ICC Educational Program
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HV XLPE Cable Design and Manufacturing

Axel Schlumberger

Forte
POWER SYSTEMS
A Southwire Company

Overview

1. Design — Industry Standards
2. Design — Conductors
3. Design — Insulation
4. Design — Bedding Tapes
5. Design — Sheath/Screen & Jacket
6. Manufacture — Extrusion Methods
7. Manufacture — Compounds
8. Manufacture — Sheath/Screen
9. Manufacture — Quality Assurance

DESIGN

Industry Standards

1. AEIC Association of Edison Illuminating Companies
2. CIGRE Internat. Conf. for Large Scale Electric Systems
3. ICEA Insulated Cable Engineers Association
4. IEC International Electrotechnical Commission
5. IEEE Institute of Electric and Electronics Engineers
6. UPSC TAC:
   Utility Power Cable Standards Technical Advisory Committee
   ICEA Group seeking input from ICC (IEEE), AEIC and NEMA with ANSI Standard as final product.

Industry Standards - AEIC

- Cable Engineering Committee founded in 1938
- Members are Utilities
- Participates in the UPS TAC Process
- First Solid Dielectric HV Standard issued 1987
- Present standard: AEIC Cable Standard (CS) 7 – 1993

What is covered?

Cable only

AEIC CS7-93

Industry Standards - AEIC

Pros

- Covers constructive detail
- Void, contaminant and eccentricity specs
- Comprehensive Routine Test protocol

Cons

- Cable only
- Obsolete insulation thicknesses
- Max Stress design inadequate
- Limited to 138kV
- Does not cover available designs

Industry Standards - CIGRE / IEC

- CIGRE Study Committee 21 established in 1927
- Members from utilities, manufacturers and universities / institutes from 31 countries
- Interfaces with IEC TC 20, which actually publishes international standards
- HV solid dielectric cable specific: IEC 60840, IEC 62067
- Other relevant standards: IEC 229, 815, 949, 859, etc etc.

Industry Standards - IEC 60840-1999

Pros

- Covers voltages up to 150/161/170kV and has a big brother
- Includes accessories (Splices and terminations)
- Covers after installation tests and, by reference, jacket tests for specially bonded systems
- Sets performance criteria rather than design detail

Cons

- Routine tests are marginal – eccentricity loose
- No check for voids and contaminants other than AC withstand and PD test
- Confusing cross references to other standards

Industry Standards - IEC 62067-1999

- Also see notes for IEC 60840

Pros

- Only standard for 230kV and higher – up to 500kV (Other than national standards such as EdF)
- Includes a system prequalification test
- Eliminates after laying DC test
- Eccentricity 10% max

Cons

- Includes a system prequalification test (see above)

Industry Standards - IEC

- IEC 229 – Tests on jackets
- IEC 815 – pollution / creepage for outdoor insulators
- IEC 859 – GIS (and transformer) interface
- IEC 949 – Short circuit
- IEC 287 – Current ratings

Industry Standards - ICEA / UPCS TAC

- I(P)CEA established in 20's.UPCSTAC 1994
- ICEA: Historically composed of manufacturers
- Draft Standard S108-720-2002
- Document developed through UPCSTAC
- Will replace AEIC CS7
- Status: Submitted to ICC for comments
- Will be approved by NEMA, IEEE, AEIC and adopted as an ANSI standard

Industry Standards - ICEA S108-720-xxxx

Pros

- Finally a North American Standard to up to 230kV
- Input from all groups concerned
- Best of both worlds approach

Cons

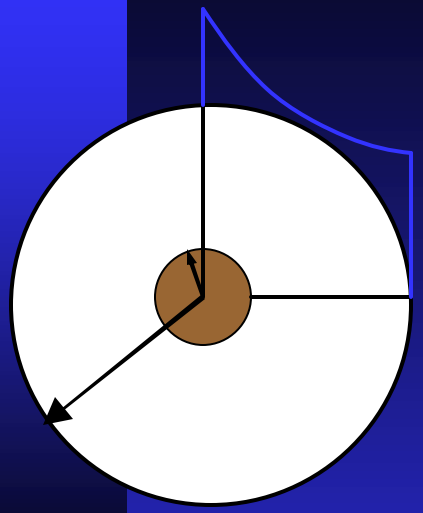
What is covered?

Cable only !!

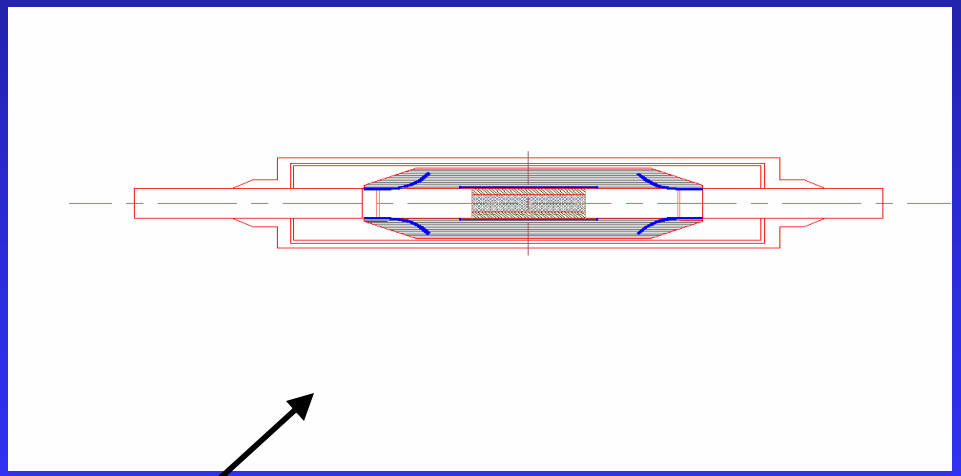
Conductors

- Copper or Aluminum
- ASTM B8/231 or IEC 228?
- Compact – for small sizes
- Reverse Concentric Compressed Class B – most common
- Segmental – Milliken for large sizes
- Hollow conductors / Keystone conductors
- Special constructions – enamelled or oxide coated wires
- Waterblocking or not?

Insulation



$$MaximumStress = \frac{U}{r \bullet \ln\left(\frac{R}{r}\right)}$$



Longitudinal Stress at the Cable & Stress Cone interface

Important criteria:
Maximum Stress
Surface Stress
Capacitance
Dielectric Losses

AEIC CS7 Full Wall Design

Rated Volt. KV	Cond. Size kcmil	Ins. Thickn. mils	Stress @ operating Voltage (kV/mm)		Stress @ impulse Voltage (kV/mm)		Capacitance mF/1000ft	Dielectric Loss W/1000ft
			Conductor	Insulation	Conductor	Insulation		
69	750	650	3.7	1.7	32.4	14.6	0.045	29
115	1250	800	4.9	2.3	40.6	19.1	0.049	82
138	1750	850	5.4	2.6	43.9	21.1	0.053	128

AEIC Maximum Stress Based Design

Rated Volt. KV	Cond. Size kcmil	Ins. Thickn. mils	Stress @ operating Voltage (kV/mm)		Stress @ impulse Voltage (kV/mm)		Capacitance mF/1000ft	Dielectric Loss W/1000ft
			Conductor	Insulation	Conductor	Insulation		
69	750	340	6	3.7	52.5	32.4	0.079	47
115	1250	420	8	4.9	66.3	40.6	0.080	133
138	1750	510	8	4.8	65.0	39.0	0.078	187
Limits based on experience:					<85	<35		

Forte Recommendation

Rated Volt. KV	Cond. Size kcmil	Ins. Thickn. mils	Stress @ operating Voltage (kV/mm)		Stress @ impulse Voltage (kV/mm)		Capacitance mF/1000ft	Dielectric Loss W/1000ft
			Conductor	Insulation	Conductor	Insulation		
69	750	450	4.8	2.6	42.0	22.8	0.063	38
115	1250	650	5.7	2.9	47.2	24.0	0.057	95
138	1750	725	6.1	3.2	49.7	25.9	0.057	138

Bedding Tapes

- Bedding and protection
- Centering of cable core
- Waterblocking through swelling agent (polyacrylate powder)
- Maintain electrical contact

Metallic Sheaths

- Carry capacitive and short circuit currents
- Radial moisture barrier
- Longitudinal moisture barrier in combination with swellable tapes
- Mechanical protection of the cable core
- Withstand stresses during pulling
- Thermo-mechanical aspects
- Miscellaneous

Metallic Sheaths

- Aluminum, extruded and corrugated
- Aluminum, welded and corrugated
- Copper, welded and corrugated
- Laminates, copper or aluminum
- Lead, extruded
- New: Welded Aluminum Laminate (France)

Metallic Sheaths

Metallic Sheaths

- Outer diameter ⇒ Laminate?
- Cable weight ⇒ Aluminum?
- Ground fault requirements ⇒ Copper?
- Mechanical stress ⇒ Corrugated Sheath?
- Lead: hazardous waste ⇒ An issue for me?

Cable Jackets

- Standard: LLDPE or MDPE
- PVC – fire retardant but has halogens
- Halogen Free Fire Retardant (HFFR)
- Semi-conductive outer layer for jacket integrity test – extruded or graphite paint
- Specially bonded system – jacket test

MANUFACTURING

Extrusion Processes

- Vertical Extrusion Line (VCV)
  High building or deep hole
- Horizontal Extrusion Line (MDCV)
  Long land die, lubricant, speed, large conductors
- Catenary Extrusion Line (CCV)
  Catenary shape, small conductors

Extrusion Keywords

- Compound feed
- True Triple Extrusion
- X-ray dimensional scanning
- Dry curing
- Dry cooling
- Stress relaxation
- Post extrusion scanning

Compounds

Conductor Shield

Compound	***Designation***	***Surface protrusions larger 20 microns***	***Surface protrusions larger 30 microns***	***Surface protrusions larger 40 microns***	***Surface protrusions larger 50 microns***
Conventional	Depends on manufacturer	6000	100	7	1
Super Smooth	Depends on manufacturer	10	0.1	0	0

(number per m^2) Use Super Smooth Conductor Shields only for High Voltage Cable

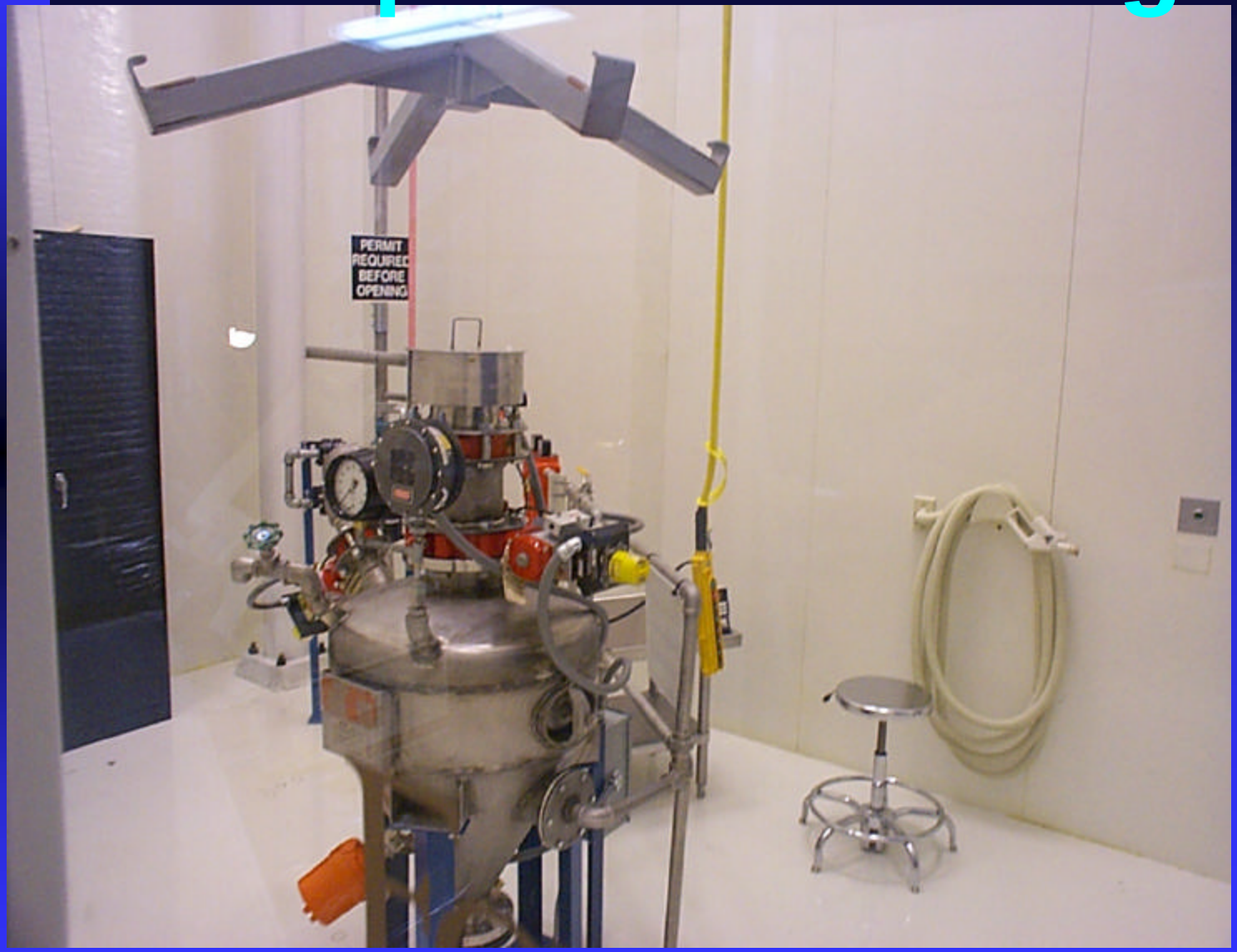
Insulation

Compound	***Designation***	***Grade***	***Contaminant Size***	***Max Allowable***
Medium Voltage	Depends on manufacturer	Extra Clean	5-9 mils	3
High Voltage	Depends on manufacturer	Super Clean	>4 mils	0

Use Super Clean Compound only for High Voltage Cable

Use firmly bonded insulation shields only

Compound Handling



Class 1,000 bag handling room

Sheath / Screen

- Extruded - heat
- Welded – integrity of the weld
- Laminate – integrity of overlap seam
- Consistency – thermo-mechanical requirements
- Neutrals – bedding and indent

Quality Assurance

- ISO 9001 QA system required
- Quality Culture and education
- Testing to AEIC, IEC marginal
- Additional tests, such as hot oil visual
- Consistent procedures for non-conforming material

Thank you