ENGINEERING LINGO

WHEN YOU HEAR AN ENGINEER SAY

A NUMBER OF DIFFERENT APPROACHES ARE BEING IMPLEMENTED

It Means
ENGINEERING LLINGO

WE HAVEN’T A BLOODY CLUE ABOUT WHAT WE'RE TALKING ABOUT!!

ENGINEERING LINGO

When You Hear An Engineer Say:

Preliminary Operational Costs Were Inconclusive

It Means
ENGINEERING LINGO

The @#$% Thing
Blew Up
When I Flipped
The Switch

ENGINEERING LINGO

...and lastly, when you hear an engineer say:

The Test Results
Were Extremely Gratifying

It Means
ENGINEERING LINGO

Thank God,
The Stupid Thing
Worked

AGENDA

• INDUSTRY STANDARDS
• MEDIUM VOLTAGE CABLE DESIGN
• CABLE MANUFACTURING PROCESSES
• QUALIFICATION AND ROUTINE PRODUCTION TESTING
MEDIUM VOLTAGE CABLE COMPONENTS
INDUSTRY STANDARDS

• ICEA - INSULATED CABLE ENGINEERS ASSOCIATION

• AEIC - ASSOCIATION OF EDISON ILLUMINATING COMPANIES

• UL - UNDERWRITERS LABORATORY

• ASTM - AMERICAN SOCIETY FOR TESTING AND MATERIALS

• CUSTOMER PROJECT SPECIFICATIONS
CABLE COMPONENTS

- Conductor
- Semi-conducting Strand Screen
- Insulation
- Semi-conducting Insulation Screen
- Metallic Shield
- Protective Covering
  - Jacket / Armor

CONDUCTOR PURPOSE

DEFINED RESISTANCE
Conductors

• Copper or Aluminum
  Cu 100% Conductivity
  Al 61% Conductivity

• Shapes
  Concentric
  Compressed
  Compact
  Sector
  Segmental
Conductors - Stranding

1
1 + 6 = 7
1 + 6 + 12 = 19

Conductors

37 Strands Concentric 37 Strands Compressed 37 Strands Compact
STRAND DIMENSIONS

- CONCENTRIC = 100%
- COMPRESSED = 97% CONCENTRIC
- COMPACT = 93% COMPRESSED
- COMPACT = 90% CONCENTRIC

Conductors – ASTM Standards

*Copper Standards*

- B 3 Soft or Annealed Copper Wire
- B 8 Concentric-Lay-Stranded Copper Conductors, Hard Medium-Hard, or Soft
- B 33 Tinned Soft or Annealed Copper Wire for Electrical Purposes
- B 496 Compact Round Concentric-Lay-Stranded Copper Conductors
Conductors – ASTM Standards

**Aluminum Standards**

- B 233 Aluminum 1350 Drawing Stock for Electrical Purposes
- B 231 Concentric-Lay-Stranded Aluminum 1350 Conductors
- B 609 Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes
- B 800 8000 Series Aluminum Alloy Wire for Electrical Purposes – Annealed and Intermediate Tempers
- B 400 Compact Round Concentric-Lay-Stranded Copper Conductors

**Conductor Screen**
Conductor Screen

Cables rated 5 kV and above
Purpose: To reduce voltage stress at the interface between the conducting and insulating components
A cylindrical, smooth surface between the conductor and insulation

Insulation – Chief Purpose

To withstand the electrical field applied to the cable for its design life in its intended installed environment
Normal and Emergency Voltage and Current
XLP & EPR

• 1955  GE and peroxide cure polyethylene

• 1962  First EPR available

Insulation – Typical Materials

• Ethylene Propylene Rubber (EPR)

• Crosslinked Polyethylene (XLPE)
WALL THICKNESSES

<table>
<thead>
<tr>
<th></th>
<th>15 kV</th>
<th>25 kV</th>
<th>35 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 %</td>
<td>175 mils</td>
<td>260 mils</td>
<td>345 mils</td>
</tr>
<tr>
<td>133 %</td>
<td>220 mils</td>
<td>320 mils</td>
<td>420 mils</td>
</tr>
<tr>
<td>173 %</td>
<td>260 mils</td>
<td>460 mils</td>
<td>650 mils</td>
</tr>
</tbody>
</table>

Shielding

- To confine the electrical field within the insulation.
- To reduce the chance of electrical shock when properly grounded.
- To provide a symmetrical distribution of voltage stress.
- To prevent surface discharge.
- To reduce electrical interference.
- To monitor voltage.
Shielding

- Components
  - Non-metallic semiconducting layer
  - Metallic layer

Insulation Screen

Purpose: To reduce voltage stress at the interface between the conducting and insulating component
A cylindrical, smooth surface between the insulation and shield
Insulation Screen

- MAXIMUM ELECTRICAL STRESS

\[ S = \frac{KV}{(d/2)\ln(D/d)} \]
Semiconducting layers
(conductor and insulation screens)

- Extruded
- Electrical conductivity requirement at room and elevated temperature
- ICEA volume resistivity stability requirement

Shielding - Types

- Flat copper or bronze tape
- Corrugated copper or bronze tape
- Concentric applied copper wires
- Lead sheath
- Corrugated aluminum sheath
- Aluminized Polyester tape
Shielding
Non-Shielded

Shielded
Protective Coverings

• Metallic Armor
  – Interlocked Armor
  – Continuously welded corrugated armor (CLX)
  – Galvanized steel wires
• Jackets (non-metallic covering)
  – Cable Jackets

Cable Testing

• Factory Production Tests
• Qualification Tests
• Defined by ICEA & UL standards and customer specification
Cable Testing - Factory

- Conductor Resistance
- Insulation
  - ac Withstand Test
  - Partial discharge test (≤ 5 kV)
- Shield continuity
- Jacket spark test (shielded cable)
- Dimensional measurements

Cable Testing - Qualification

- ICEA, UL, Customer spec
  - Physical Tests - tensile, elongation
  - Aging Tests, degree of cure
  - Insulation Resistance, EM60 (SIC & % pf)
  - Oil Resistance
  - Vertical Flame VW-1 and VTFT
  - Cold Bend
  - Heat Distortion
  - Gravimetric Water Absorption
Cable Selection

Balance of Properties for the intended Application

MANUFACTURING PROCESSES

• COMPOUNDING

• EXTRUSION
## FORMULATION

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Role</th>
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<tbody>
<tr>
<td>Polymer</td>
<td>dielectric</td>
</tr>
<tr>
<td>Clay</td>
<td>filler</td>
</tr>
<tr>
<td>Plasticizers</td>
<td>viscosity modifiers</td>
</tr>
<tr>
<td>Metal Oxides</td>
<td>heat/moisture stabilizers</td>
</tr>
<tr>
<td>Antioxidant</td>
<td>aging characteristics</td>
</tr>
<tr>
<td>Co-Agent</td>
<td>co-curing agent</td>
</tr>
<tr>
<td>Organic Peroxide</td>
<td>curing agent</td>
</tr>
</tbody>
</table>

### Ingredients

![Ingredients Image]
Continuous Vulcanization (CV) Extrusion
CABLE INSTALLATION

PARAMETERS

Cable Installation
Design Parameters

• Maximum Pulling Tension
• Maximum Sidewall Pressure
• Minimum Bending Radius
• Conduit Fill
• Jamming
Maximum Pulling Tension

Pulling Eyes or Bolts

Triplexed Cables into Duct

\[ T_m = 0.008 \times n \times \text{cmil} \]

EXAMPLES OF COMPRESSION TYPE PULLING EYES AND BOLTS
Maximum Pulling Tension

Pulling Eyes or Bolts

Three or Four Cables
Paralleled Into Duct

\[ T_m = 0.008 \times (n-1) \times \text{cmil} \]

Maximum Pulling Tension

Pulling Grips

1000 lbs per Grip
TENSION AND SIDEWALL PRESSURE IN A BEND

\[ T_{out} = T_{in} + T_a \text{ (lbs.)} \]

\[ T_a = \text{Force in lbs. to conform cable to conveyor sheave} \]
\[ \text{(Approx. 150 lbs for large cables)} \]

Sidewall Pressure
\[ SWP = \frac{T_{out}}{R} \text{ lbs. ft.} \]

MAXIMUM SIDEWALL PRESSURE
(lbs. Per ft of radius)

<table>
<thead>
<tr>
<th>Type of Cable</th>
<th>Conductor Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POWER</strong></td>
<td></td>
</tr>
<tr>
<td>One Single Cable</td>
<td>8 AWG</td>
</tr>
<tr>
<td>Two or More Cables or</td>
<td>300</td>
</tr>
<tr>
<td>Conductors in Cable (parallel or plex)</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>&gt;8 AWG</td>
</tr>
<tr>
<td></td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>1000</td>
</tr>
<tr>
<td><strong>MULTICONDUCTOR CONTROL</strong></td>
<td></td>
</tr>
<tr>
<td>One Cable</td>
<td>ALL SIZES</td>
</tr>
<tr>
<td>Two or More Cables</td>
<td></td>
</tr>
<tr>
<td></td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>1000</td>
</tr>
<tr>
<td><strong>INSTRUMENTATION</strong></td>
<td></td>
</tr>
<tr>
<td>Single Pair</td>
<td>ALL SIZES</td>
</tr>
<tr>
<td>Multipair</td>
<td></td>
</tr>
<tr>
<td></td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>500</td>
</tr>
</tbody>
</table>
MINIMUM BENDING RADIUS
Cables Without Metallic Shielding or Armor

<table>
<thead>
<tr>
<th>Thickness of Conductor Insulation</th>
<th>Overall Diameter of Cable Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inch</td>
<td>Minimum Bending Radius as a Multiple of Cable Diameter</td>
</tr>
<tr>
<td>0.155 &amp; less</td>
<td>4</td>
</tr>
<tr>
<td>0.170 - .310</td>
<td>5</td>
</tr>
<tr>
<td>.315 &amp; over</td>
<td>-</td>
</tr>
</tbody>
</table>

Jamming Conditions

Jamming may occur when the sum of the diameters of the cables being pulled approximately equal the ID of the conduit or duct.
Example

L1 = 500 feet

600 V 1/c 500 kcmil Cu OD = 1.1"  Wgt/ft = 1.83#

Maximum Pulling Tension = 0.008 x 500,000cmil = 4000 pounds

Coefficient of Friction = 0.35

Conduit OD = 2"

T1

Case A

Case B

T2

T3

90 deg Bend

T4

L2 = 50 ft

L2 = 50 ft
CABLE AGING CRITERIA

VARIOUS POLYETHYLENE INSULATIONS

- Bakelite polyethylene 1960
- 4201Bakelite vulcanizable polyethylene 1962
- 4208 (?) 1967
- 6202 TR-HMWPE 1979
- 4202A TR-XLPE 1983
- 7521 TR-HMW-LLDPE 1984
- 4203 NEXT GENERATION TR-XLPE. 1991
- 4300 HIGH VOLTAGE XLPE 1992
- 4202B TR-XLPE 2000
- 8202A EBR 2001
- 8202B 2002
HIGH MOLECULAR WEIGHT POLYETHYLENE (HMWPE)
CROSS LINKED POLYETHYLENE (XLPE)
COMPOSITE CHART:
HMWPE AND XLPE
ENGINEERING TOOL
ENGINEERING TOOL