NRC Cable Aging Management Workshop

EPRI Perspective

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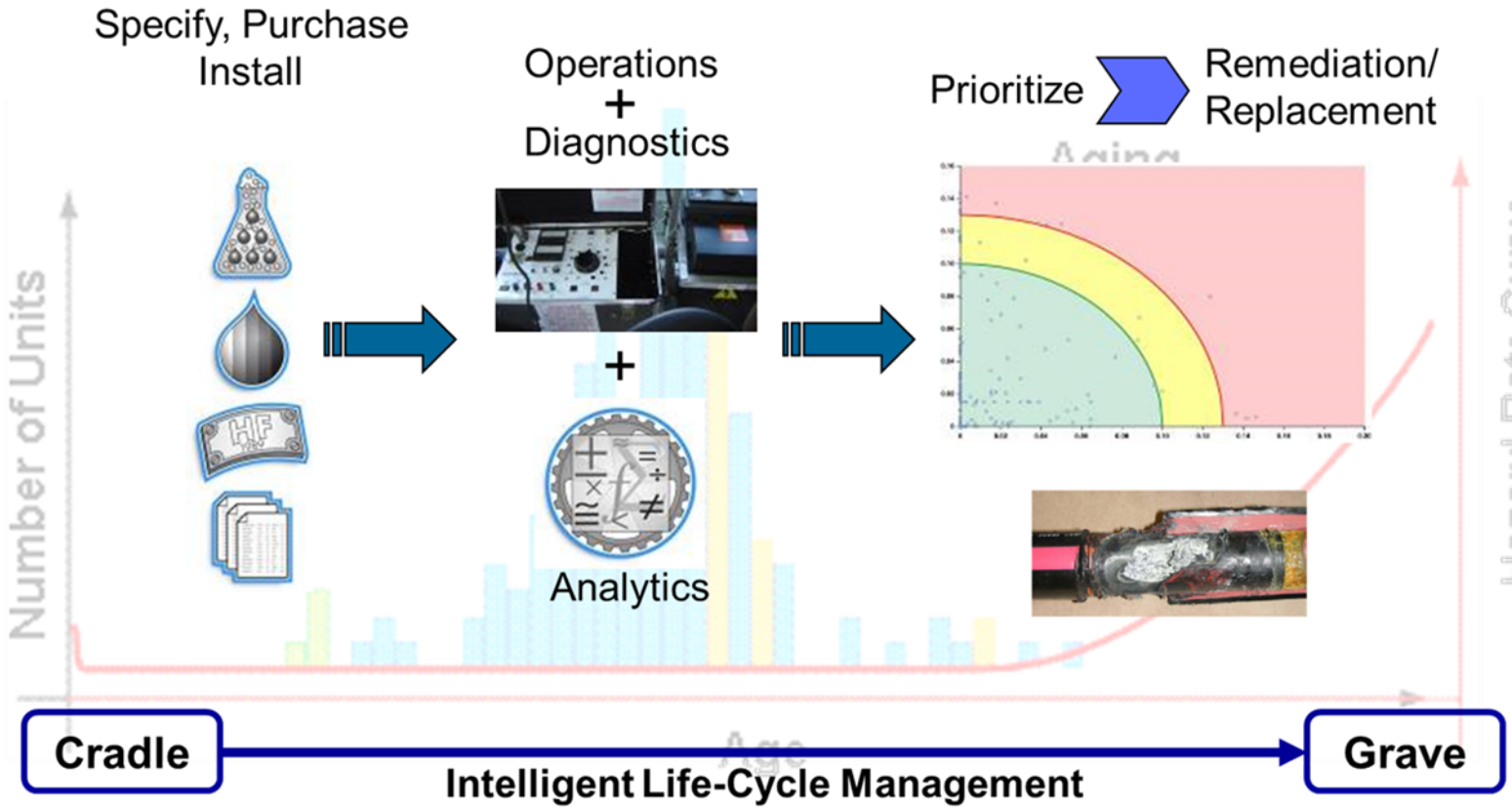
Principle Technical Leader

January 23, 2020

EPRI Cable Program Mission Statement

Support implementation of members' cable system aging management programs and perform research that supports cable reliability through end of plant operation



Focus should be on the condition of cables in **"Adverse Environments"** because those are the ones that may need to be replaced. If they are good, the ones in benign environments will be good.

State of Research Discussion

Cable Aging Management

- Research exist to support aging management programs
- Program implementation guidance is available
- Knowledge Retention to maintain expertise of changing workforce
  - Cable User Group and Cable Training
  - Cable Polymer Handbooks'
- Better understanding cable operating environments
- Improved Condition Monitoring methods are being developed

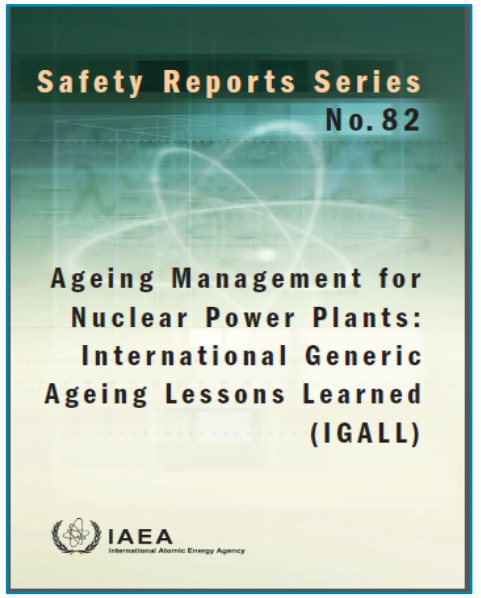
Existing EPRI Cable Research

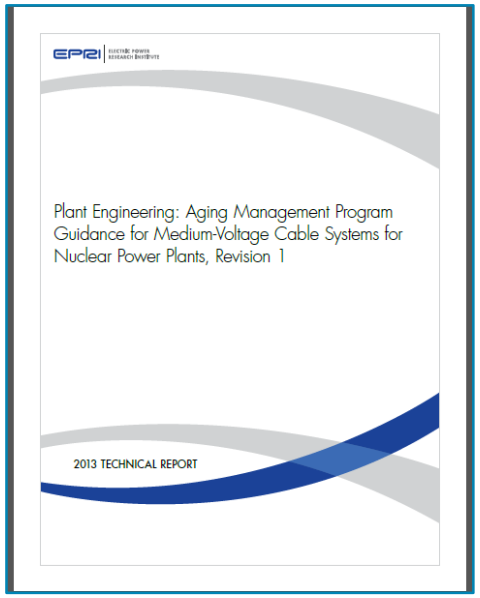
Medium-Voltage Cable Research

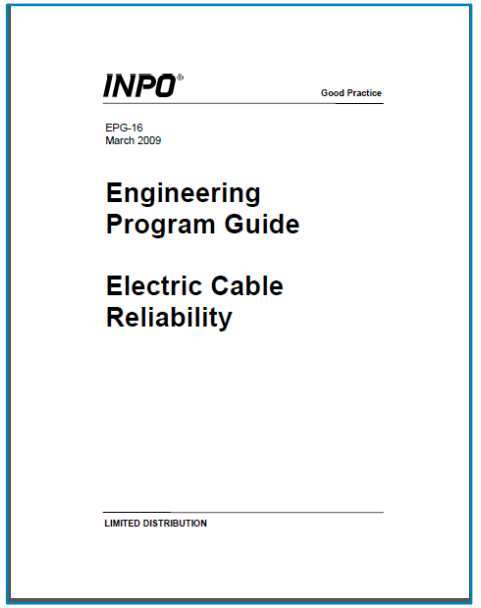
Research Area	Subject	EPRI Report
Cable Aging Management	Aging management program implementation guidance and harvesting guide	3002000557, 1021070 3002002994
Condition Monitoring-	Test applicability matrix: Tan Delta test evaluation: Effects of Withstand Test on MV Cable	1022969 3002005321, 1025262 3002010591
Stressor/Degradation Modes-MV Cable Failure Mechanism Research	Evaluation of wet aging of various MV cable types, MV Cable Polymer Handbook	1018777,1021069, 1022965, 1024894, 3002000554, 3002002993, 3002005323 3002005322
Mitigation- Life cycle management	End of life guide for MV cable and accessories Black EPR Rejuvenation	1025259 3002000551

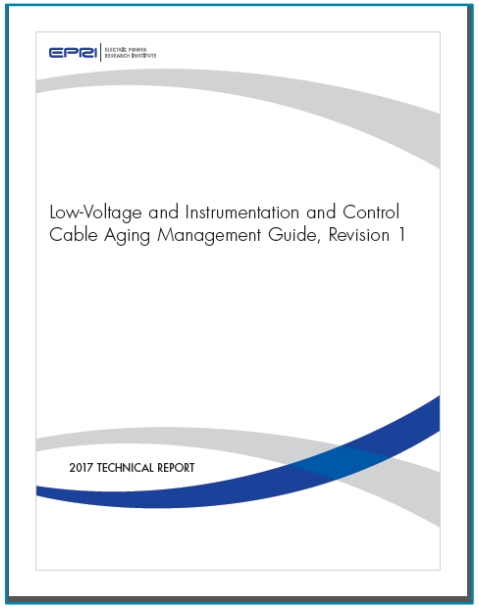
Cable Aging Management Guidance

- Aging management programs per EPRI, NRC, INPO, and IGALL guidance are being implemented worldwide to:
  - Identify and monitor cables in adverse environments
    - **Leading indicators compared to cables in mild locations – bounding for cables in milder environments**
- Cables in mild environments are expected to be reliable > 80 years
  - Focus on condition of cables in **"Adverse Environments"** because those are the ones that may need to be replaced



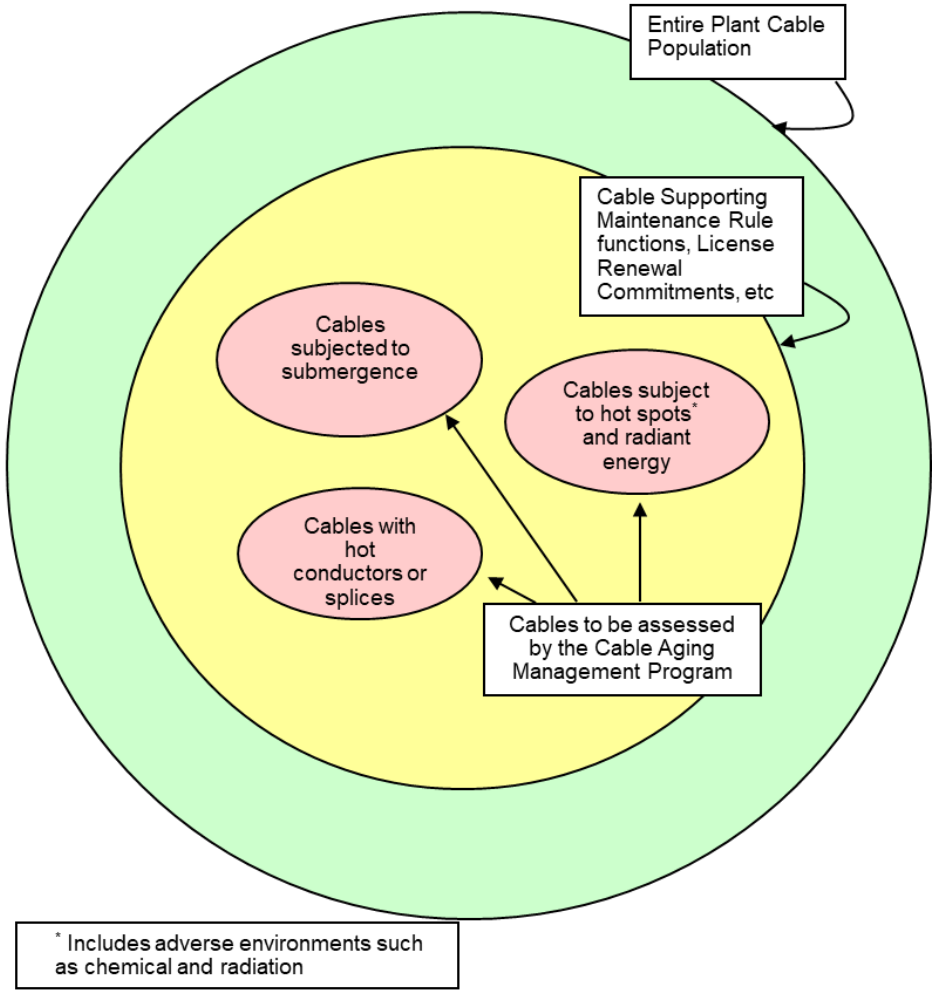






Cable Aging Management Program- What is it?

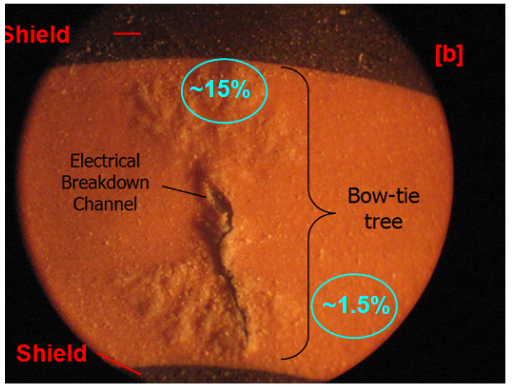
Scope



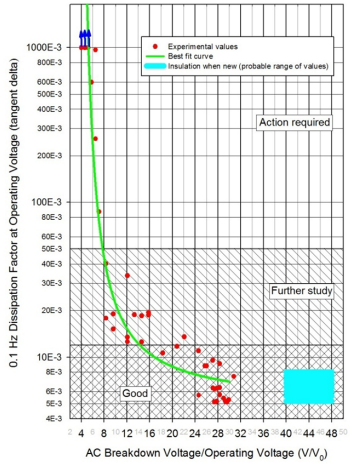
Degradation Stressor of Cables

Heat/Ambient

Water/Treeing

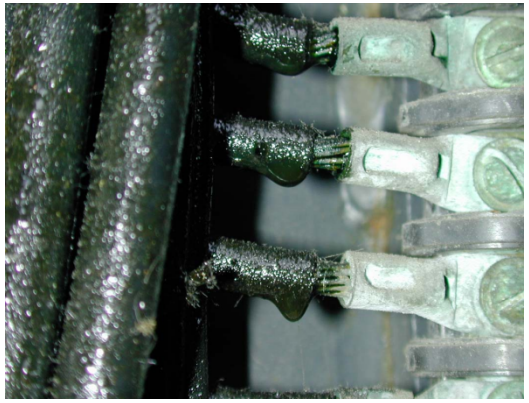


Electrical Stress

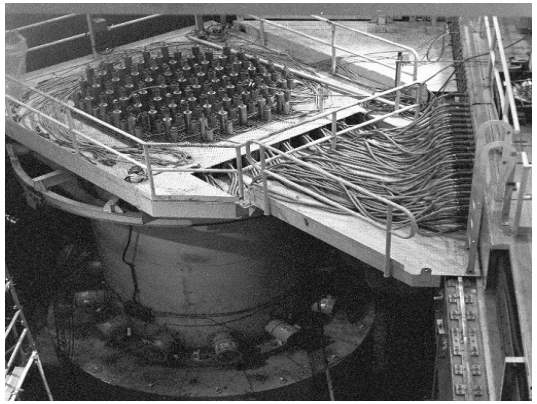


Mechanical

Corrosion



Radiation



Aging Concerns Low vs Medium Voltage

Low Voltage

- Major concern
  - Thermal >50° C
  - Radiation >2000 KGy
- Lesser concern/more rare
  - Chemical
  - Polymer stability in water
  - UV (just sunlight?)

Medium Voltage

- Electrical stress induced degradation
  - Water treeing
  - PD in splices or terminations
- Lesser concerns
  - Thermal
  - Thermal/radiation
  - Ohmic heating
  - Chemical

Cable Aging Management (continued)

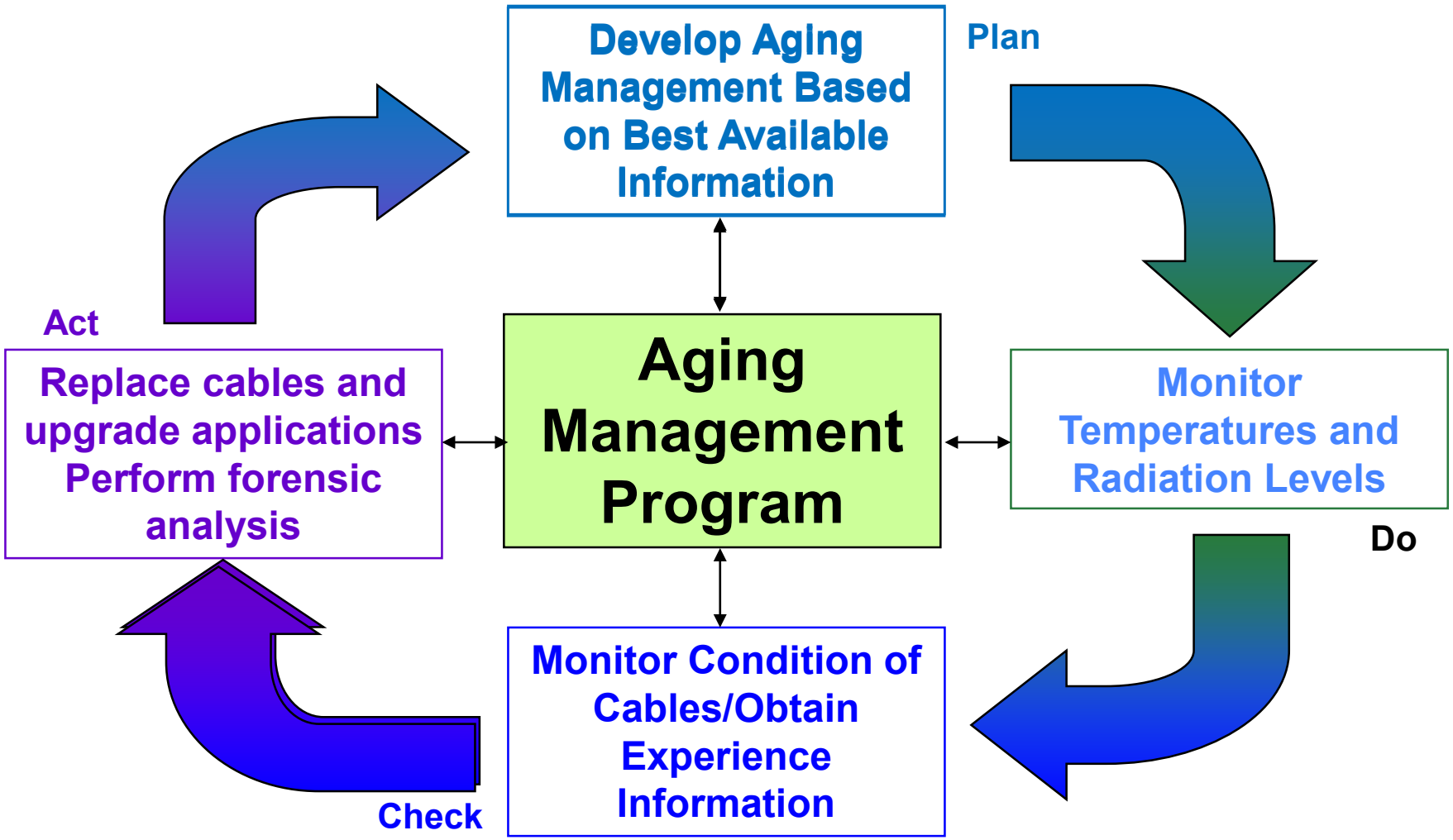
Periodically assess cables in adverse environments

- Low voltage cables
  - Visual/tactile examination
  - Surveillance testing
  - Insulation resistance (wet)
  - Frequency domain reflectometry (dry)
  - Review operating experience
- Medium voltage cables
  - Visual/tactile examination
  - Tan delta testing (wet, shielded cables)
  - Insulation resistance (wet, non-shielded cables)
  - Review operating experience

Key Takeaway

Assessing and performing condition monitoring of a relatively small population of cables in adverse environment allows plant operators to manage a large population of cables that are in benign environments.

Cable Aging Management (continued): On-Going Program



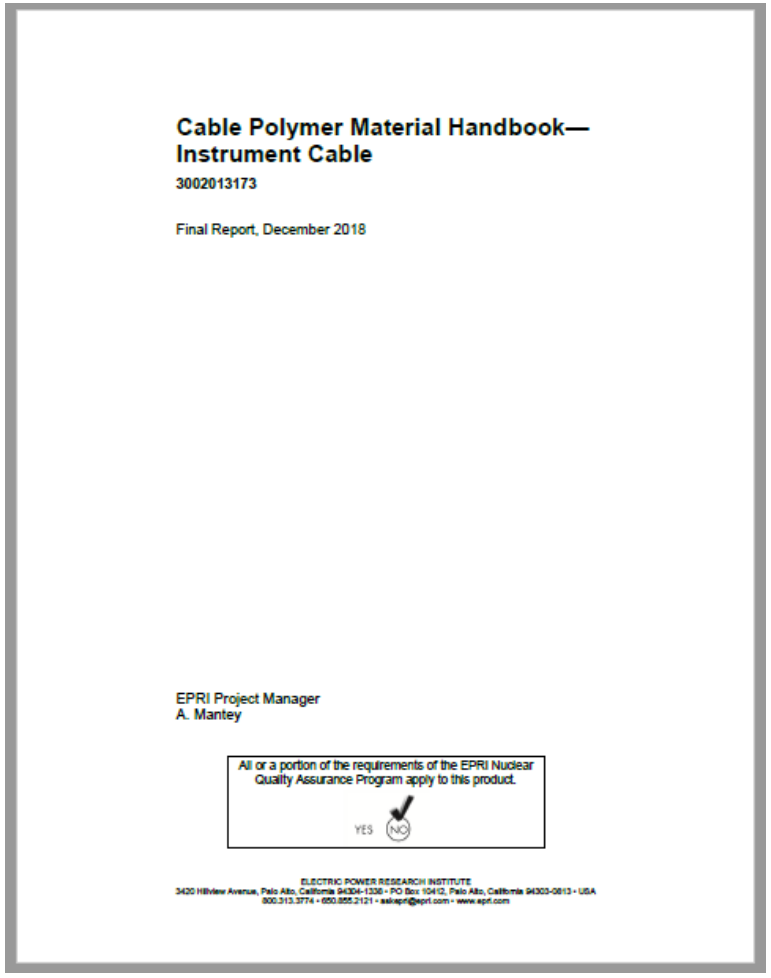
Knowledge Retention

Cable User Group and Aging Management Courses

- Cable User's Group
  - Meets every January to discus
    - Implementation status of aging management programs
    - Operating Experience and Case Studies
    - Research Updates and Technology Transfer
- Training
  - Low voltage and Medium Voltage Courses

Knowledge Retention – Cable Polymer Handbooks

- Cable polymer guides


Cable Polymer Material Handbook—Instrument Cable

3002013173

Final Report, December 2018

EPRI Project Manager
A. Mantey

All or a portion of the requirements of the EPRI Nuclear Quality Assurance Program apply to this product.
YES NO

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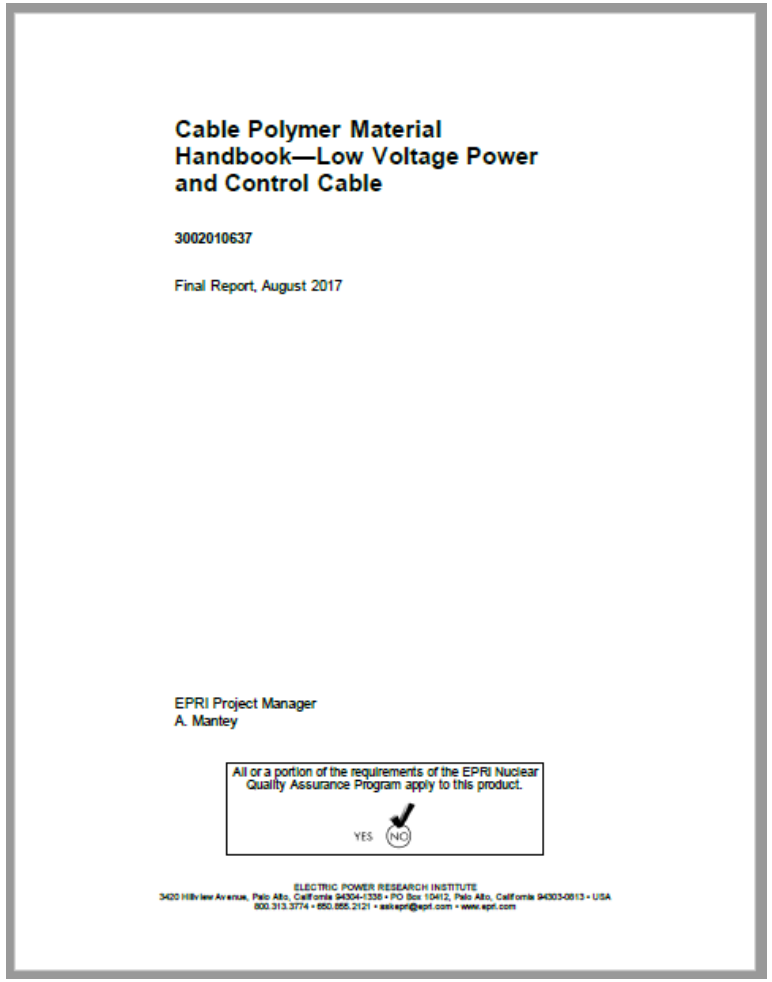
Cable Polymer Material Handbook—Low Voltage Power and Control Cable

3002010637

Final Report, August 2017

EPRI Project Manager
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All or a portion of the requirements of the EPRI Nuclear Quality Assurance Program apply to this product.
YES NO

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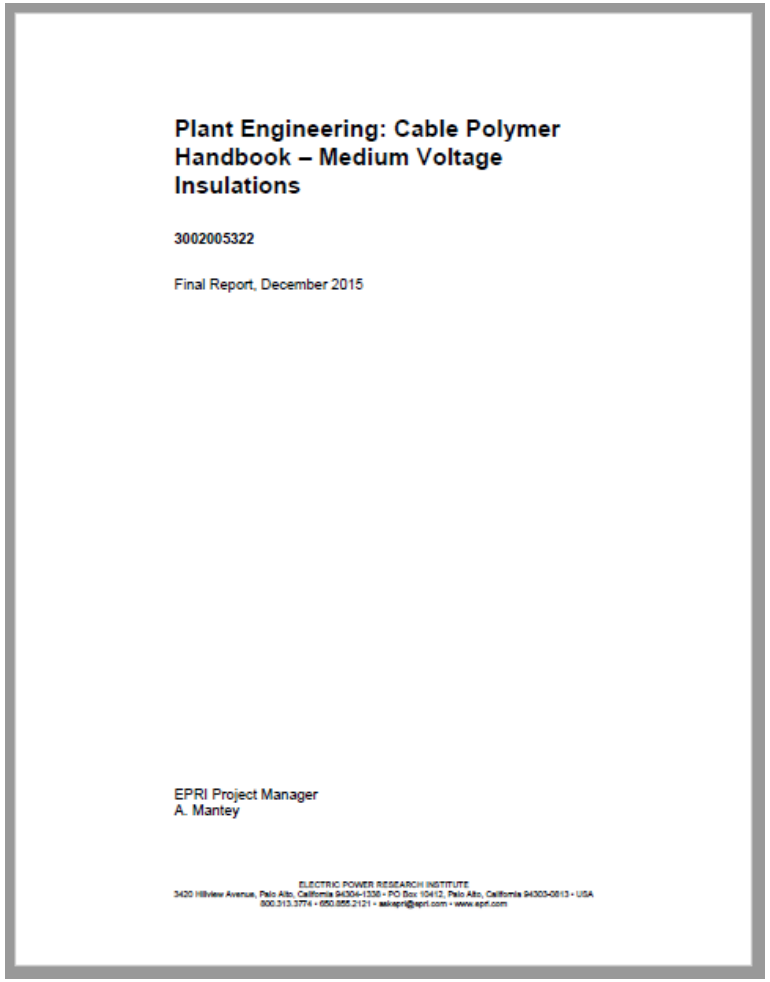
Plant Engineering: Cable Polymer Handbook – Medium Voltage Insulations

3002005322

Final Report, December 2015

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Polymer Handbooks

- Capture knowledge of
  - Polymer types
  - Manufacturing methods
  - Installation
  - Degradation stressor
  - Walkdowns
  - Testing

Understanding Operating Environments

Operating Environments

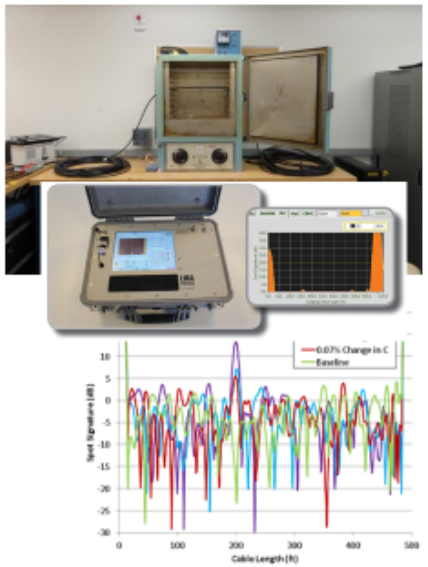
Monitor No.	Building	Monitor Location Description	Elevation Level	Installed Period	TLD Radiation Result Rad (Gy)	TLD Dose Rate Rad/hr. (Gy/hr)	TLD 40-Year Dose Rad (Gy)	TLD 60-Year Dose Rad (Gy)	TLD 80-Year Dose Rad (Gy)	Plant 40-Year Normal Radiation Dose Rad (Gy)	Material Suitable EXCEPT for:
C1	Containment	Inside Pressurizer Cubicle, attached to Conduit 2EZC2ANBX25, next to Conduit 2EZC3ABRR22.	Main/Top	10/16/2015 to 4/24/2017	1.70E+01 (1.70E-01)	1.27E-03 (1.27E-05)	4.47E+02 (4.47E+00)	6.70E+02 (6.70E+00)	8.93E+02 (8.93E+00)	9.60E+05 (9.60E+03)	N/A – All Suitable
C2	Containment	Inside Pressurizer Cubicle, North side	Main/Top	10/16/2015 to 4/24/2017	1.20E+01 (1.20E-01)	8.99E-04 (8.99E-06)	3.15E+02 (3.15E+00)	4.73E+02 (4.73E+00)	6.31E+02 (6.32E+00)	9.60E+05 (9.60E+03)	N/A – All Suitable
C3	Containment	Outside North side of Pressurizer Cubicle, near box 2EZC3ABKRJ09 which is near Safety Injection Tank.	Main/Top	10/16/2015 to 4/19/2017	1.20E+01 (1.20E-01)	9.07E-04 (9.07E-06)	3.18E+02 (3.18E+00)	4.77E+02 (4.77E+00)	6.36E+02 (6.36E+00)	9.60E+05 (9.60E+03)	N/A – All Suitable
C4	Containment	At SI Valve 2JSIAHV605, below Box 2EZC3DAKKJ02, near Safety Injection Tank.	Main/Top	10/24/2015 to 4/24/2017	1.00E-02 (1.00E-04)	7.60E-07 (7.60E-09)	2.67E-01 (2.67E-03)	4.00E-01 (4.00E-03)	5.33E-01 (5.33E-03)	9.60E+05 (9.60E+03)	N/A – All Suitable
C5	Containment	At bend of cable tray 2EZCNTLCB	Main/Top	11/9/2015 to 4/24/2017	5.00E+02 (5.00E+00)	3.92E-02 (3.92E-04)	1.37E+04 (1.37E+02)	2.06E+04 (2.06E+02)	2.75E+04 (2.75E+02)	3.50E+06 (3.50E+04)	N/A – All Suitable
C6	Containment	On Cable Support Structure SW corner	Main/Top	11/9/2015 to 4/19/2017	1.00E+03 (1.00E+01)	7.91E-02 (7.91E-04)	2.77E+04 (2.77E+02)	4.16E+04 (4.16E+02)	5.54E+04 (5.54E+02)	3.50E+06 (3.50E+04)	N/A – All Suitable
C7	Containment	On Cable Support Structure SE corner	Main/Top	11/9/2015 to 4/19/2017	8.10E+02 (8.10E+00)	6.40E-02 (6.40E-04)	2.25E+04 (2.25E+02)	3.37E+04 (3.37E+02)	4.49E+04 (4.49E+02)	3.50E+06 (3.50E+04)	N/A – All Suitable
C8	Containment	At bend of cable tray 2EZC3BNTLBB	Main/Top	11/9/2015 to 4/24/2017	2.90E+02 (2.90E+00)	2.27E-02 (2.27E-04)	7.96E+03 (7.96E+01)	1.19E+04 (1.19E+02)	1.59E+04 (1.59E+02)	3.50E+06 (3.50E+04)	N/A – All Suitable
C9	Containment	Just below cable tray 2EZC3ACTYAA	Main/Top	11/9/2015 to 4/24/2017	1.90E+02 (1.90E+00)	1.49E-02 (1.49E-04)	5.22E+03 (5.22E+01)	7.83E+03 (7.83E+01)	1.04E+04 (1.04E+02)	3.50E+06 (3.50E+04)	N/A – All Suitable
C10	Containment	On Cable Support Structure NW corner	Main/Top	11/9/2015 to 4/19/2017	7.80E+02 (7.80E+00)	6.17E-02 (6.17E-04)	2.16E+04 (2.16E+02)	3.24E+04 (3.24E+02)	4.32E+04 (4.32E+02)	3.50E+06 (3.50E+04)	N/A – All Suitable
C11	Containment	On Cable Support Structure NE corner	Main/Top	11/9/2015 to 4/19/2017	9.50E+02 (9.50E+00)	7.51E-02 (7.51E-04)	2.63E+04 (2.63E+02)	3.95E+04 (3.95E+02)	5.27E+04 (5.27E+02)	3.50E+06 (3.50E+04)	N/A – All Suitable
C12	Containment	At bend of cable tray 2EZCNTKAB	Main/Top	11/9/2015 to 4/24/2017	2.00E+02 (2.00E+00)	1.57E-02 (1.57E-04)	5.49E+03 (5.49E+01)	8.24E+03 (8.24E+01)	1.10E+04 (1.10E+02)	3.50E+06 3.50E+04)	N/A – All Suitable

Condition Monitoring Techniques

Condition Monitoring Techniques

MV Cable Condition Monitoring

- Frequency Domain Reflectometry
- Dissipation Factor (tan δ)
- High Potential Testing
- Partial Discharge

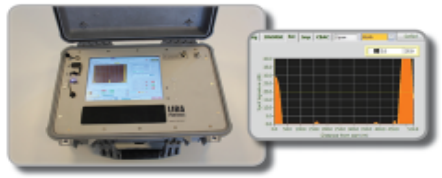


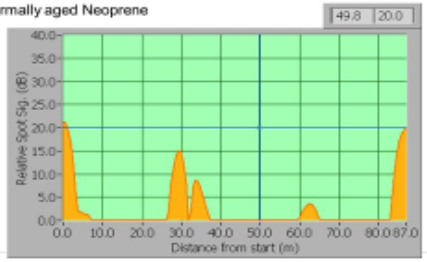
LV Condition Monitoring Tools

- Visual/Tactile
- Insulation Resistance (wet insulation only)
- Indenter
- Frequency domain reflectometry (FDR)

Neoprene not thermally aged

Thermally aged Neoprene



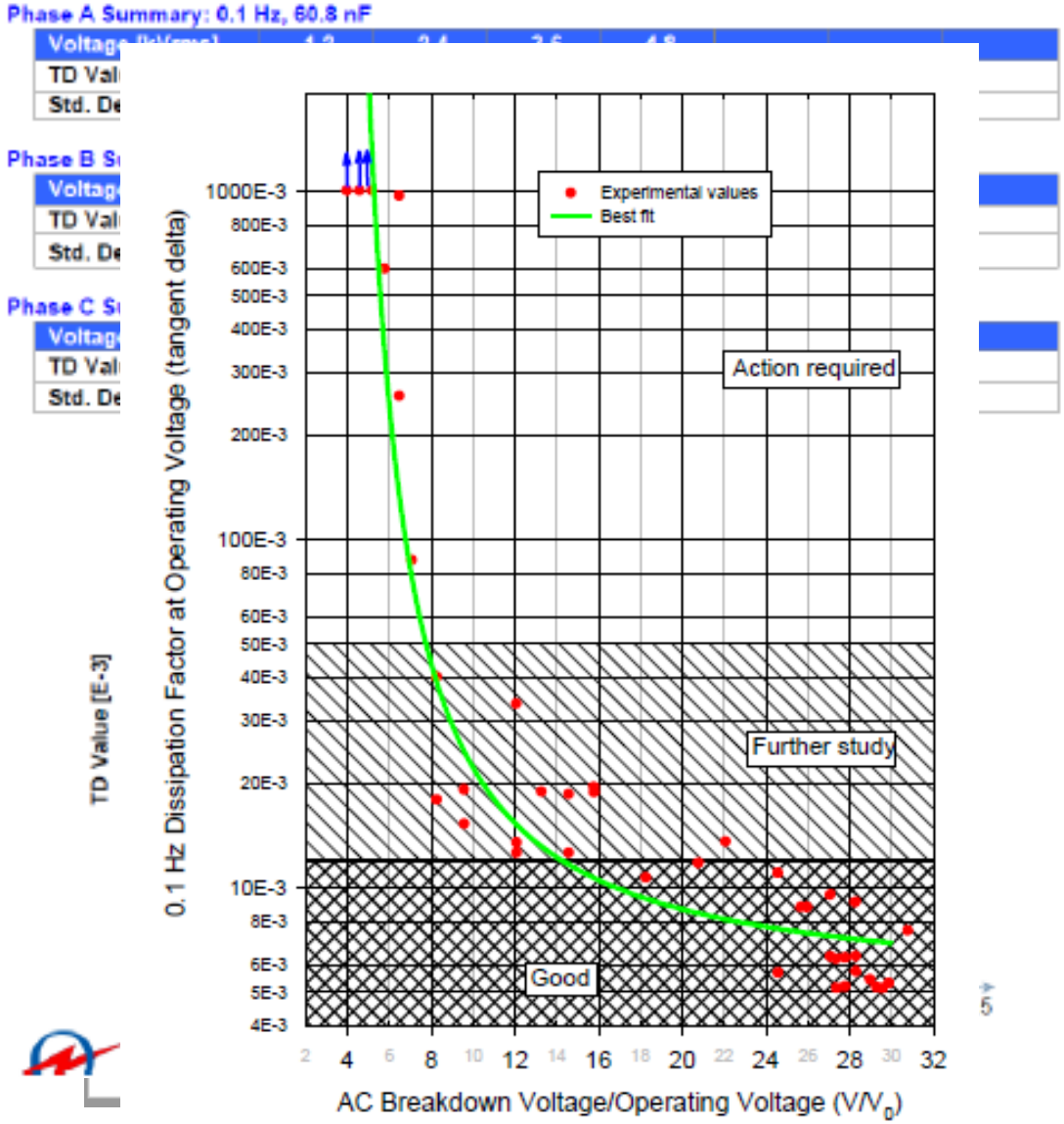


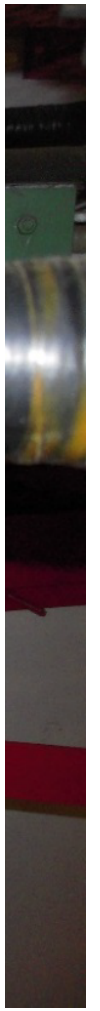
- Good tools exist for global evaluation of MV shielded cables
- LV cable condition monitoring needs better tools
  - Methods exist for localized defects, but all insulation types are not covered or access is required for data acquisition

No global tool to evaluate Low Voltage cables like tan-delta for Medium and High Voltage cables.

Condition Monitoring for Medium Voltage Cables

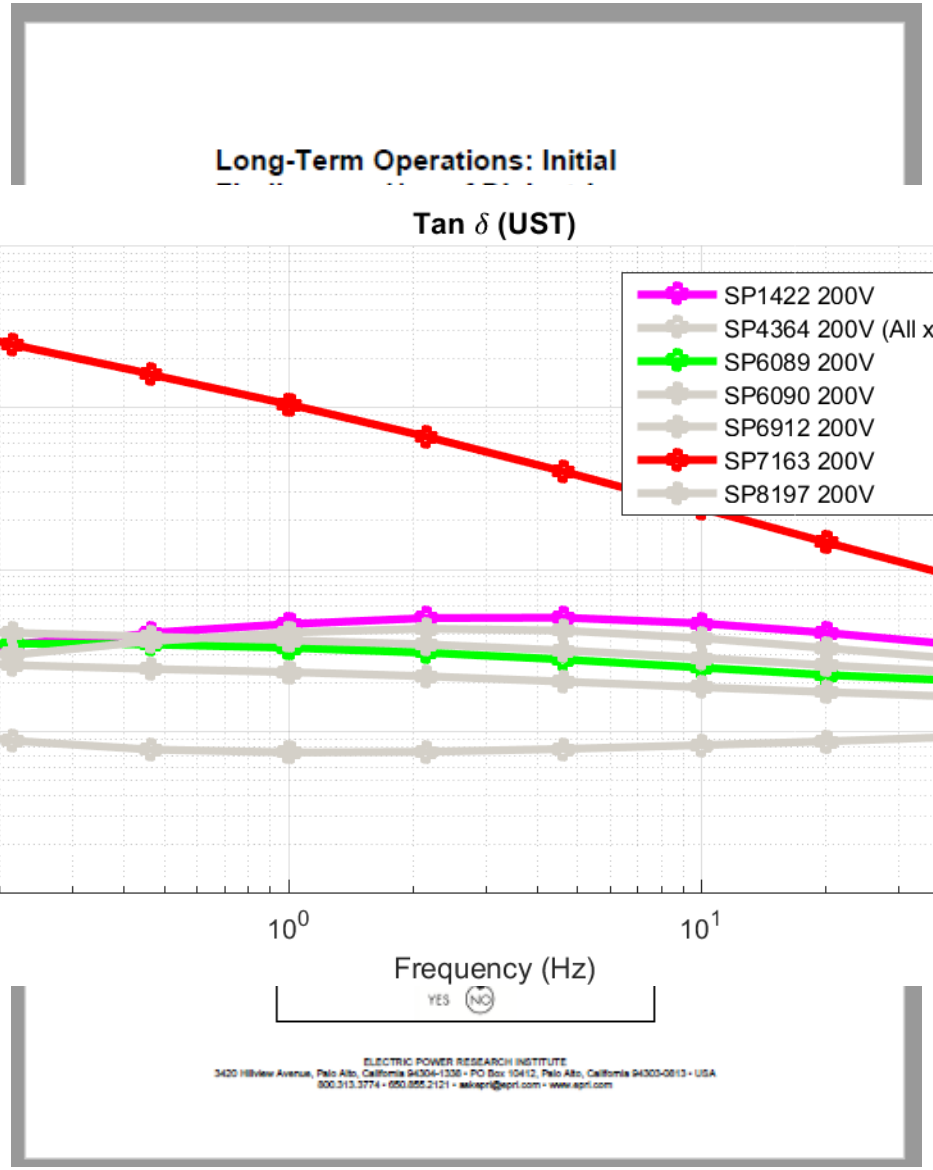
- Tan delta/withstand testing of medium voltage cables
  - Identifies degraded insulation and indication of most splice and termination degradation
  - Correlates with AC breakdown testing of good and degraded cables





Improved Condition Monitoring

- Research is indicating that low frequency dielectric spectroscopy (tan delta for low voltage cable) will provide similar results for low identifying low voltage cable degradation



Future Improvements

- Condition Based Qualifications
  - MAI/TEAM – Polyage model of degradation to evaluate remaining life
  - SNERDI – Condition based qualification of cable demonstration
- On-line/Continuous Monitoring
  - Spread spectrum time domain reflectometry
  - Distributed temperature monitoring
- Update of aging management guides
  - Incorporate DOE research on EMDA gap research results?
  - NRC condition monitoring research results?
- Operating experience identified research needs

Summary

Summary

- **Licensees' have the tools to effectively manage cable aging**
- Guidance or developing and implementing aging management programs exists and will continue to be updated
- Need to maintain knowledge level of changing work force through training and cable polymer handbooks
- Operating conditions can be better understood through obtaining temperature and radiation data specific to cable locations
- Condition monitoring methods exist for medium voltage cables
- Improved condition monitoring tools are being researched

Together...Shaping the Future of Electricity