PILC Replacement: Getting the Lead Out

Spring ICC

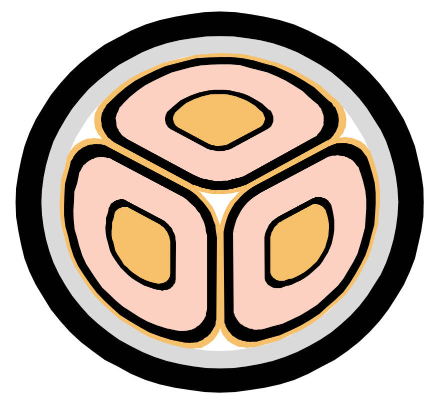
Cincinnati, OH

April 30, 2003

PILC IS GREAT!

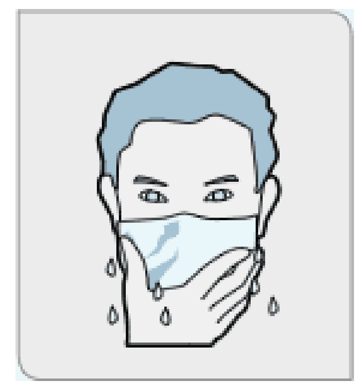
- Low Profile
- High Fault Current Capability on Shield
- High Degree of Water Blocking

…So why shouldn’t you use it?



Why the Move Away From PILC?

- Fatigue Cracks in the Lead
- Oil Migration on Slopes
- EPA Rulings on Lead (#1 Hazardous Material)
- Comparative Expense
- Diminishing Installation Expertise



Replacement Challenges

- Small Duct Diameters
- Duct Conditions
- Cable Operating Temperature
- Fault Current Capability of Shield

How to Fit Extruded Dielectric Cables Into Existing Ducts

(Without Real Design Changes)

- Reduce the cable clearance to the duct wall. (Generally recommended minimum is 1/2")
- Reduce the thickness of the extruded jacket.

  (Some utilities accept a .025" thick jacket over 750 kcmil Cu 25kV Cable)
- Extrude over compact sector conductors.

But These Options May Not Always Work

- Duct clearance should not be reduced to less than 1/2."
  - Ducts are no longer in good condition.
  - Cable may be damaged during pulling.
- Jacket thickness should not be reduced excessively.
  - Thin jackets may tear rather easily.
  - The benefits of the jacket are then lost.
- Difficult to extrude over compact sector.
  - Rotation of conductor can cause problems.
  - Costly process.
  - Splicing and terminating may be a problem.

Primary Objectives

- Utilize a DRY Cable Design
- Keep a Low Profile
- Match Shield to Fault Current Requirement
- Match Ruggedness of Cable to Duct System
- Specify an Easy-to-Install Cable

Utilize a DRY Cable Design

- Consider the Sheath Material
  - Lead Over Extruded Dielectric
  - Corrugated and Welded Bronze
  - Sealed Corrugated and Folded Copper Tape
- Use Strand Filling in the Conductor
- Use Other Water Swellable Components

Keep a Low Profile

- Several Methods to Reduce the Cable Diameter
  - Compact the Conductor
  - Reduce the Thickness of Extruded Components (Even the Insulation!)
  - Use Flat Strap Concentric Neutrals

Match Shield to Fault Current

- Although lead sheath carries a high fault current, new cable may not need to carry the equivalent rating of the lead sheath.
- Determine fault requirements to optimize metallic sheath.
- Over designing the shield will result in increased I^2R losses. ($$$)

Match Ruggedness of Cable

- What is the Condition of Your Ducts?
- A Thin Wall Jacket May Be Used If It's Tough Enough
  - Consider Toughness and Heat Stability
  - LLDPE, HDPE, Polypropylene
- Determine Amount of Clearance Required – Can it Be Reduced to Less Than ½"?

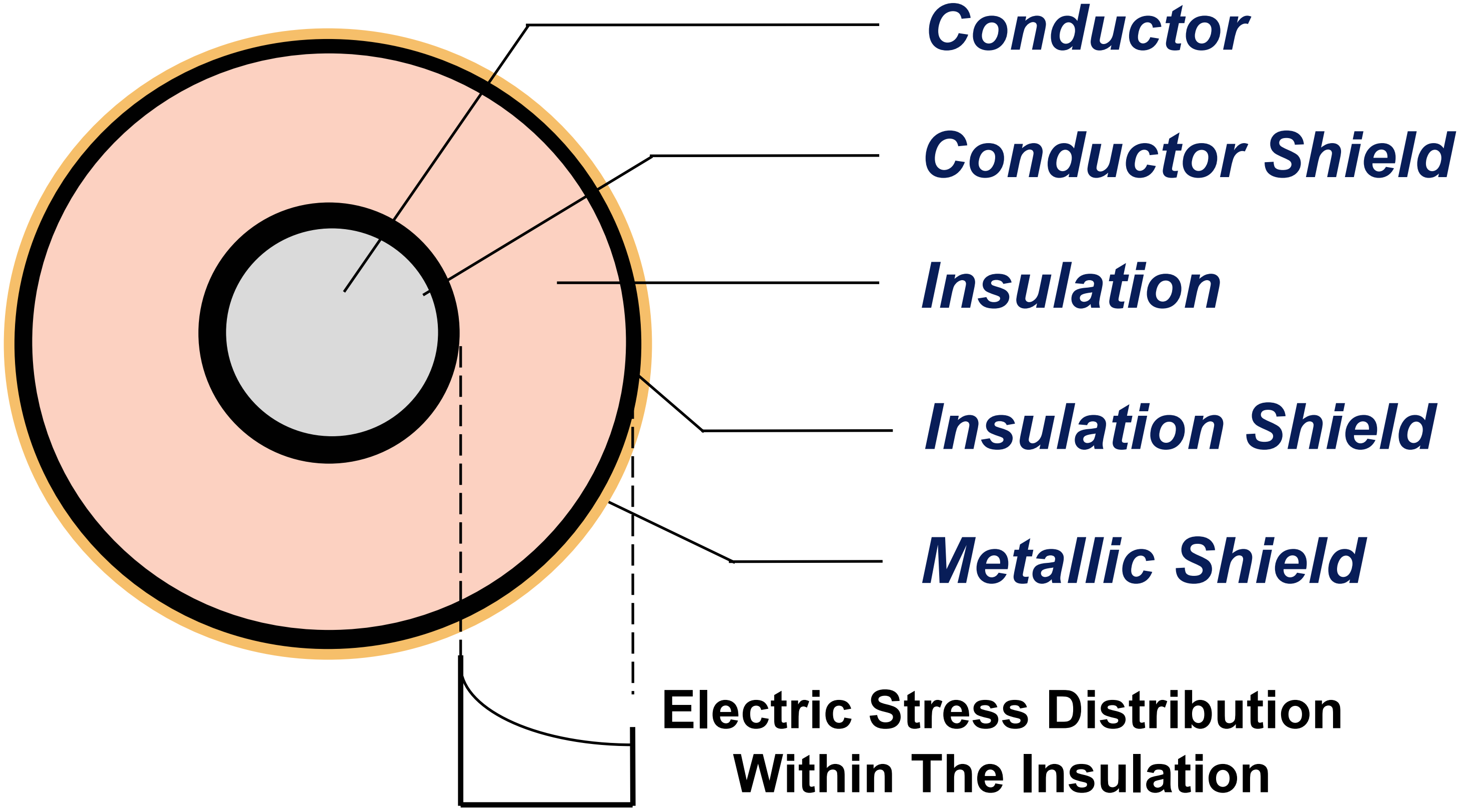
Specify Easy-to-install Cable

- Round Conductors vs. Sector Conductor
- Flexibility is Key
- Connectability to existing system
- Consider Pulling Length

Design Higher Stress Cables

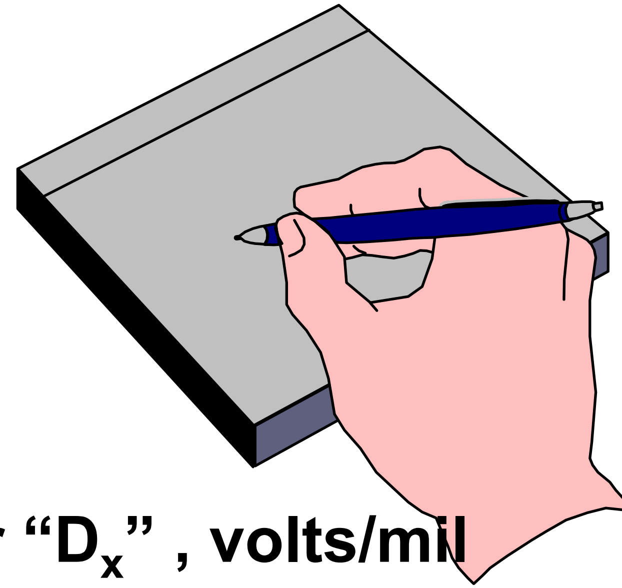
- A common design practice for HV power cables is to design the cable with a high maximum stress (e.g. EPR 240kV Class @ 10kV/mm)
- In MV cables, the design operating at the highest voltage stress is the 35kV #1/0 AWG Conductor (4 kV/mm).
- If the same insulation is used, why NOT design MV cable to a higher stress?

Electric Stress Variations Within Cable Insulation



Calculation of Voltage Stress in Cables

$$S@D_x = \frac{2.0 \times E}{D_x \times LN\,\frac{D}{d}}$$



Where:

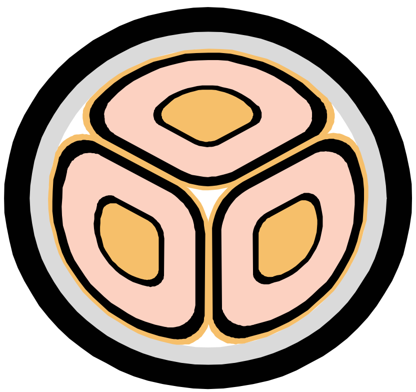
$S@D_x$	=	Stress at diameter "D_x" , volts/mil
E	=	Voltage across insulation, volts
D_x	=	Diameter of interest, mils
D	=	Diameter over insulation, mils
d	=	Diameter over conductor shield, mils

Reducing the Insulation Thickness Is The Last Step

- Compact Conductor
- Use a Flat Strap Neutral
- Reduce the Jacket Thickness
- Reduce Thickness of the Conductor and Insulation Shields
- Reduce Clearance to Duct
- THEN Reduce the Insulation Thickness

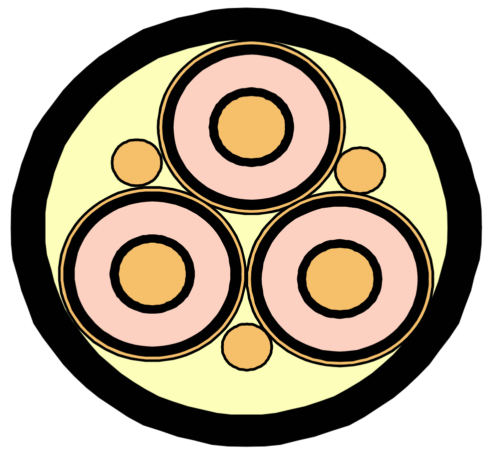
CABLE DESIGN SELECTION

Standard Designs - 15 KV



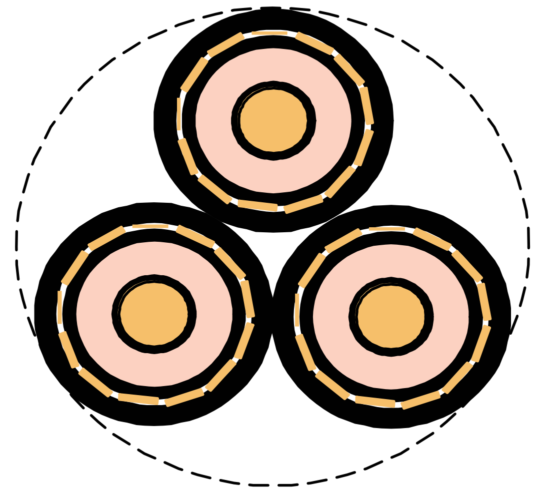
750 KCM
2.95 INCH OD

PILC



3/C 750 KCM
3.50 INCH OD

175 MILS EPR
140 MILS JKT

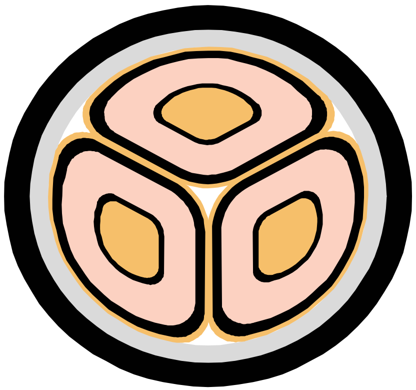


3-1/C 750 KCM
3.65 INCH OD

175 MILS EPR
80 MILS JKT

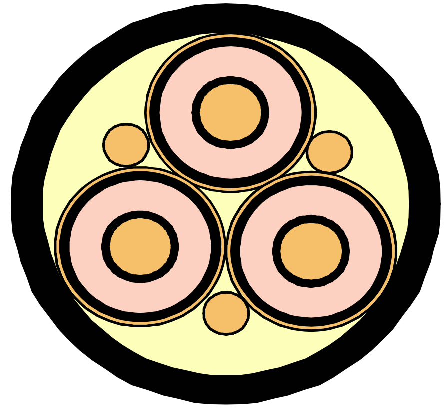
CABLE DESIGN SELECTION

Reduced Wall Designs - 15 KV



3/C 750 KCM
2.95 INCH OD

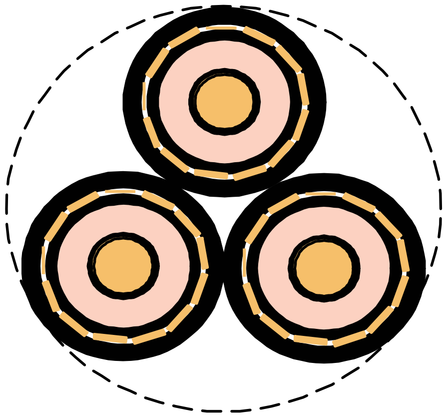
PILC



3/C 750 KCM
3.10 INCH OD

125 MILS EPR
120 MILS JKT

140 MILS EPR
110 MILS JKT



3-1/C 750 KCM
3.10 INCH OD

125 MILS EPR
50 MILS JKT

Testing the Design

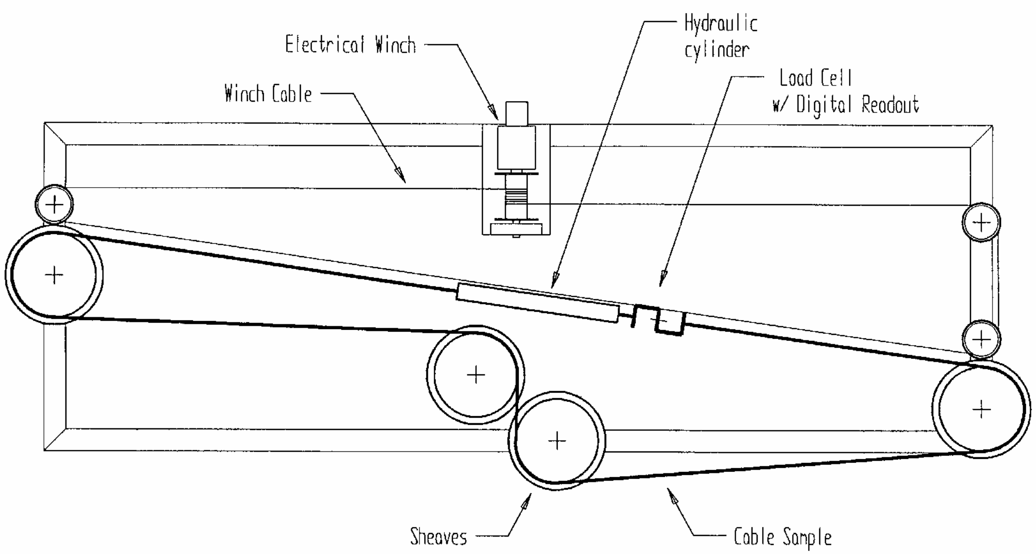
- Testing should show that the proposed design will stand up to the rigors on the installation and operation.
- Electrical and Mechanical Tests
- Testing should be at or above proposed operational limits.
  - (AEIC CG11-02 recommends same test level as used on the 100% insulation level.)

Electrical Testing

- AC Breakdown Study
- Ionization Factor
- AEIC Qualification
  (As Applicable)
- Accelerated Water Treeing Testing (AWTT)
- Accelerated Cable Life Testing (ACLT)

Mechanical Testing

- Should replicate the actual installation conditions, or be more severe
- May include such factors as:
  - Reverse Bends
  - High Sidewall Pressure
  - Small Minimum Bending Radii
  - Several Cycles of Pulls
- Electrical Testing Should Follow with No Significant Reduction in Electrical Properties



Mechanical Cyclic Pulling and Bending Test Setup

Reduced Insulation Wall Summary

- In Use for Over Ten Years
- Tested with Accessories
- A Definite Design Alternative for Tight Duct Situations

Accessories

- In general, premolded accessories may not pass corona tests when installed on reduced insulation thickness cables.
- Cold-shrink and heat-shrink accessories should pass electrical tests.
  - Trifurcating splices are available.
- Electrical Stress on Reduced Insulation Wall Cables Must Be Controlled at Both Conductor Shield and Insulation Shield Interfaces.

Accessories

- Joint size should allow installation in existing smaller manholes.
- Cold-shrink terminations can be used to replace potheads.
- Compression connectors can be used to shape sector conductors.
- Should be qualified to IEEE Std. 404.

Summary & Conclusions

- Overall cable design is more important than any individual component.
- Complete redesign not always necessary.
- Several types of shields are available.
- High temperature jackets should be considered.
- **Reduced Insulation Wall Is a Viable Option**

Summary & Conclusions

- Properly designed PILC replacement cables have been found to be both electrically and mechanically suitable for installation and operation on utility network systems.
- Whatever the design chosen:
  - There should be no significant change in the electrical and physical properties when comparing the reduced wall samples to the full wall samples.
  - There should be no significant change in the electrical and physical properties after severe mechanical conditioning.