# *Environmental Qualification – Strategy and Progress*

*Charles W. Hills, PhD*

*April 8, 2009*

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# Introduction

- Strategy
  - Assessment
  - Qualification
- Progress
  - Physical properties
  - Electrical properties
  - Aging
    - Arrhenius
- Experimental Work
  - Oxidative Induction Time (OIT)

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# Assessment

- Physical Properties
  - Our product meets all known next generation requirements
- Electrical Properties
  - Rated to 90°C dry / 75°C wet
  - In-house testing validates 90°C wet
    - NRTL certification in progress
- Environmental Qualification
  - Rated to 40 year lifetime
  - Radiation exposure and DBE to IEEE 323-1974 and IEEE 383-1974 standards

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# Next Generation Qualification Requirements

- 60 year lifetime
- DBE Qualification (reactor specific)
- Radiation exposure (reactor specific)

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# Progress

- Electrical Properties
  - In-house testing validates 90°C wet
  - NRTL certification in progress
- Environmental Qualification
  - Lifetime
    - 60 year analysis (legacy data)
    - Experimental work in-house in progress
- Radiation Exposure
  - High level exposure tests underway
  - GCC Spain performing temperature – dosage studies
- Fiber Systems
  - Installed blown fiber system for South Carolina Electric and Gas (Virgil B. Summer)

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# Accelerated Aging Analysis

$$k = Ae^{\frac{-E_a}{RT}}$$

## Arrhenius Equation:

k = reaction rate
A = pre-exponential factor (frequency factor)
$E_a$ = Activation Energy
R = Boltzmann's gas constant
T = Temperature (Kelvin)

$$\log k = -\frac{E_a}{R}\frac{1}{T} + \log A$$

Plotting log(k) vs. 1/T provides a line whose slope is related to the activation Energy ($E_a$) and whose intercept is log(A)

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# Failure Criteria

- Mandrel bend with voltage breakdown
  - Ages the entire cable, copper conductor included
  - Closely related to actual cable end-use conditions
  - Has a service requirement inherent in the test

- Elongation Retention
  - Ages only stripped insulation
  - Consistent with air aging tests for most wire and cable products

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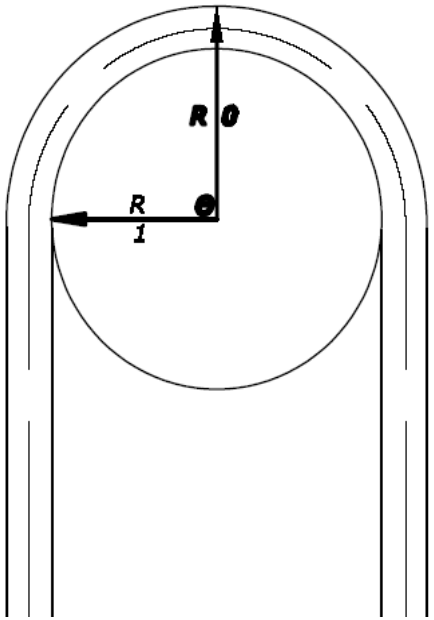
# Mandrel Bend

***Insulated Conductor: #12 AWG 0.030" Insulation O.D. – 0.155"***

***Mandrel: (8 x O.D. of insulated conductor) 1.25"***

***Assume $\Theta R_i$ (elongation) retains original length***




$$\Theta R_i = \frac{\Theta R_o - \Theta R_i}{\Theta R_i}$$

$$= \frac{R_o - R_i}{R_i}$$

$$= \frac{.155''}{(\frac{1.25''}{2})}$$

| Temperature | Time to Failure |
|---|---|
| 113°C | 15684 hours |
| 121°C | 4320 hours |
| 136°C | 1068 hours |
| 150°C | 394 hours |

***Elongation = 25%***

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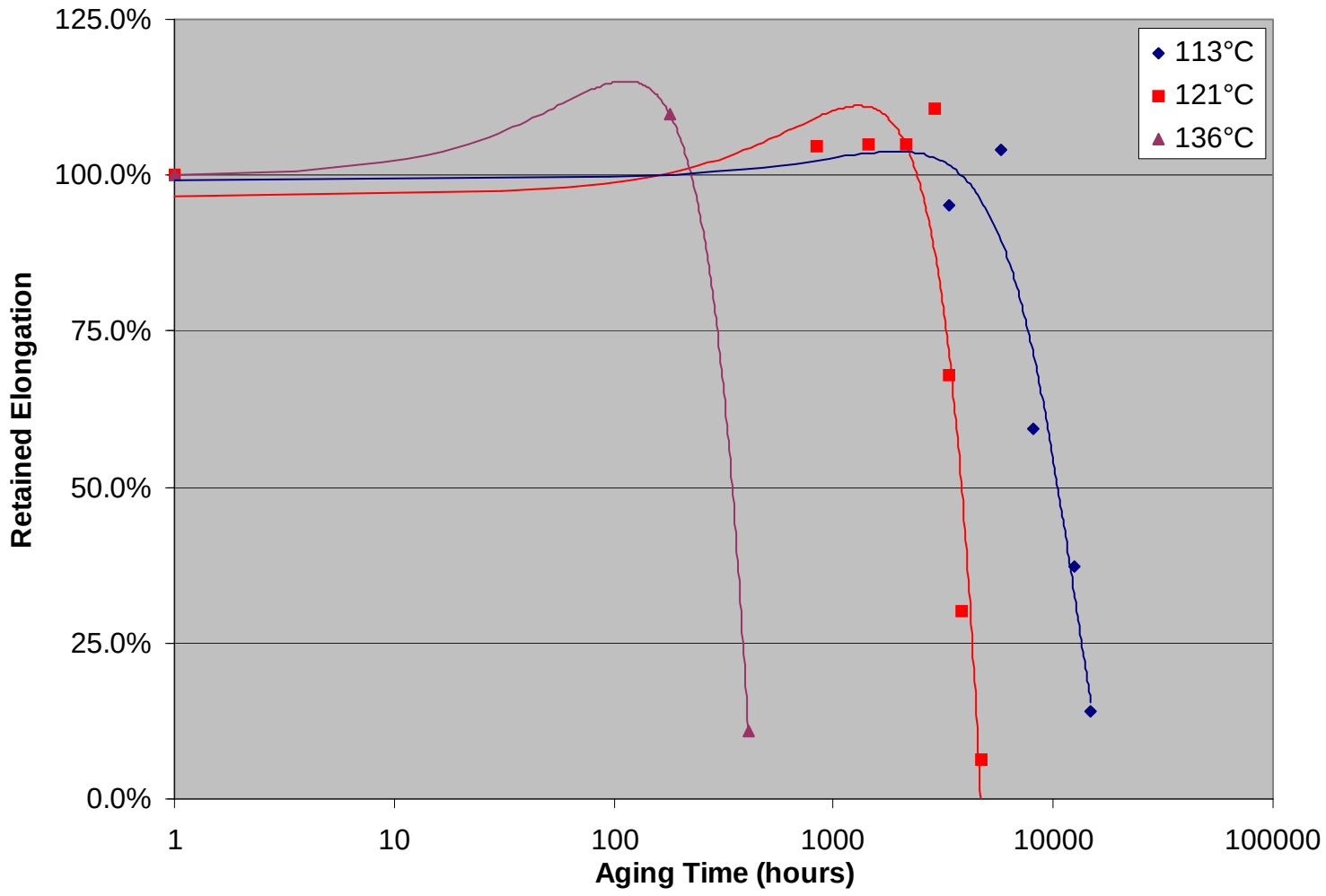
# Elongation Data – Ultrol®

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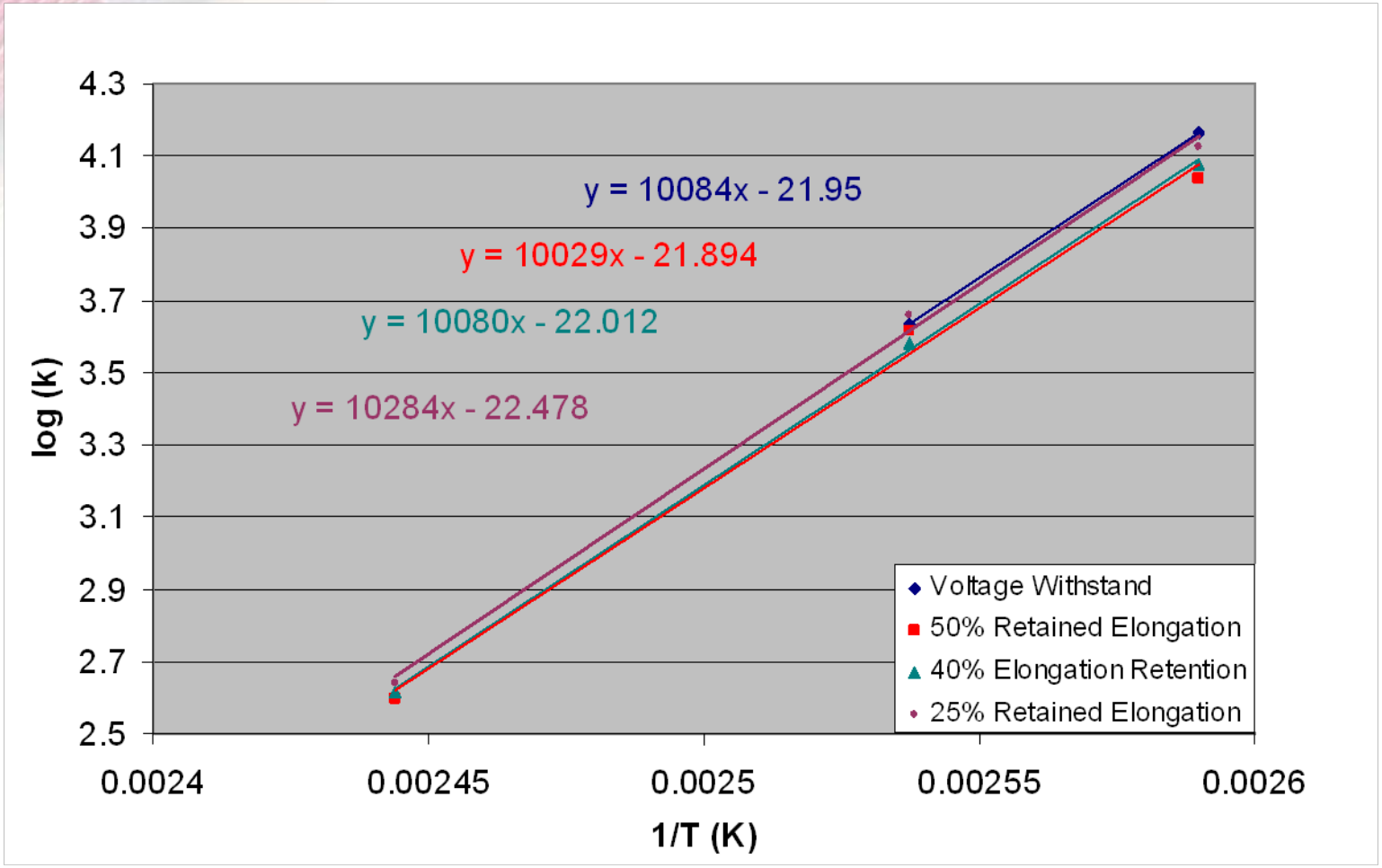
# Arrhenius Fit

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# Data Analysis

- **Arrhenius plot was fit using least squares regression**
  - **Results used to calculate operational lifetime at 90°C**

| Failure Criterion | Calculated Lifetime | $E_a$ |
|---|---|---|
| Mandrel Bend with Voltage Withstand | 72.9 years | 1.20 eV |
| Retained Elongation (25%) | 78.7 years | 1.23 eV |
| Retained Elongation (50%) | 60 years | 1.20 eV |

- ***All 3 failure criterion yield calculated lifetimes ≥ 60 years***

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# Work In Progress

- 60 year life validation
- Fiber qualification program
- Full Environmental Qualification to IEEE 323 and 383 (1974 and 2003)
  - DBE
  - Radiation exposure
- Submittal for qualification

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# Further Research Topics

- Submergence Testing
  - Long-term electrical tests
    - 3-52 week duration
    - Not post-LOCA test
    - 75°C and 90°C water temperatures
  - DBE inclusion
    - Post-LOCA
    - Duration per design

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# Oxidative Induction Temperature (OIT)

- Probe of chemical resistance to oxidative decomposition
- Run using a Differential Scanning Calorimeter (DSC)
- Run in pure oxygen at elevated temperatures
- Aging setup:
  - Run using various temperatures to provide pseudo-aging program
  - Run in different atmospheres (air, oxygen, nitrogen)

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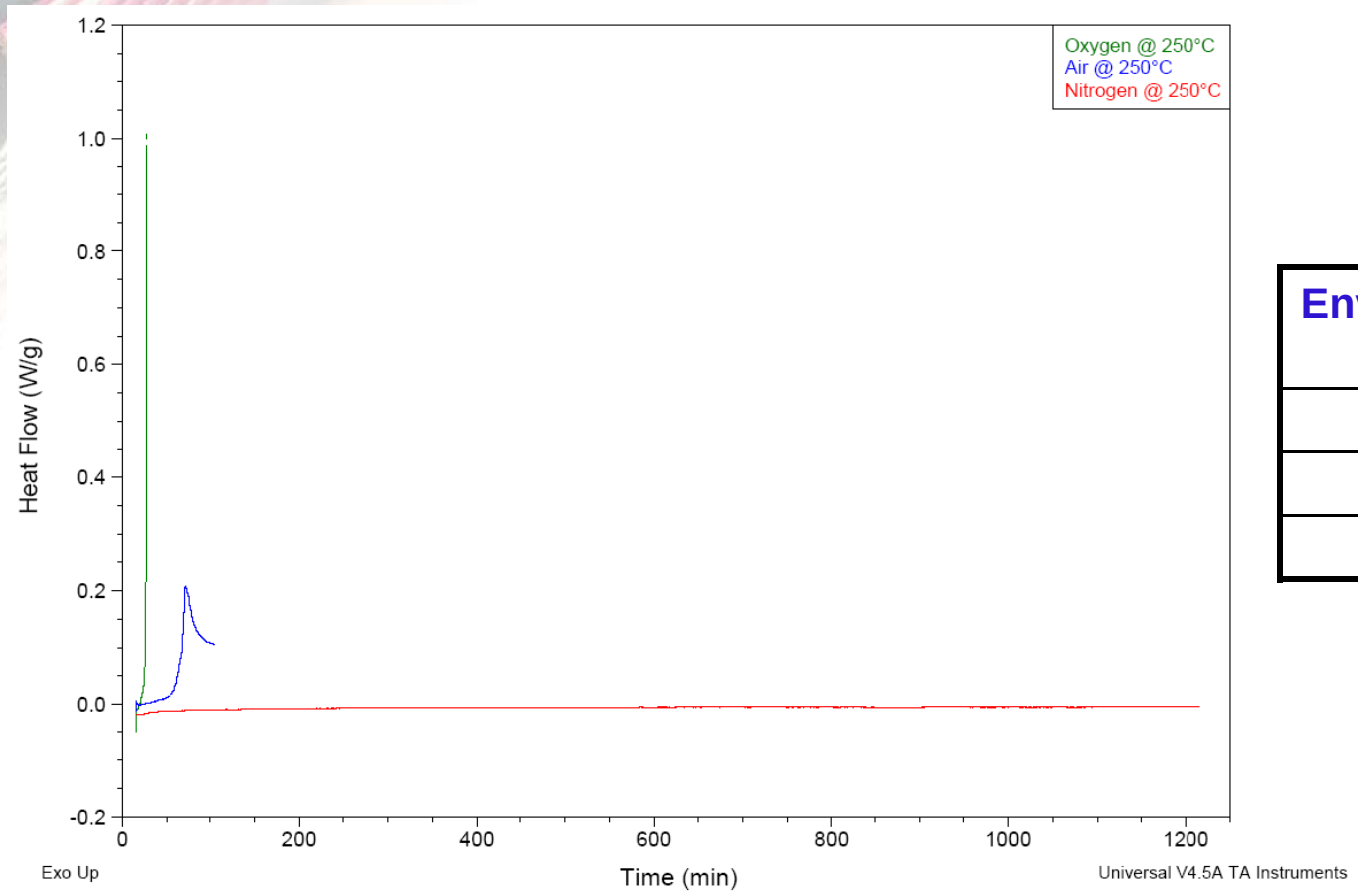
# Environmental Effects




| Environment | OIT (minutes) |
|---|---|
| Oxygen | 11.2 |
| Air | 51.4 |
| Nitrogen | --- |

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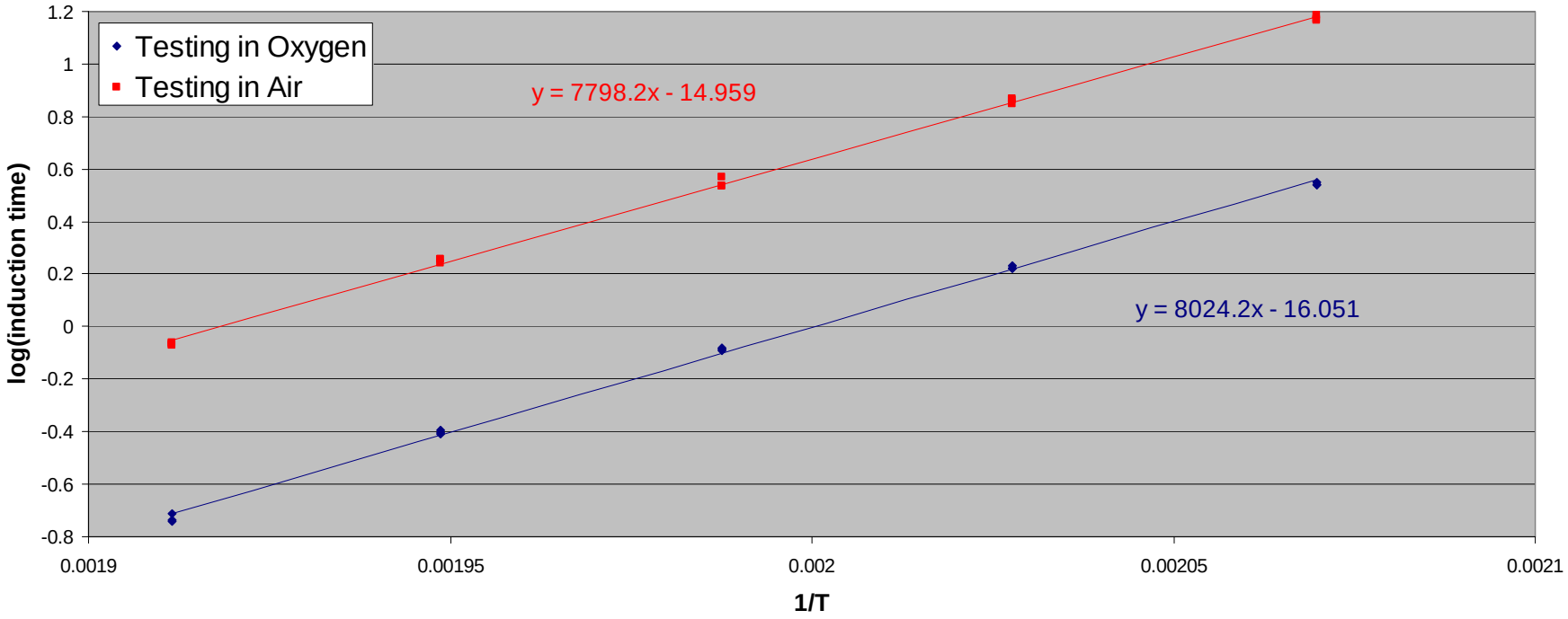
# LV XLPE Insulation




| Activation Energy ($E_a$) | eV |
|---|---|
| Oxygen | 0.96 |
| Air | 0.94 |

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# Conclusion

- EQ Qualification underway
  - Analysis of original aging complete
  - New aging study underway
  - Radiation resistance under investigation
  - LOCA submittal being prepared
- Further testing
  - Submergence testing
  - OIT – Environment and Condition Monitoring
- Comments?
- Questions?

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