends are clean and dry and retest
- Ensure the cable isolated from other components
  - The issue could be with the terminations or other equipment
  - Keep at least 1ft separation between cable ends and conductive paths
- Ensure the cable length is within the test sets limitations

- Note: good practice to ensure the crew is prepared to install a new splice prior to being testing.

Contact Info

Blair Sackney

- Email: Blair.sackney@texcan.com
- Office: 604-528-3673
- Cell: 604-209-4259
- LinkedIn: https://www.linkedin.com/in/blair-sackney-texcan/