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RECOMMENDED:	M. Lamoureux, B.Hazlett	NO: **GCS0004**	1 OF 19	REV: **4**
APPROVED:	C. Malone			
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Underground Primary & Secondary

Cable Installation

REVISION SHEET

Revision	Description	Date	Initial
0	Original Document	2002-09-30	km/csm
1	Sections added / Corrected Table 3-3 metric SWBP-RWU table added / 5-2 Ref. to direct buried plant removed	2008-12-03	kh/km/csm
2	Revisions to update wording and also to include ERP, PILC, & 46kV cables	2012-09-17	rcb/csm
3	Revisions to update wording and to add reference to cable removal	2013-11-27	rcb/csm
4	Added Schedule 1 – pulling log Added 750 kcmil RWU	2017-04-13	ml/bh/csm

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1. Introduction

This specification covers the installation of underground primary voltage (from 5kV through to 46kV Polymer (XLPE or EPR and PILC cables) ranging from #2 AWG aluminium/copper conductor through to 1000 kcmil aluminium/copper conductor and secondary voltage cables (from 300V to 1000V) ranging from #2 AWG to 750 kcmil aluminium/copper which comply with Hydro Ottawa Engineering Specification document number GMS0005,GMS0008, and GMS0037. These cables will be installed in concrete encased duct and cable chamber system, direct buried duct systems or direct buried. For cable pulled in duct, the cable-duct configuration shall be determined / approved by Hydro Ottawa.

2. Reference

AEIC – CG5 2005 – Underground Extruded Power Cable Pulling Guide
CEA Report # 204 D 426 – Cable & Joint Arc-proofing Tests & Recommendations - 1986
Edison Electric Institute – Underground Systems Reference Book
Hydro Ottawa - ECS0002 - 120/240V Underground Residential Meter Socket
Hydro Ottawa – ECS0012 – Conditions of Service
Hydro Ottawa – GCS0005 - Installation of Civil Works for Underground Distribution
Hydro Ottawa - GCS0012 - Electrical Underground Distribution Plant Identification
Hydro Ottawa – GCS0023 - Asbestos Removal from Cables in Manholes
Hydro Ottawa – GDG0004 - Underground Power Duct Selection for the Installation of Telecommunication Cable
Hydro Ottawa - GMS0005 - Underground Secondary
Hydro Ottawa - GMS0008 - Underground Primary XLPE Concentric Neutral Cable
Hydro Ottawa – GMS0037 - PILC Cable
Hydro Ottawa - GQS0001 - Electrical Contractor Qualifications to Work On Hydro Ottawa Electrical Underground Electrical Distribution System
Hydro Ottawa - GQS0002 - Civil Contractor Qualification to Work on or Around Hydro Ottawa Electrical Underground Distribution System
Hydro Ottawa - NPS0001- Nomenclature
Hydro Ottawa - UCG0002 - Manhole Cable Routing up to 46kV #2-2/0 Polymer 612
Hydro Ottawa - UCG0003 - Manhole Cable Routing up to 46kV 4/0–1000MCM Polymer 612
Hydro Ottawa - UCG0004 - Manhole Cable Routing up to 15kV 350-600MCM PILC 612
Hydro Ottawa – UCS0033 - Manhole Hardware Cable Rack Heavy Duty Non Metallic
Hydro Ottawa - UCS0034 - Manhole Hardware Cable Rack Heavy Duty Metallic
Hydro Ottawa – UDS0018 - Frame Duct Seal for Fibre Optic Cable
Hydro Ottawa – UIS0004 – Underground Cable Chamber Inspection and Maintenance Procedure, U/C
Hydro Ottawa - UTS0004 -1 Phase Pad-mount Transformer 2.4kV-16kV
Hydro Ottawa - UTS0005 -1Phase Pad-mount Transformer 2.4kV-16kV
Hydro Ottawa – Cable Pulling Calculator in MS Excel
Okonite - Engineering Technical Center - www.okonite.com/engineering/index.html
Prysmian – Handling and Installation Excerpt from Prysmian's Wire and Cable Engineering Guide

3. Scope

This specification covers how Hydro Ottawa and its contractors install or remove cables in or from concrete encased duct and cable chamber system and/or direct buried duct systems using proper equipment set up to ensure maximum pulling tensions and sidewall bearing pressures are not exceeded.

This document excludes any standard work instructions or electrical work protection to facilitate this work. Hydro Ottawa's Standard Working Methods, Work instructions, and Infrastructure Health and Safety Association (IHSA) Rules and Safe Practice Guidelines will be adhered to at all times while installing cable unless otherwise approved by all parties.

4. Definitions

"Approved Contractor" see Conditions of Service (ECS0012);

"Around" see GQS0002;

"Cable Chamber" see Conditions of Service (ECS0012);

"Consumable Materials" means materials used in aiding the installation but do not form part of the permanent distribution system (eg. ropes & twine, rags, caulking, pulling lubricant, etc.);

"HOL" means Hydro Ottawa Limited;

"Non-consumable Materials" means materials used in the installation and are consider permanent as part of the distribution system (eg. ducts, concrete, cable, etc.);

"**Qualified Contractor"** see Conditions of Service (ECS0012).

5. Cable Pulling Methods

Cable that cannot be pulled in or out manually shall be installed or removed by means of an appropriate type and load size of cable puller, an electric winch, a deck winch on a radial boom derrick, or pulling cable trailer that is approved by Hydro Ottawa. In each case, the machine operator shall have access to a means of determining the pulling tensions on the cable (e.g. gauges which indicate direct line pressure or gauges which indicate hydraulic pressure which can be converted to line tension via a conversion table, dynamometer or a recordable tension meter) to ensure that the maximum pulling tension of the cable is not exceeded. Cable pulling with trucks, backhoes, or any other method whereby the amount of pulling tension is not measurable, is unacceptable.

6. Preparation

6.1 Calculations

The direction of the pull must be established first. This is based on safe pulling tensions, sidewall bearing pressure calculations and minimum bending radius for a Hydro Ottawa specific cable to be installed (see Appendix 'A' Tables 6-1, 6-2, 5-3, 6-4, 6-5A, 6-5B, and MS Excel pulling calculator). Where ducts do not terminate in a building, the main trunk duct system is designed and installed to support primary trunk cable and should provide 2-way cable installation within the safe limits.

Pulling equipment shall be properly selected in order to provide smooth speed control at the anticipated tensions.

6.2 Cable End Pulling Preparation

Based on the safe pulling tension and distance, determine if the cable pull requires a basket grip or a pulling eye attached to the conductor (see Appendix A Table 6-1). Basket grips or pulling eyes shall be attached to the pulling rope or cable by an appropriate sized swivel head. Smaller cables and straight pulls less than 100m that have minimal bends in the duct run may be pulled in using basket grips, otherwise pulling eyes shall be used.

6.3 Duct Preparation

It is the cable installer responsibility to determine if the ducts are in a clean and healthy condition before the cable installation begins.

With new duct installations, each duct will be rodded with an appropriate size brush and mandrel (as per GCS0005) by the civil installer to ensure the ducts are properly fitted, and that they are free of all dirt, stones, scale, water, etc. If the ducts have been proofed within the last 90 days, this step may be omitted. Where site conditions are poor or continually changing, proofing the ducts at shorter intervals may be warranted.

Ensure the pull rope or flat line has the required tensile rating. Avoid the use of elastic or abrasive materials which can pose a safety hazard to the installers or damage the duct interior.

6.4 Cable Guides

For installations in conduit, place cable guides wherever necessary to avoid abrasion and/or damage to the cable e.g. when guiding the cable from the reel to the duct mouth or trench (reversed for removal), when passing through or exiting manholes or when exiting or entering a duct run. Cable guides shall be in the form of large diameter, smooth-surfaced free turning sheaves or rollers. Cable guides shall be designed to ensure that cable will not ride off the end of the roller or be pinched into a sheave contour. Guide tubes or chutes may be used for the

installation, provided they have a smooth burr-free working surface, well flared entrances, largest possible bending radius and are securely fastened so that the cable passes smoothly over them. In any case, equipment shall be installed to ensure the minimum-bending radius of the cable is not exceeded; see Appendix A - Tables 6-5A & 6-5B. Where cable is pulled across sheaves or other curved surfaces under tension, it is imperative that the Side wall bearing pressure limit of the cable is not exceeded; see Appendix A - Table 6-4.

6.5 Reel Location

For installations using suitable reel mounting equipment, locate and position the reels such that cable tension at the feeding end is minimized. Larger cable reels may require hydraulic cable tension feeding trailers.

7. Pulling Lubricant

Pre-lubricate cable(s)/duct runs or setup lubrication points along the duct run (e.g. feed in point(s), pull through manholes, etc.) to reduce pulling tension and abrasion to the cable jacket. For long heavy pulls, pre-lubrication of conduit and pull rope is essential to prevent abrasion at the bends, particularly plastic conduit bends, which can become softened due to frictional heating. In the case of long duct lengths or excessive bends in the duct, the cable may have to be pulled in from two directions from an intermediate cable chamber.

The recommended amount of lubricant is dependent on the size and length of the conduit system into which the cable is being pulled. Typically, a ratio of 6.4 liters of lubricant per 100 linear meters of 100 mm duct would be used. The manufacturer's instructions shall be followed for the appropriate application of pulling lubricant.

Hydro Ottawa will accept water-based Bentonite Clay lubricants. Compounds containing oils or greases are not acceptable as they can adversely affect the cable jacket. The following table provides a list of pulling lubricants, which are acceptable to Hydro Ottawa. Lubricant not shown on this table shall not be used without prior approval by Hydro Ottawa (Table 7-1).

TABLE 7-1 Cable Pulling Lubricants

Product Trade Name	Manufacturer
Polywater J	American Polywater Corporation
Cable Glide	CRC Industries

8. Cable Pulling

Poly rope is not to be used for any mechanical pulling (e.g. conductor/winch line, overhead or underground). Poly rope stretches when subjected to high tension and can create a safety hazard. Low tension manual pulling (by hand) using poly rope is acceptable.

When using a mechanical means to complete a pull (e.g. capstan, clutch-able capstan, boom, vehicle winch), a Samson flat line rope or equivalent shall be used as it presents less of a hazard.

Ensure two-way voice communication and adequate resources at both feeding and pulling ends of the run to include any intermediate chamber locations.

Apply pulling lubricant liberally during the cable pulling operation.

To minimize back reel tension, accelerate slowly and smoothly from rest and do not exceed a maximum pulling speed of approximately 30 metres/minute, which can be monitored mechanical or manually. Avoid stopping the pull midway through the installation / removal; the drag due to friction is greatly increased when pulling is restarted.

Record dynamometer readings at regular distance intervals (maximum at 30m) during each pull and record it in the "cable pulling log" (i.e. location, length, type of cable, reel number, tension report, etc. see Schedule 1).

8.1 One Way Pull Direction

Position the pulling equipment at the pulling manhole or transformer base. Set up equipment to maintain the minimum bending radius of cable being pulled. See example in Figure 8-1 and Figure 8-2 for Polymer Insulated cables, **not preferred for PILC Insulated cables.**

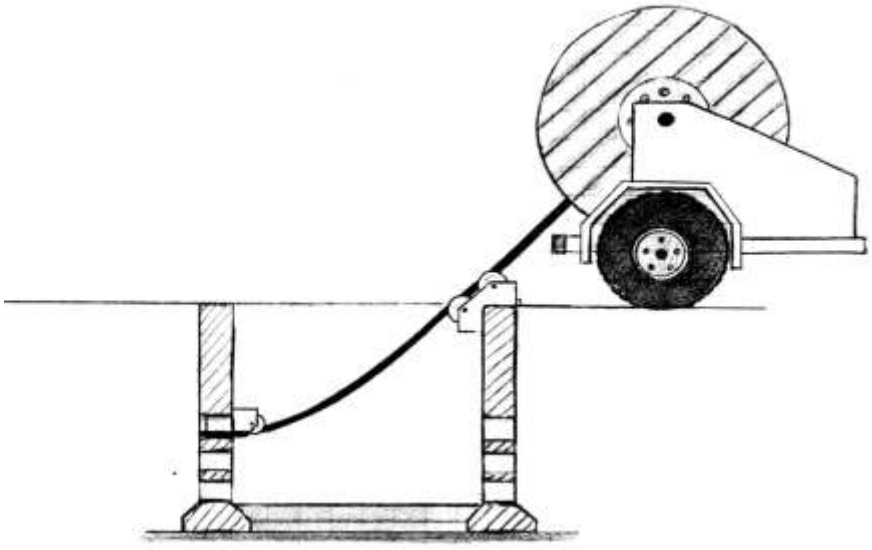

Figure 8-1 Pull End Setup for Polymer cable – Transformer Base

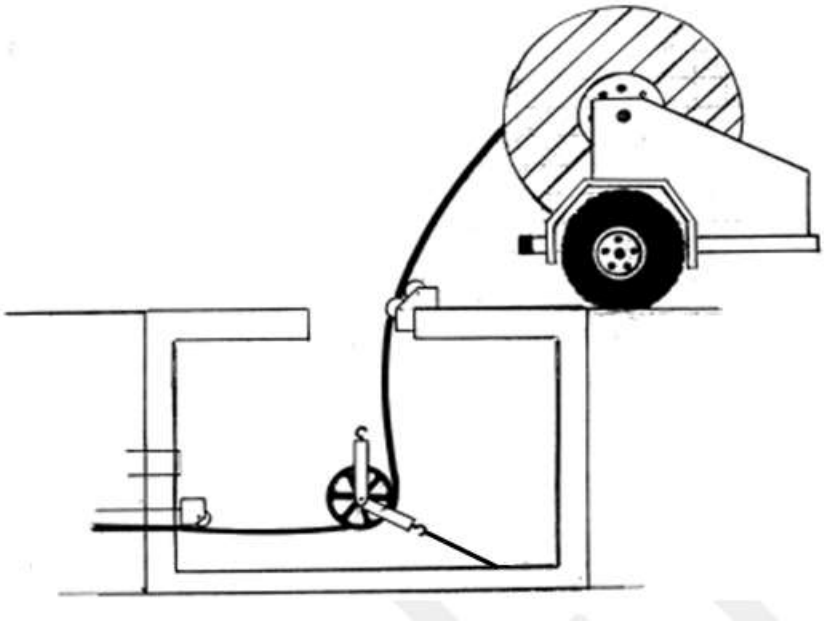

Figure 8-2 Pull End Setup for Polymer cable – Manhole

8.2 One Way Feed Direction

Position the cable reel so that the cable can be handfed into the manhole. When possible, the cable shall be pulled off the reel by hand to reduce pulling tensions; see Figure 8-3 and Figure 8-4. Figure 8-4 is the only preferred reel position and tension for PILC cable fed into a manhole (**NOTE: The lay of the cable fed off the reel should not be reversed to prevent insulation damage for PILC insulated cable).**

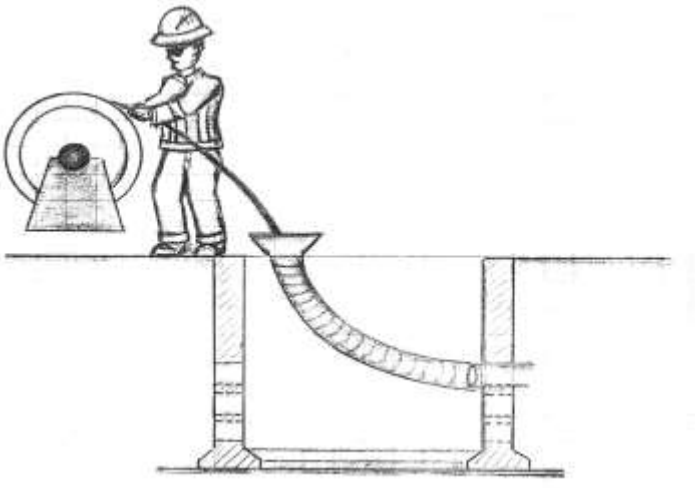

Figure 8-3 Reel End Setup for Polymer cable – Transformer Base

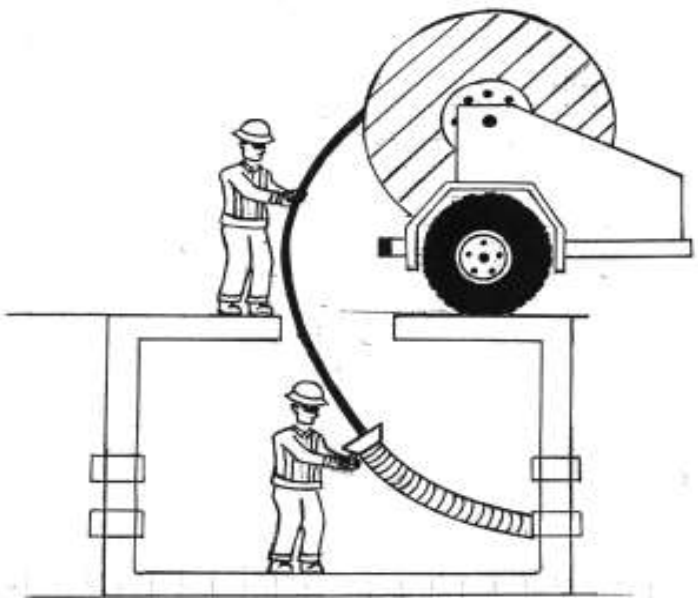

Figure 8-4 Reel End Setup for Polymer & PILC cable – Manhole

8.3 Two Way Pull

Position the cable reel near the center of your pull and pull required cable one way according to all tension guidelines and pertinent specifications (see Figure 8-5 for Polymer Insulated cables, **not for PILC Insulated cables).**

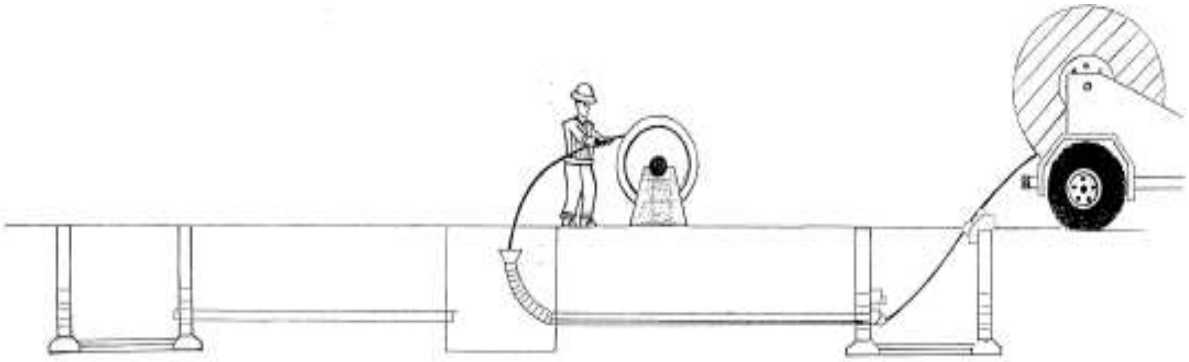

Figure 8-5 Initial 2-way pull Setup

Back reel cable length required for pull in other direction on debris free ground or a tarp in a coil formation, large enough to not exceed minimum cable bending radius (see Figure 8-6 for Polymer Insulated cables, **not for PILC Insulated cables).**

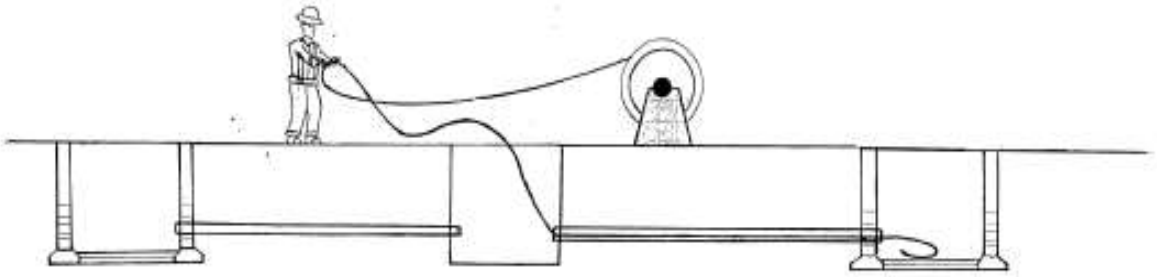

Figure 8-6 Back reel cable in a coil formation

Position puller at pulling end and begin pulling. Maintain slack loop of cable at feed end into duct structure (see Figure 8-7 for Polymer Insulated cables, **not for PILC Insulated cables).**

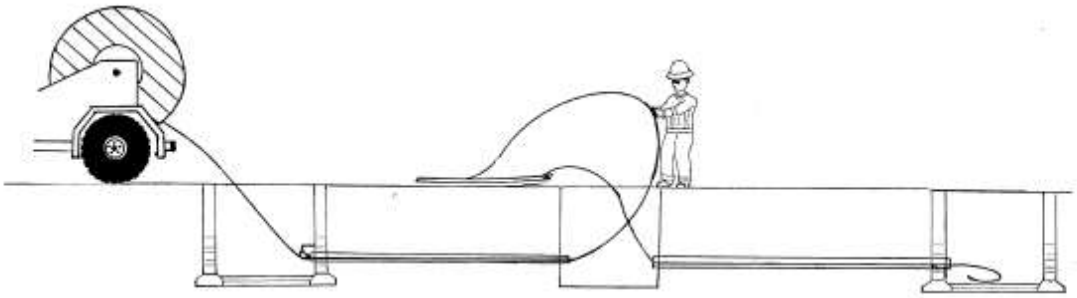

Figure 8-7 Final 2-way pull Setup for Polymer Insulated cables, **not PILC Insulated cables**

8.4 Cable Care After the Pull

Seal the ends of the installed cable and the ends of unused cable remaining on the reel with a Hydro Ottawa approved sealant or cap, pending splicing or terminating, to prevent ingress of moisture and contaminates.

Observe the minimum bending radius when training cable into final position. Secure cables to manholes, riser poles, etc., as per Hydro Ottawa Engineering Specifications.

Provide suitable mechanical protection for exposed cables during project construction.

8.5 Cable Removal

Position the pulling equipment at the pulling manhole or transformer base. Set up equipment to maintain the minimum bending radius of the cable being pulled. Ensure that the **duct surface tension is released** from the cable being removed using a set of web/chain blocks **before** attempting to remove it with the pulling equipment. Releasing the duct surface tension from the cable will help to minimize pulling equipment damage at start up. See example in Figure 8-8 and Figure 8-9.

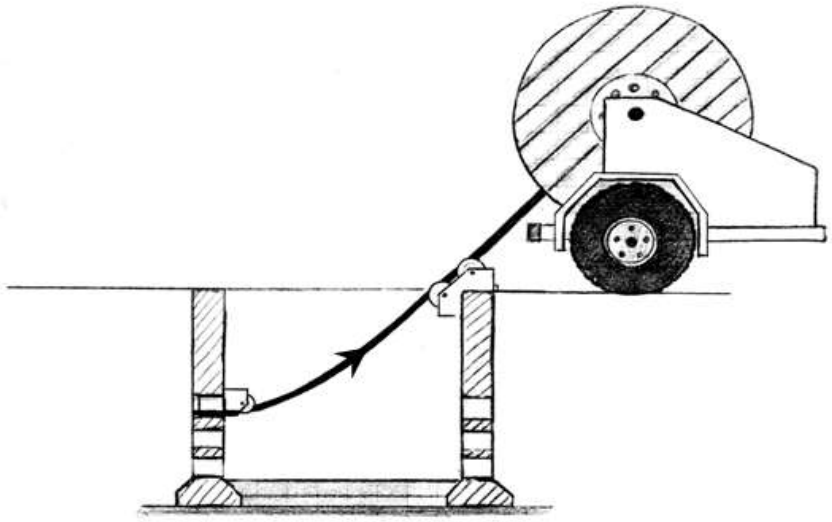

Figure 8-8 Cable Removal Setup for Polymer cable – Transformer Base

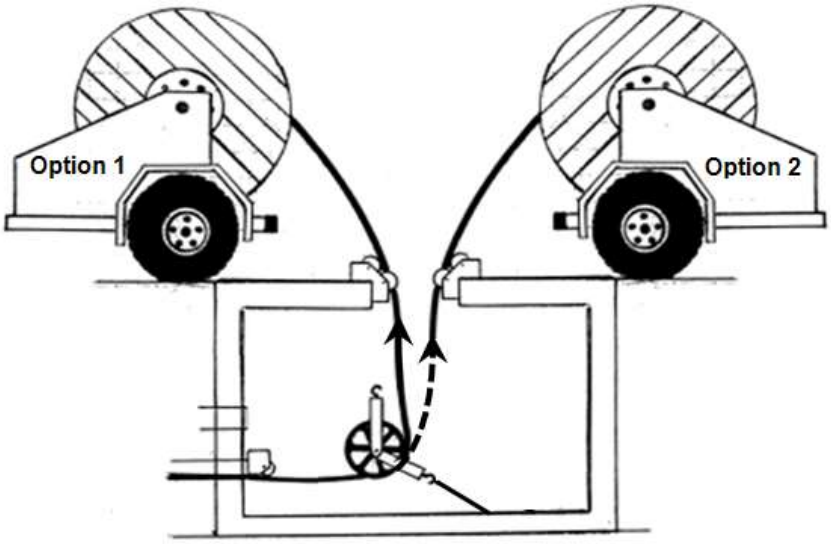

Figure 8-9 Cable Removal Setup

Note: Option 1 is the preferred setup for PILC Insulated Cables to minimize insulation damage

9. Cable Identification

All cables shall be identified as per Hydro Ottawa specifications GCS0012, UTS0004, UTS0005, ECS0002 and NPS0001. Cables shall also be tagged as per approved designed nomenclature and where applicable, cable tags shall be installed outside of arc-proof tape.

10. Cable Training in Cable Chambers

10.1 Transformer and Pedestal Bases

At transformer bases and primary pedestals, primary cables shall be trained from the bottom of the base to the elbow insert. Care should be taken to allow for the installation of elbow compression connectors with the proper turn to fit the insert. Care should also be taken to ensure that cables are not crossed or tangled with adjacent cables. Freedom of movement for energized switching operations is also essential (see Hydro Ottawa Engineering Specification UTS0005).

Secondary cables shall be trained from the bottom of the transformer base to the secondary bus of the transformer with care taken to ensure cables are not crossed and do not cause a downward force on the transformer bus bars (see Hydro Ottawa Engineering Specification UTS0004). The minimum bending radius of cables shall not exceed the limits as outlined in Appendix 'A', Table 6-5A & 6-5B.

10.2 Manholes and Switching Bases

Hydro Ottawa shall determine the duct allocation, cable training location and rack position of the cable as per the project design and racking guidelines (UCG0002, UCG0003, and UCG0004). The minimum bending radius of cables shall not exceed the limits as outlined in Appendix 'A', Table 6-5A & 6-5B. All trunk primary cables (greater than 3/0) in manholes, vaults, switchgear bases, and inside stations shall be shimmed at all duct mouths with Hydro Ottawa approved shims.

11. Racking in Cable Chambers

Typically, the lower voltage cables are to be installed towards the upper part of the manhole. The highest voltage cables are to be installed towards the bottom of the manhole while fibre optic cables are to be installed towards the top of the wall/roof separately with approved support straps.

Hydro Ottawa shall determine the cable racking method and location to be used. Cables in manholes and switchgear bases shall be racked along the wall of the structure using Hydro Ottawa approved tray and support system (UCS0033 & UCS0034).

Certain cable chambers, such as manholes and substation basements, are designed for racking cables along walls or on structural support lattice. As well, to support the cables moving horizontally around the cable chamber, the approved cable rack system shall be installed at each integrated splice bay on the chamber wall to securely support the cables.

With the cables racked at the wall, the cable chamber top access shall be kept clear of cables so that personnel and equipment can freely be moved in and out of the chamber.

Triplexed cables are to occupy the same cable rack support position and spliced within the same cable rack support position with the splices longitudinally offset.

Where primary trunk cable phases are installed in separate ducts, the preferred duct and cable rack position shall be by horizontal separation rather than vertical separation. This will allow for sufficient separations for other circuits and for better fault tolerance.

Where large vertical changes occur within the duct bank, cable grips may be required to secure the cable within the cable chamber to prevent cable creep in the duct.

Secondary moles are to be racked along the top of the manhole walls away from duct entries. Primary moles and primary Tee-elbow connections are to be avoided in manholes.

12. Secondary Services

With new residential subdivision installations, secondary cables are to be pre-installed to lot lines, staked up to a suitable support (1 m onto private property with a minimum 2 m of cable tail) and the cable ends sealed with Self-Amalgamating Polyethylene (SAPP) tape to prevent the ingress of moisture and contaminates.

13. Arc-Proofing Cables

All trunk primary cables (greater than 3/0) in manholes, vaults, switchgear bases, and inside stations are to be arc-proof wrapped with Hydro Ottawa approved arc-proofing tape. The arc-proof tape shall stop at the termination joint in the switchgear.

Outside of substations, small local primary cables (less than or equal to 3/0) are to be arc-proof wrapped if they are within 500mm of trunk primary cables unless otherwise directed by Hydro Ottawa.

Inside of substations, all cable jackets with a flame retardant rating of less than FT4 that are not enclosed in a covered raceway or conduit, shall be arc-proof wrapped with Hydro Ottawa approved arc-proofing tape.

Primary triplexed cables shall be wrapped as one cable with arc-proof tape.

Hydro Ottawa arc proofing tape on cables in cable chambers shall be applied as per the manufacturer's specifications.

14. Sealing Ducts

For all civil installations where the ducts are terminated directly into clean backfill (typically some residential secondary installations), the ducts shall have a temporary plastic duct plug inserted into the duct end to prevent water and dirt ingress into the duct. Once the cable is installed, the duct end shall be filled with clean rags around the cables to prevent dirt ingress into the duct.

Where ducts enter a building from a manhole system, the empty ducts in the manhole shall have a hydraulic-stop mechanical plug (aka. Chicago plug or sewer plug) installed to prevent unwanted gases, water, and rodents from entering the building. When the cable is finally trained and racked in the manhole the duct end in the manhole shall be filled with Hydro Ottawa approved fire stop caulking around the cable(s).

For installations associated with fibre optic cables, ducts entering a building or an adjacent telecom cable chamber from a Hydro Ottawa manhole system shall have an approved Hydro Ottawa duct plug and identification ring installed at both ends of the duct (see UDS0018).

Appendix A – Minimum & Maximum Technical Cable Installation Parameters

Table 6-1 - Maximum Cable Pulling Tensions
Primary Voltage Cables, PVC Jacket, POLYMER Insulation and 3/C PILC Insulation

Insulation	Conductor Size &Type	Maximum Pulling Tension							
		Basket Grip				Pulling Eye			
		Single Conductor Pull		Three Conductor Pull*		Single Conductor Pull		Three Conductor Pull**	
		Pounds	Kilograms	Pounds	Kilograms	Pounds	Kilograms	Pounds	Kilograms
Polymer	1/0 AWG Copper	1,160	526	2,320	1,052	1,160	526	2,320	1,052
	1/0 AWG Aluminum	845	383	1,690	767	845	383	1,690	767
	2/0 AWG Aluminum	1,065	483	2,130	966	1,065	483	2,130	966
	500 Kcmil Copper	5,500	2,495	11,000	4,990	5,500	2,495	11,000	4,990
	500 Kcmil Aluminum	4,000	1,814	8,000	3,629	4,000	1,814	8,000	3,629
	600 Kcmil Copper	6,600	2,993	13,200	5,986	6,600	2,993	13,200	5,986
	750 Kcmil Copper	8,250	3,741	16,500	7,483	8,250	3,741	16,500	7,483
	750 Kcmil Aluminum	6,000	2,722	12,000	5,442	6,000	2,722	12,000	5,442
	1000 Kcmil Aluminum	8,000	3,629	16,000	7,256	8,000	3,629	16,000	7,256
3/C PILC	500 Kcmil Copper	NA		1,500	682	NA		10,000	4,545
	600 Kcmil Copper			1,500	682			10,000	4,545

* Tensions are for 1 basket grip per conductor cable or one for 3 conductor cable
** Tensions are for 1 pulling eye per conductor or one for 3 conductor cable

Appendix A (con'd)

Table 6-2 Maximum Cable Pulling Tensions

Secondary Voltage Cables, 600V, POLYMER Insulation

Conductor Size & Type	Maximum Pulling Tension			
	Basket Grip		Pulling Eye	
	Two Cable Pull*		Two Cable Pull**	
	Pounds	Kilograms	Pounds	Kilograms
1/0 AWG Aluminum URD	1,690	767	1,690	767
3/0 AWG Aluminum URD	2,000	907	2,684	1,217
250 kcmil Aluminum URD	2,000	907	4,000	1,814
500 kcmil Aluminum URD	2,000	907	8,000	3,629

* Tensions are for 1 basket grip per triplexed cable

** Tensions are for 1 pulling eye per conductor

Table 6-3 Maximum Cable Pulling Tensions

Secondary Voltage Cables, 1000V RWU

Conductor Size & Type	Maximum Pulling Tension			
	Basket Grip		Pulling Eye	
	Three Cable Pull*		Three Cable Pull**	
	Pounds	Kilograms	Pounds	Kilograms
2 AWG RWU Copper	1458	660	1458	661
2/0 AWG RWU Copper	2000	907	2928	1328
4/0 AWG RWU Copper	2000	907	4654	2111
350 kcmil RWU Copper	2000	907	7700	3493
500 kcmil RWU Copper	2000	907	11000	4990
750 kcmil RWU Copper	2000	907	16499	7484

* Tensions are for 1 basket grip per triplexed cable

** Tensions are for 1 pulling eye per conductor

Appendix A (con'd)

Table 6-4 Maximum Sidewall Bearing Pressure

Primary Voltage Cables, PVC Jacket, POLYMER Insulation and 3/C PILC Insulation

Cable Type	Sidewall Bearing Pressure	
	Lbs/Ft of Bend Radius	Kg/m of Bend Radius
RWU Cable	1,200	1,786
XLPE Unshielded, Jacketed Cable (600V)	1,200	1,786
EPR Concentric Neutral Cable, Jacketed	2,000	2,976
XLPE Concentric Neutral Cable, Jacketed	2,000	2,976
PILC Cable	400	595

Table 6-5A Minimum Bending Radius (MBR)

Primary Cable (1)

Cable Size and Type	Minimum Bend Radius for Single Cable	Minimum Bend Radius For 3 Cables paralleled or triplexed
	mm (inches)	mm (inches)
15kV 1/0 AWG Cu XLPE	238 (9.5)	321 (12.5)
15kV 500 MCM Cu XLPE	337 (13.5)	NA
28kV 1/0 AWG Al XLPE	295 (11.5)	397 (15.5)
28kV 1000 MCM Al XLPE	477 (19)	NA
28kV 2/0 AWG Al XLPE	303 (12)	408 (16)
28kV 500 MCM Al XLPE	396 (15.5)	NA
28kV 750 MCM Al XLPE	447 (17.5)	NA
46kV 750 MCM Cu XLPE	526 (20.5)	NA
15kV 3c x 500 MCM Cu EPR	NA	408 (16)
15kV 500 MCM Cu PILC	808 (32)	NA

Table 6-5B Minimum Bending Radius (MBR)

Secondary Cable (1)

Cable Size and Type	For Single Cable	For 3 Cables paralleled or triplexed	For 4 Cables paralleled or quadruplexed
	mm (inches)	mm (inches)	mm (inches)
600V 250MCM Al URD	81 (3)	175 (7)	196 (7.5)
600V 3/0 AL URD	65 (2.5)	140 (5.5)	157 (6)
600V 500MCM Al URD	130 (5)	279 (11)	313 (12.5)

Note:
These limits may not be suitable for conduit bends, sheaves or other curved surfaces in situations where, during the installation, the cable may be pulled under tension due to the sidewall bearing pressure limits of the cable. The minimum radius specified refers to the inner radius of the cable bend and not to the axis of the cable.

Schedule 1 – Cable Pulling Log

Project Number			Installer	
Work Order			Date	
Project Description			Cable Manufacturer	
			Cable Type	
			Cable Reel Serial #	
			Outside Temperature	

From Structure	To Structure	Duct Position	Total Cable Length (m)	Tension in kilo-Newtons (kN) at the following installed lengths *[where 1000 lbs = 4.448 kN]*										
				0m	30m	60m	90mm	120m	150m	180m	210m	240m	270m	300m