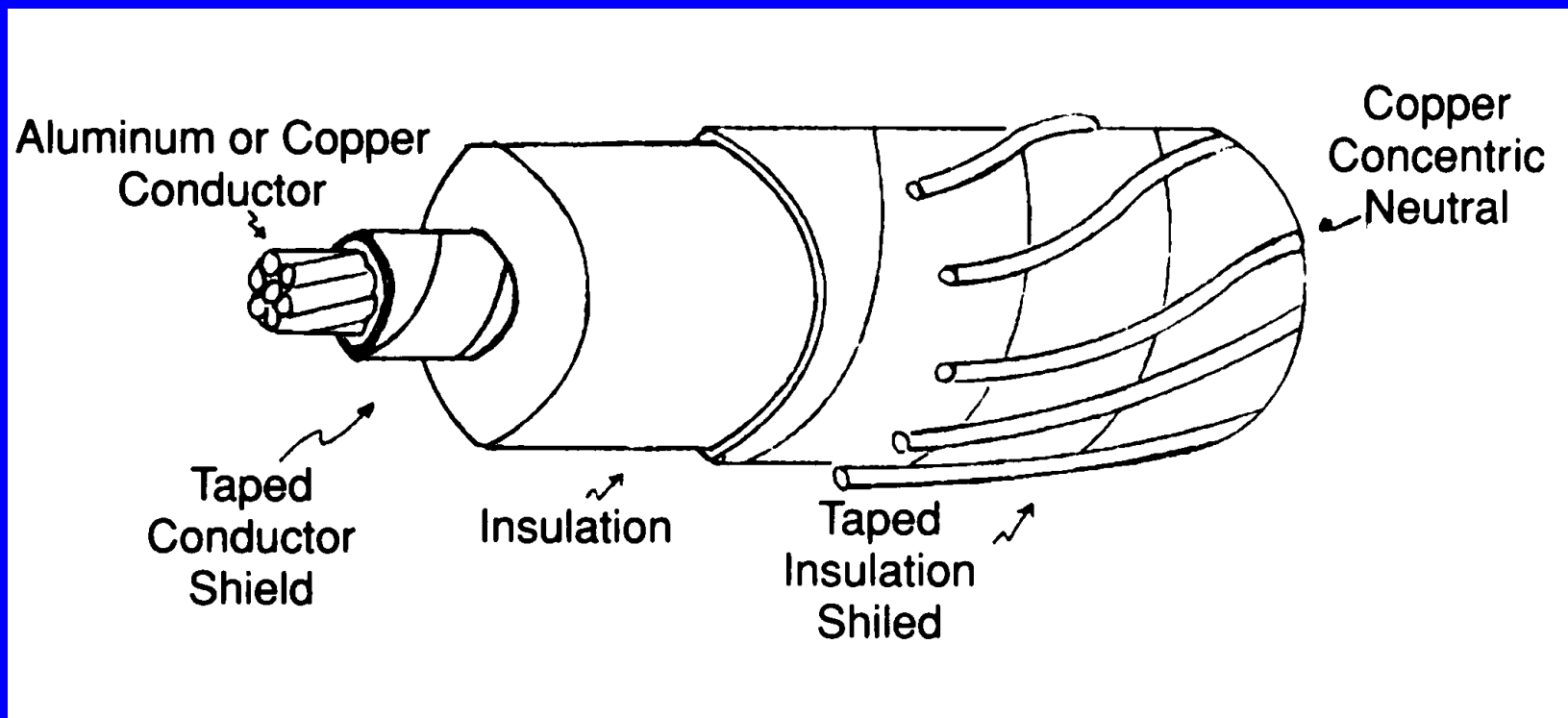


TECHNICAL TRENDS IN MEDIUM VOLTAGE URD CABLE MATERIALS AND DESIGN

Joseph H. Dudas
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URD Power Cable

Early URD Cable Design



High Molecular Weight Polyethylene

- Seemed impervious to moisture
- Higher AC breakdown strength
- Superior dielectric properties
- Expected 50 plus years life
- Reduced insulation thickness

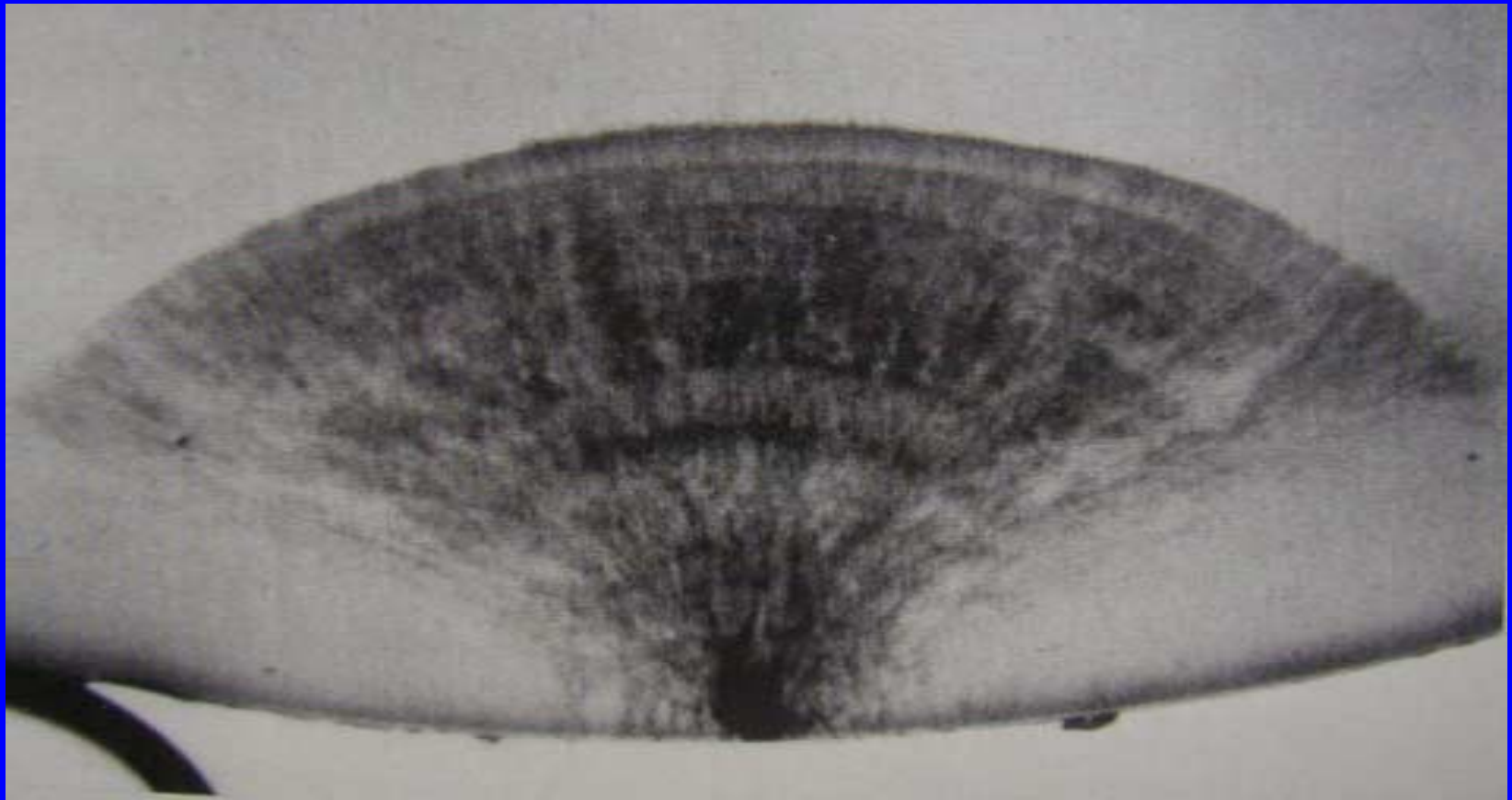
Crosslinked Polyethylene (XLPE)

- Gained favor in late 1960's
- Higher mechanical strength
- Higher operating temperature
- Higher AC breakdown strength
- Reduced insulation to 175 mils

Industry Surprised By Early Cable Failures

- Failures of HMWPE in 7 to 10 years
- Lawson & Vahlstrom first published in 1970
- Tree-like structures in failed cables
- Determined to be electrochemical or water trees

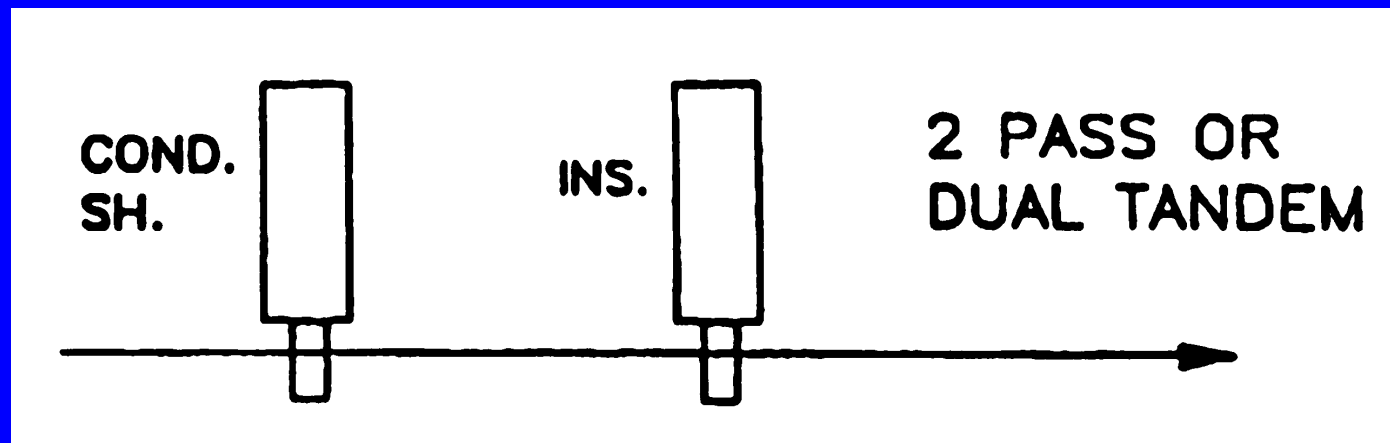
Electrochemical Tree in Failed Cable



Cable Specifications Tighten

- Specification groups become active
- Extruded shields were required
- Contaminants limited to 10 mils
- Wet electrical aging test added
- Protective jackets recommended

1970's Cable Extrusion Technology Was Limited



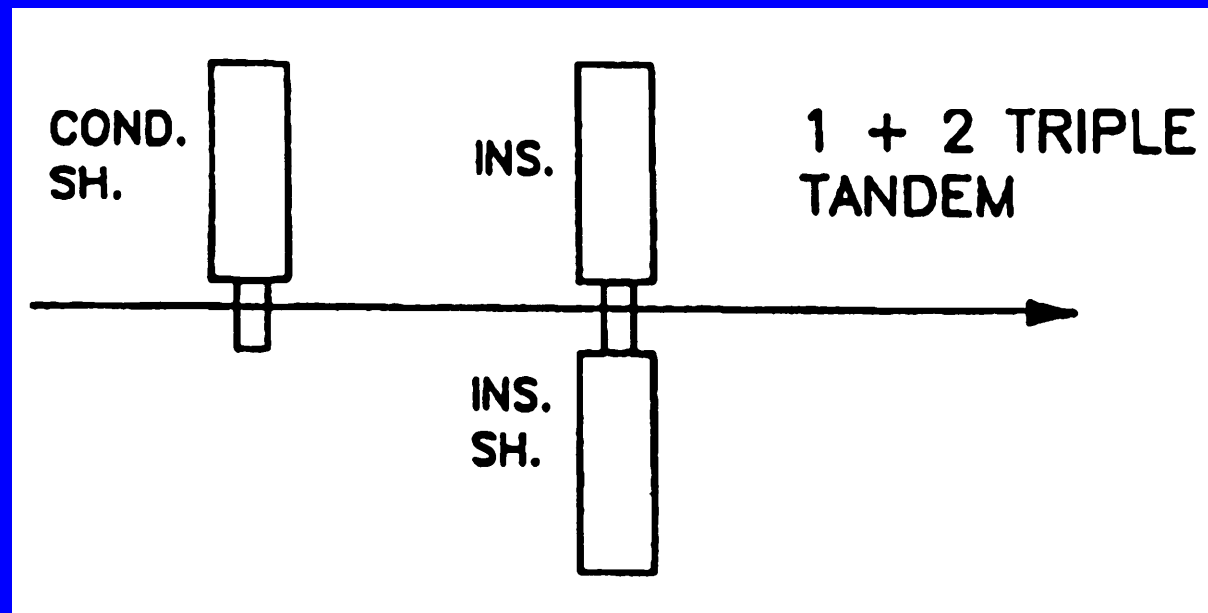
Industry Status By Late 1970's

- HMWPE cables failing at 5 per 100 mi.
- XLPE cable failing at 1 per 100 mi.
- First commercial Tree Retardant HMWPE
- Rapid acceptance by Rural Electric Coops
- IOU's mainly favored XLPE, others EPR

1980's Brought Significant Changes

- Dry nitrogen curing process was introduced
- Strippable XLPE semicon shield developed
- Extrusion technology improved.

Triple Tandem Extrusion Technology



More 1980's Significant Improvements

- Contamination was reduced significantly
- Contaminant size reduced from 10 to 5 mils
- Commercial TRXLPE introduced.
- Strand filled cables are commercialized

More 1980's Significant Events

- Jackets gain widespread acceptance
- Supersmooth Conductor shield developed
- EPR emerges to compete with TRXLPE

What choices to Make?

- What insulation? XLPE, TRXLPE, or EPR?
- Should we specify strand filled conductor?
- Are supersmooth conductor shields really better?
- Should dry cure and triple extrusion be specified?
- Should a jacket be required? What type?

25 Largest Investor Owned Utilities

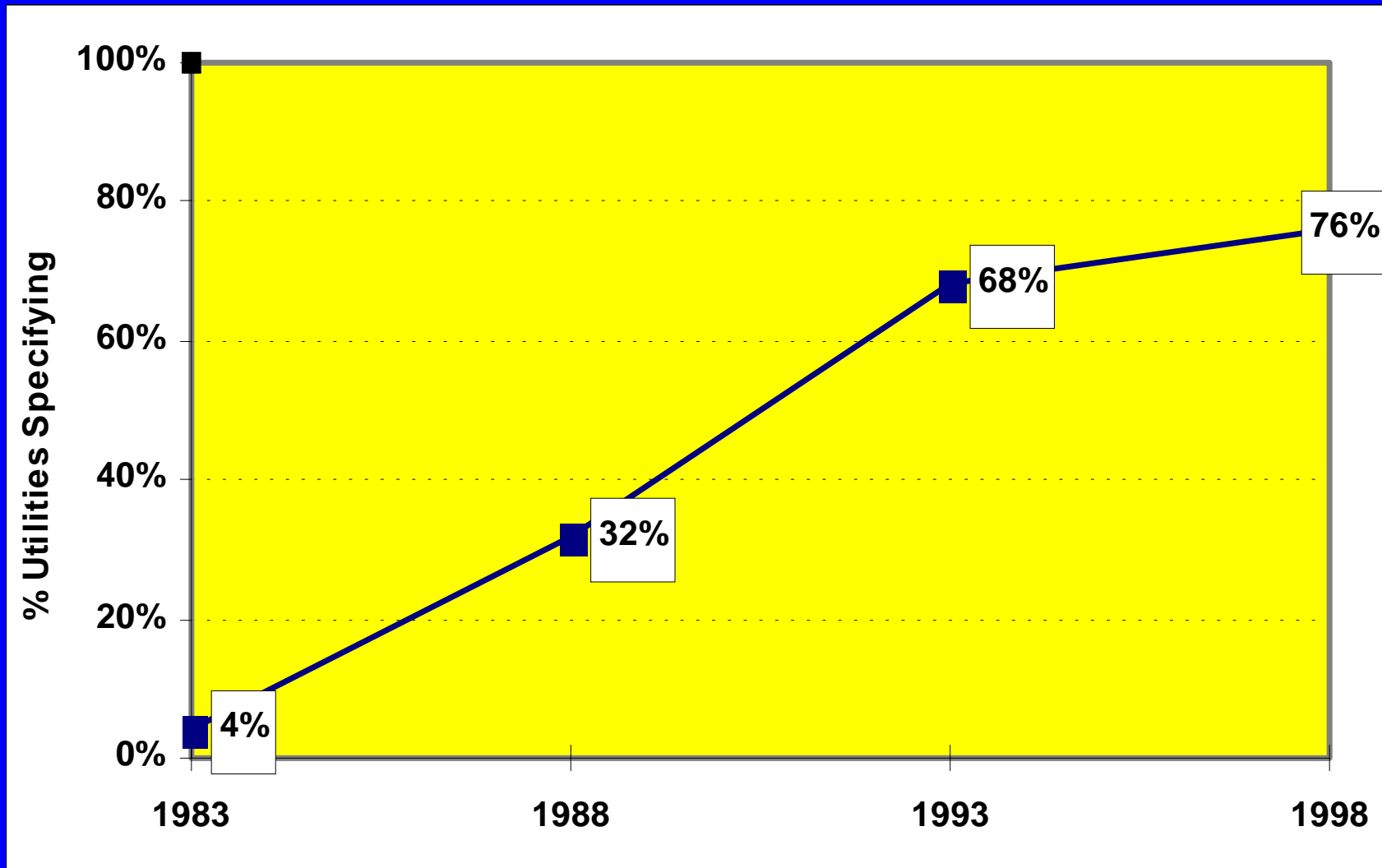
- Served 1 million or more customers
- More than 25,000 miles of installed cable
- 19 of 25 had representatives on AEIC

Rank	Company	No. Cust.
• 1	Pacific Gas & Electric	4,257,121
• 2	Southern California Edison	4,078,534
• 3	Florida Power & Light	3,263,360
• 4	Commonwealth Edison	3,249,162
• 5	Consolidated Edison of NY	2,943,281
• 6	TU Electric	2,176,549
• 7	Detroit Edison	1,941,881
• 8	Public Service Elect. & Gas	1,867,453
• 9	Virginia Electric & Power	1,805,645
• 10	Duke Power	1,662,168

Cable Specifications Analyzed

- Filled strand
- Conductor shield materials
- Insulation materials
- Extrusion method
- Curing method
- Metallic shield type
- Jacket type & material

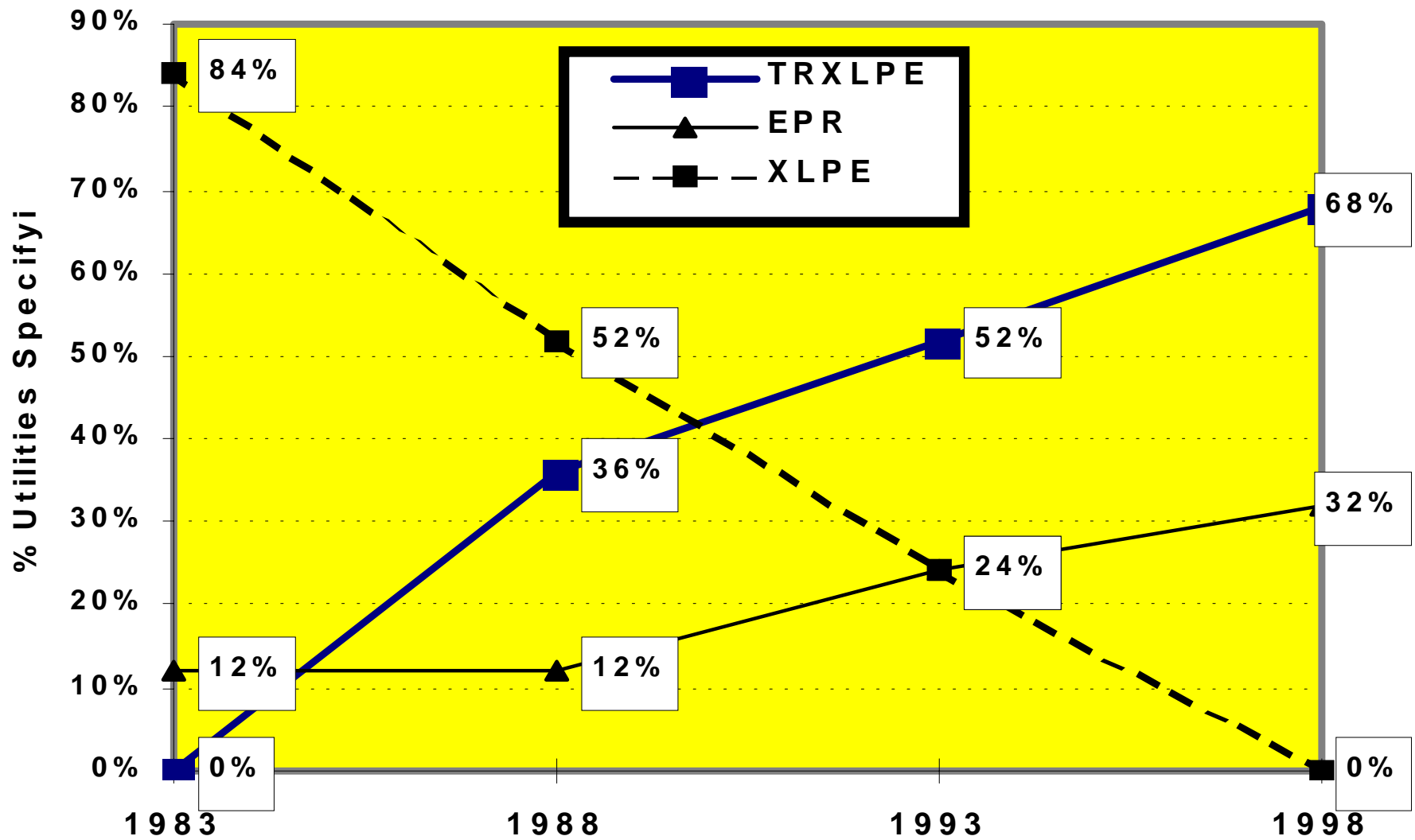
Increased use of Filled Stand Conductor over a 15-year period - 25 Largest IOU's



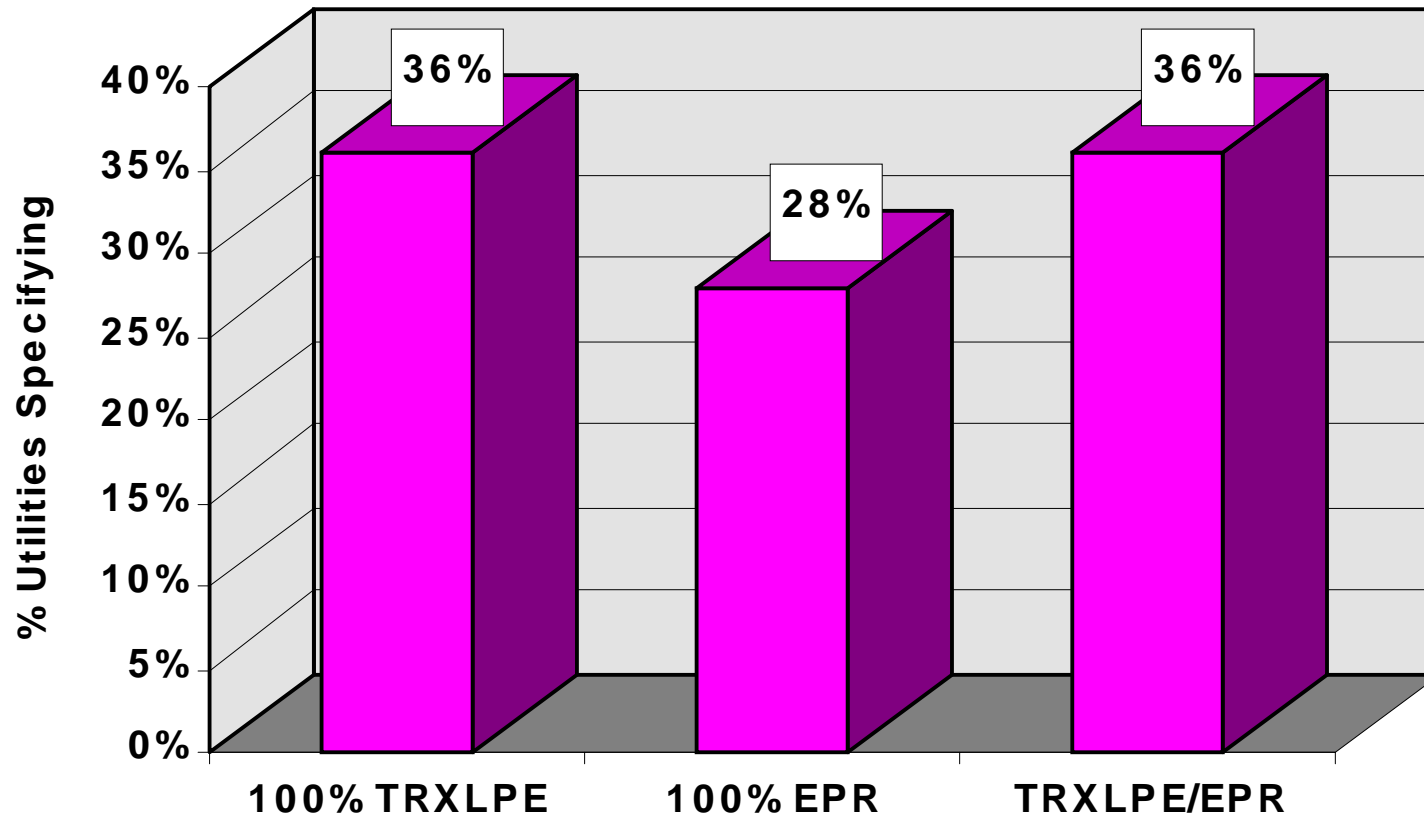
Insulation Materials Specified

- TRXLPE
- EPR
- XLPE

Insulation Compounds Specified over a 15-Year Period



Dual Use Utilities Emerged Strongly in 1998



Primary Reasons Cited for Specifying TRXLPE

- Lower cost
- Excellent service life
- Lower electrical losses

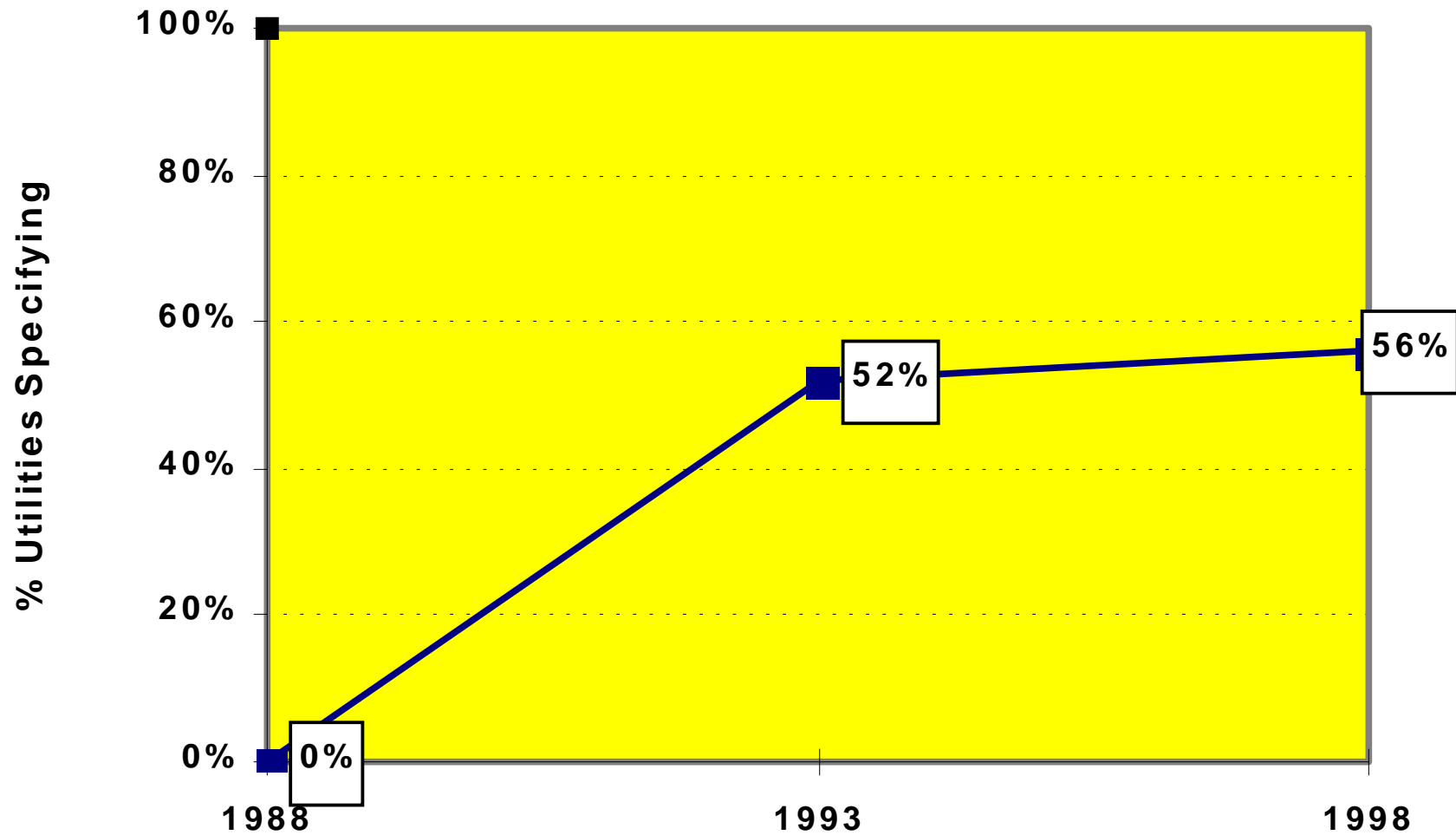
Primary Reasons Cited for Specifying EPR

- Long service life
- Better flexibility
- Less expansion during heating
- Better properties at high temperature

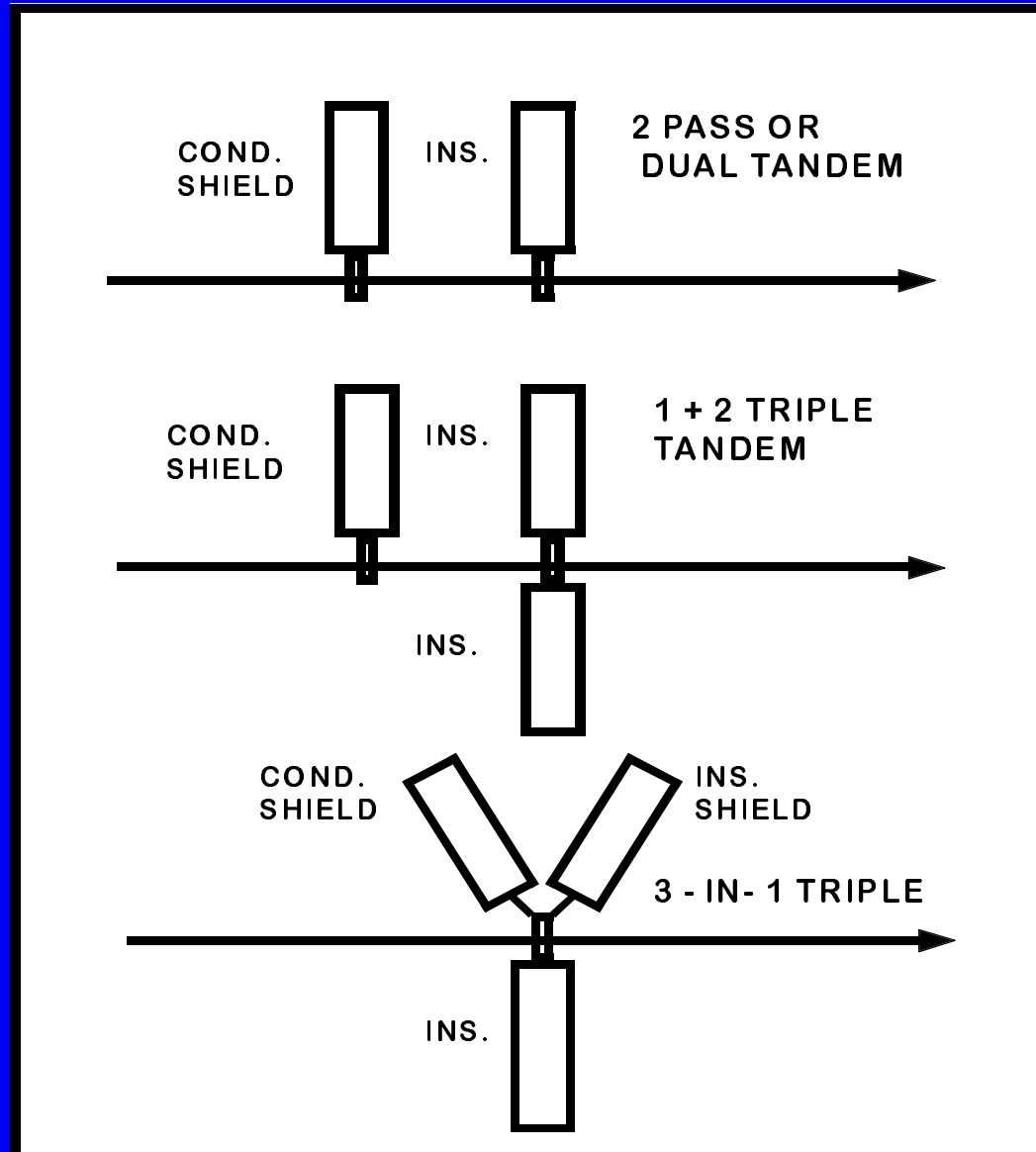
Supersmooth Semiconducting Conductor Shield Materials

- Introduced in 1988
- Formulated from acetylene carbon black
- Finer particle size
- Increased cable life

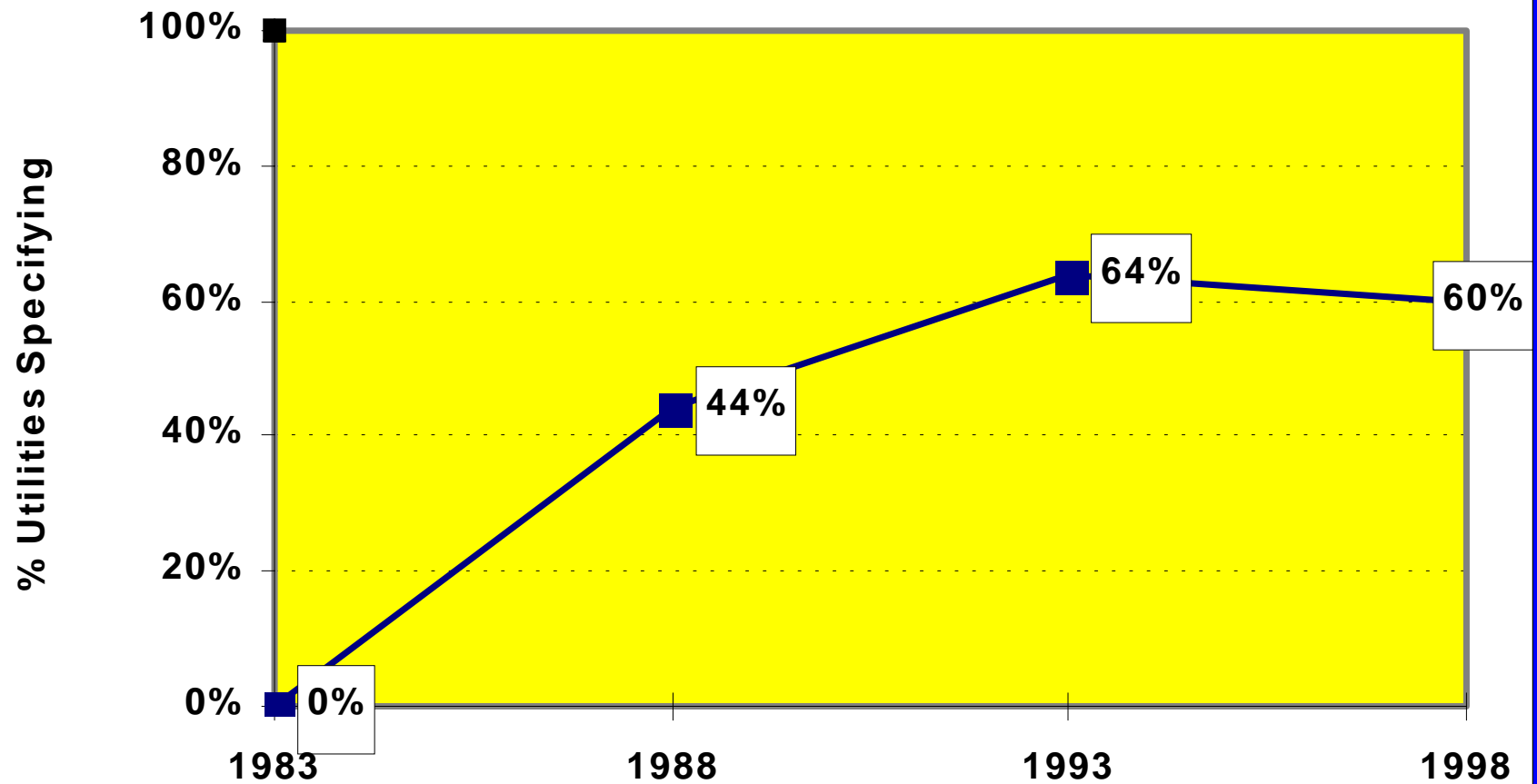
Increased use of Supersmooth Semiconducting Compound over a 10-Yr. Period - 25 Largest IOU's



Cable Extrusion Methods



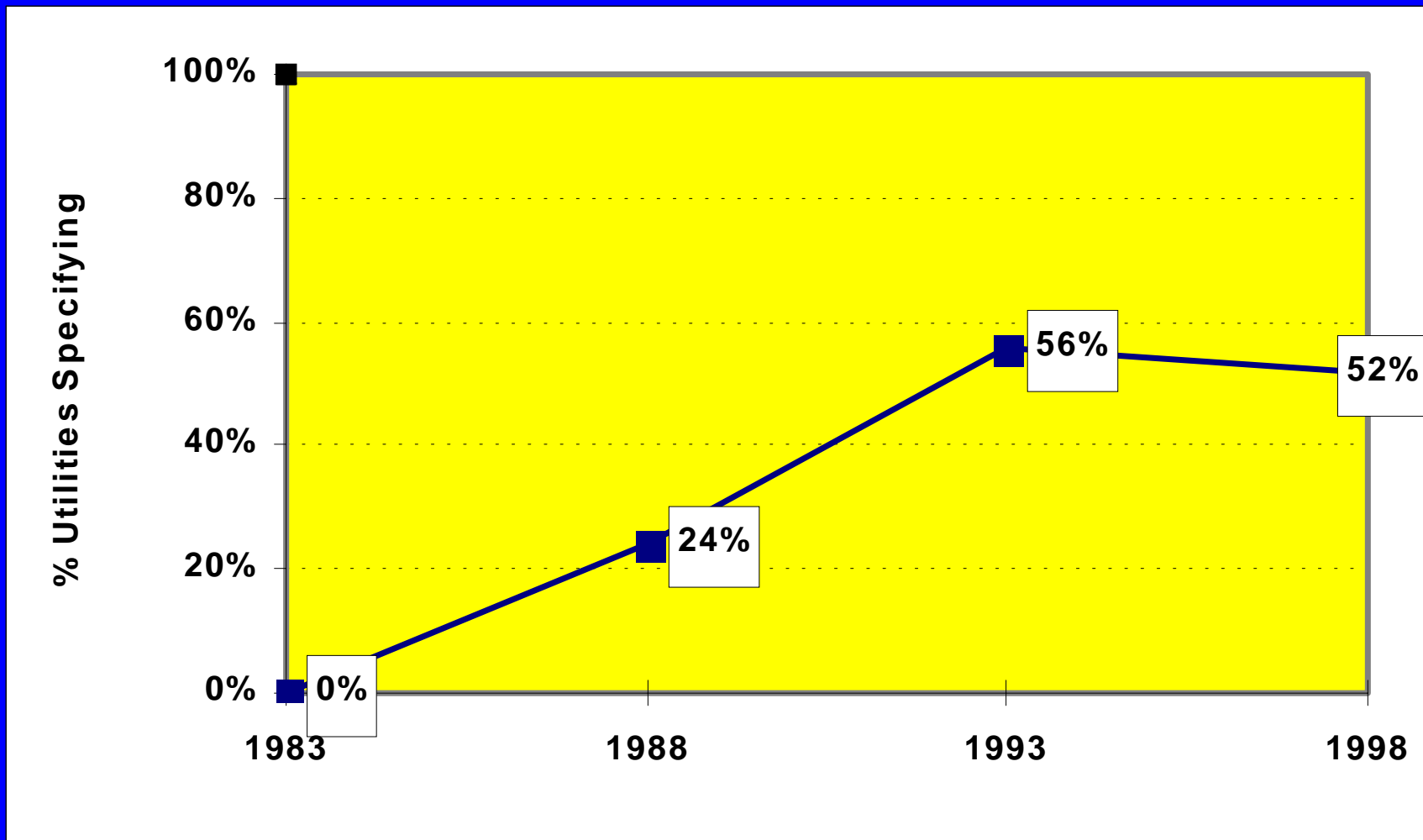
Triple Extrusion Specified over a 15-year period



Curing Method Specified

- Dry Nitrogen
- Steam
- Curing method not specified

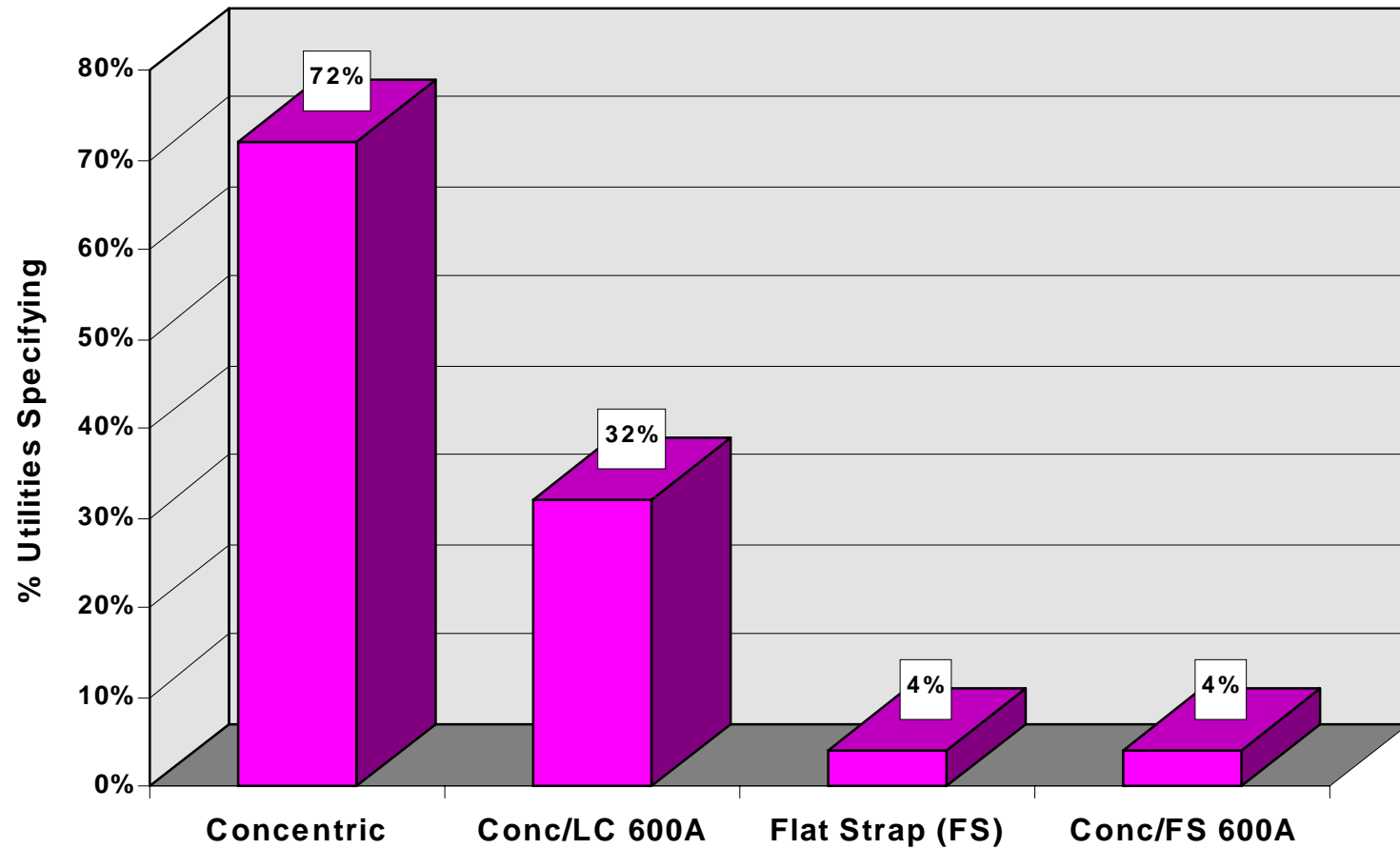
Dry Nitrogen Curing Specified over a 15-year period



Metallic Shielding

- Concentric copper wires
- Flat strap
- Longitudinal corrugated shield

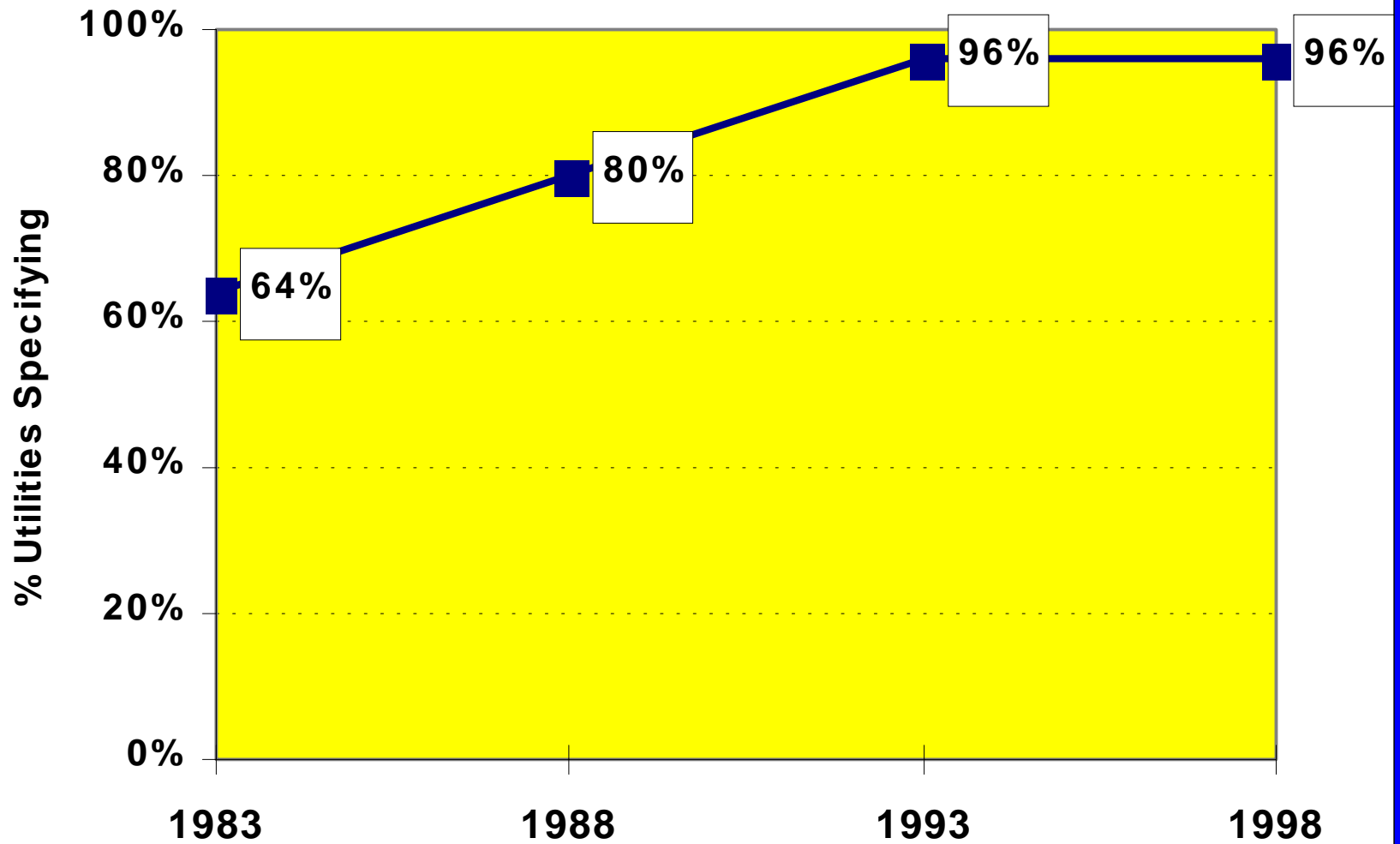
Copper Neutral Type Specified by 25 Largest IOU's 1998



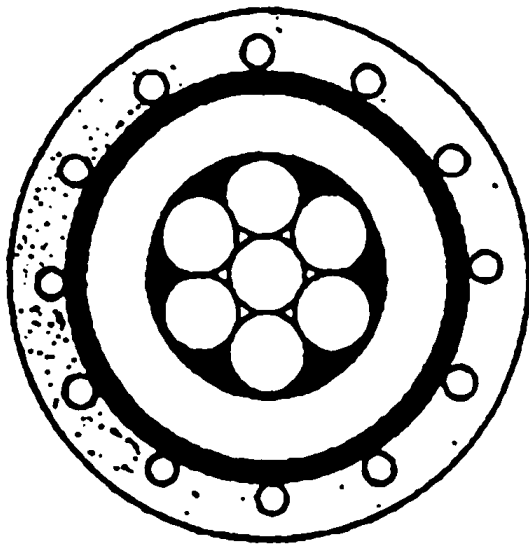
Advantages of a Protective Jacket

- Safeguard metallic shield from corrosion
- Reduce mechanical damage
- Barrier to water penetration

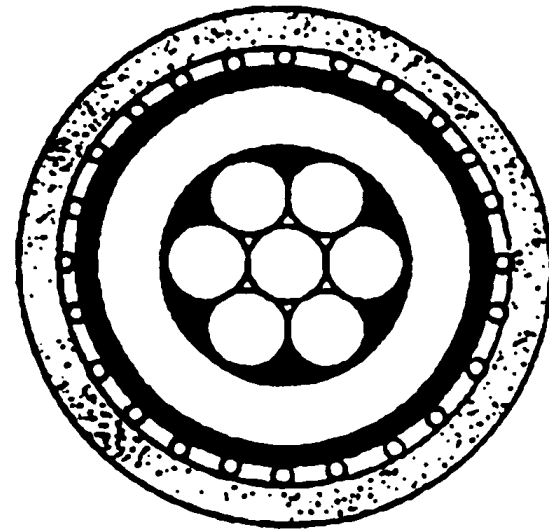
Increased use of Cable Jackets Over a 15-year period



Protective Jacket Types

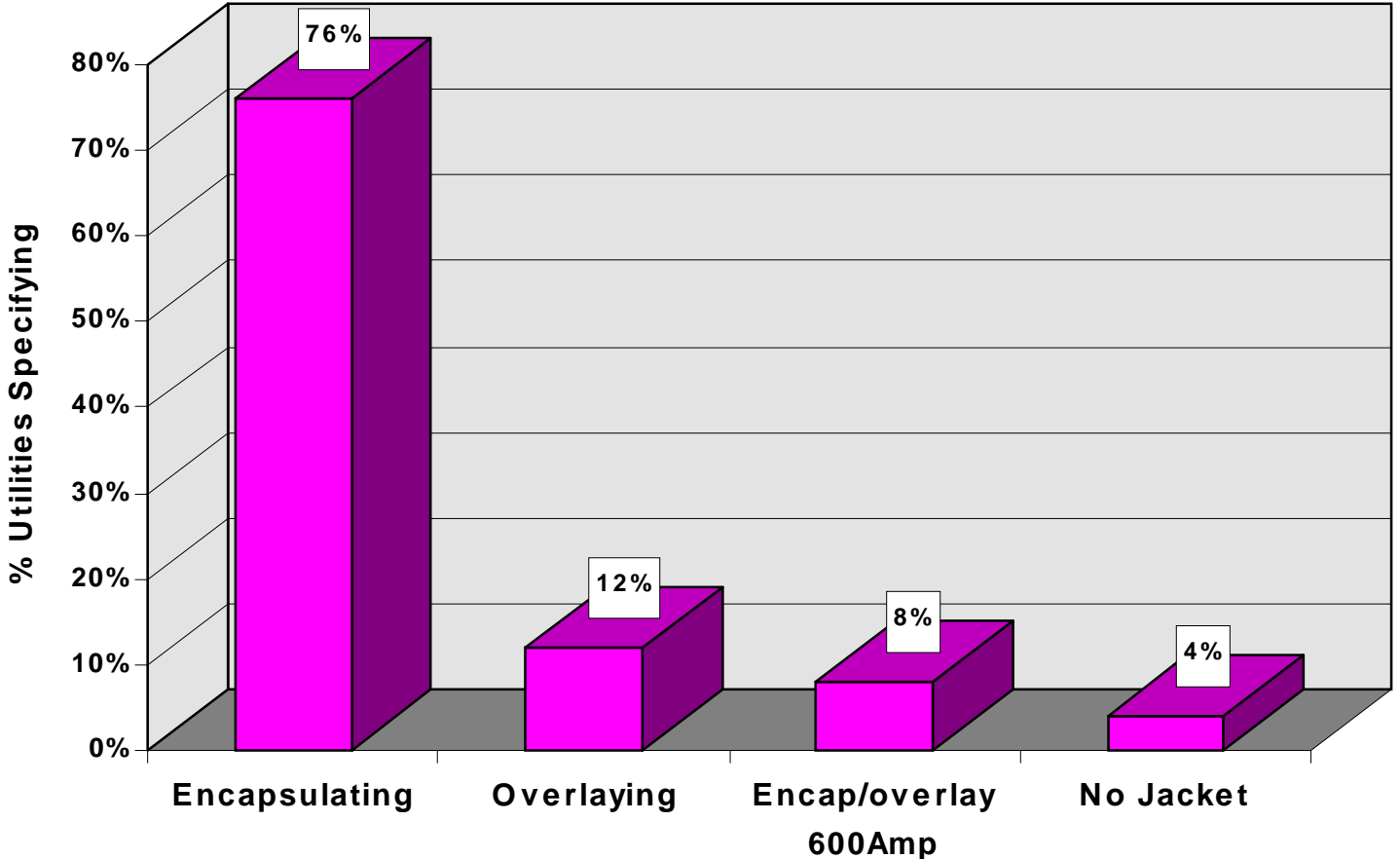


Encapsulating Jacket

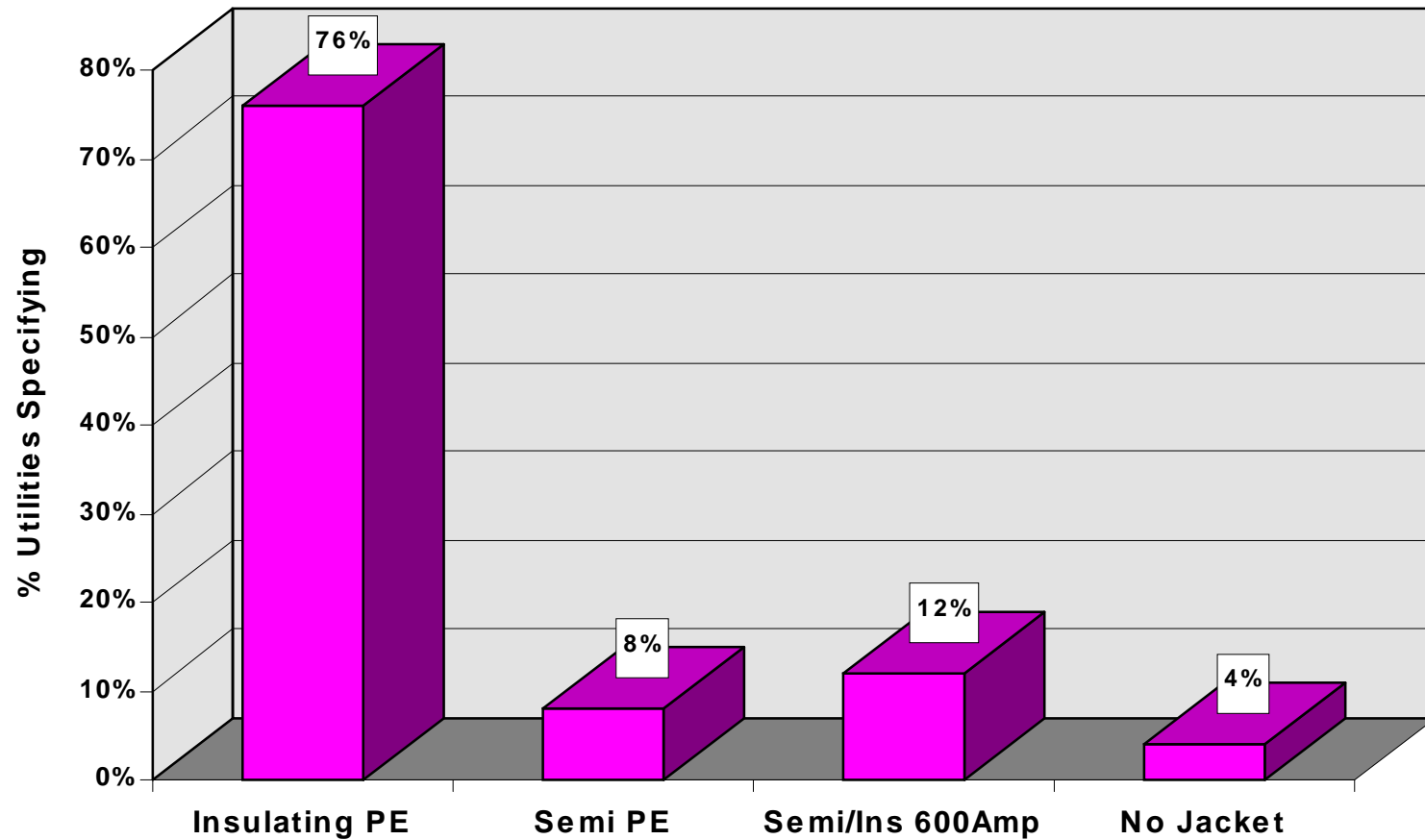


Overlaying Jacket

Cable Jacket Type Specified by 25 Largest IOU's 1998



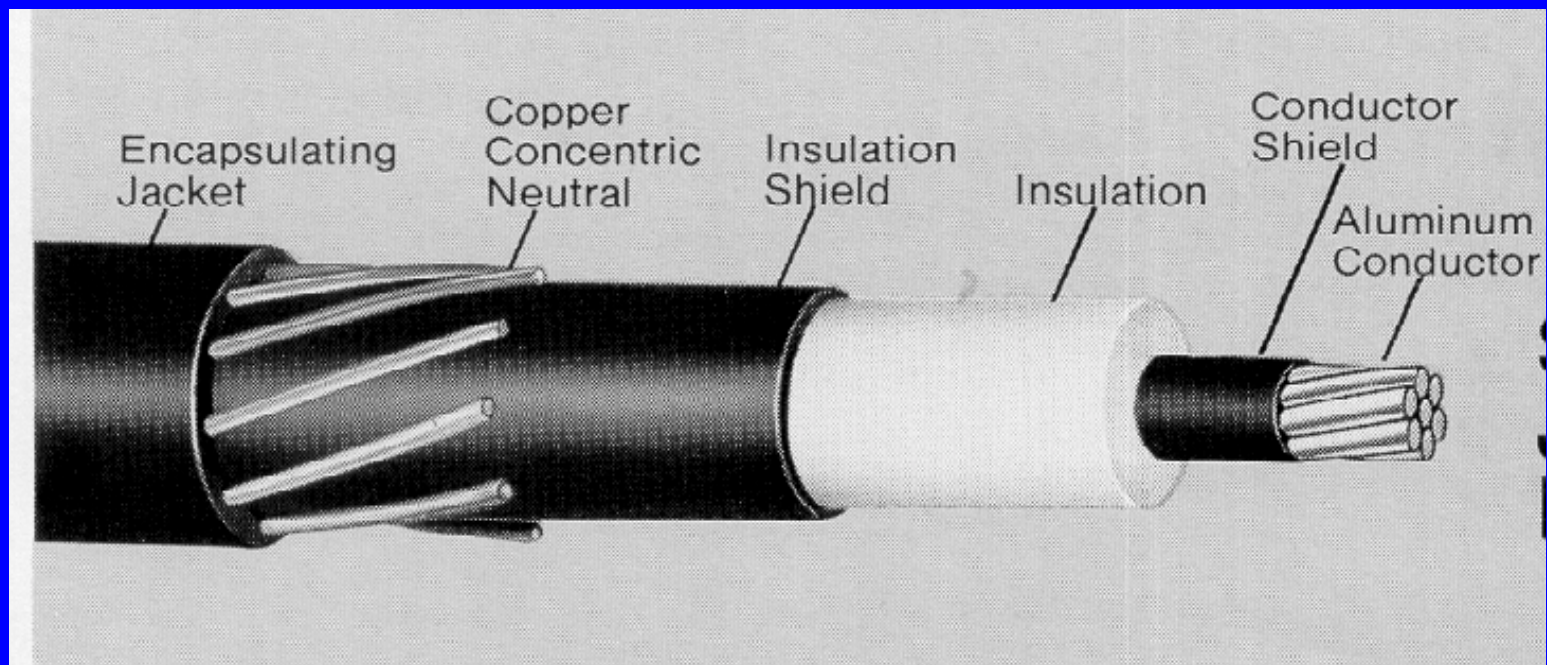
Cable Jacket Compound Specified by 25 Largest IOU's - 1998



Most Widely Specified 15-35kV Cable Constructions

- Filled strand for non solid conductors
- TRXLPE or EPR insulation compound
- Supersmooth semicon cond shld for TRXLPE
- 1+2 triple or 3 in 1 triple extruded
- Dry cured for TRXLPE
- Concentric wire or Conc/LC 600A metallic shield
- Encapsulating insulating PE jacket

Typical USA Medium Voltage Cable



REFERENCES

- Early history and technical trends of IOU's in March/April 1994 issue of Electrical Insulation Magazine.
- Technical trends of IOU's is in ICC Fall 1999 minutes and Nov/Dec 1999 issue of Electrical Insulation Magazine.
- Technical Trends of REC's in ICC Fall 1998 minutes and 1998 proceedings of Rural Electric Power Conference

Eight Utilities Specifying EPR Insulation

- 5 Specify Filled Strand
- None specify Supersmooth Strand Shield
- 2 specify 1 + 2 triple extrusion
- None specify the curing method
- 8 specify jackets