Cable Materials and Design Issues for Nuclear Plants in the 21st Century

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Historical Perspective cont.

- As a result of Three Mile Island in 1979, IEEE reissued 323 to respond to the issues involved
- RSCC requalified XLPE and Silicone Rubber to new standards
- FR XLPE qualified for 40 years at 90°C with 200 Mrads Gamma exposure and 100 day standard LOCA profile
- SR qualified for 40 year life at 125°C .....

Historical Perspective

- Prior to 1974 customer specs dominated (PVC insulation and jackets were commonly used)
- 1974 IEEE 383 & 323 issued
- 40 year life prediction by Arrhenius aging
- Flame propagation testing initiated (tray burn)

Insulation Compound Technology 1970's to 2000

- RSCC-Proprietary FR XLPE (electron beam crosslinked) provides 40 year life at 90°C
- Flame retardency achieved by a combination of brominated additive and antimony oxide
- Insulation Resistance and SIC stability in 90°C water for at least 1 year

Cont.

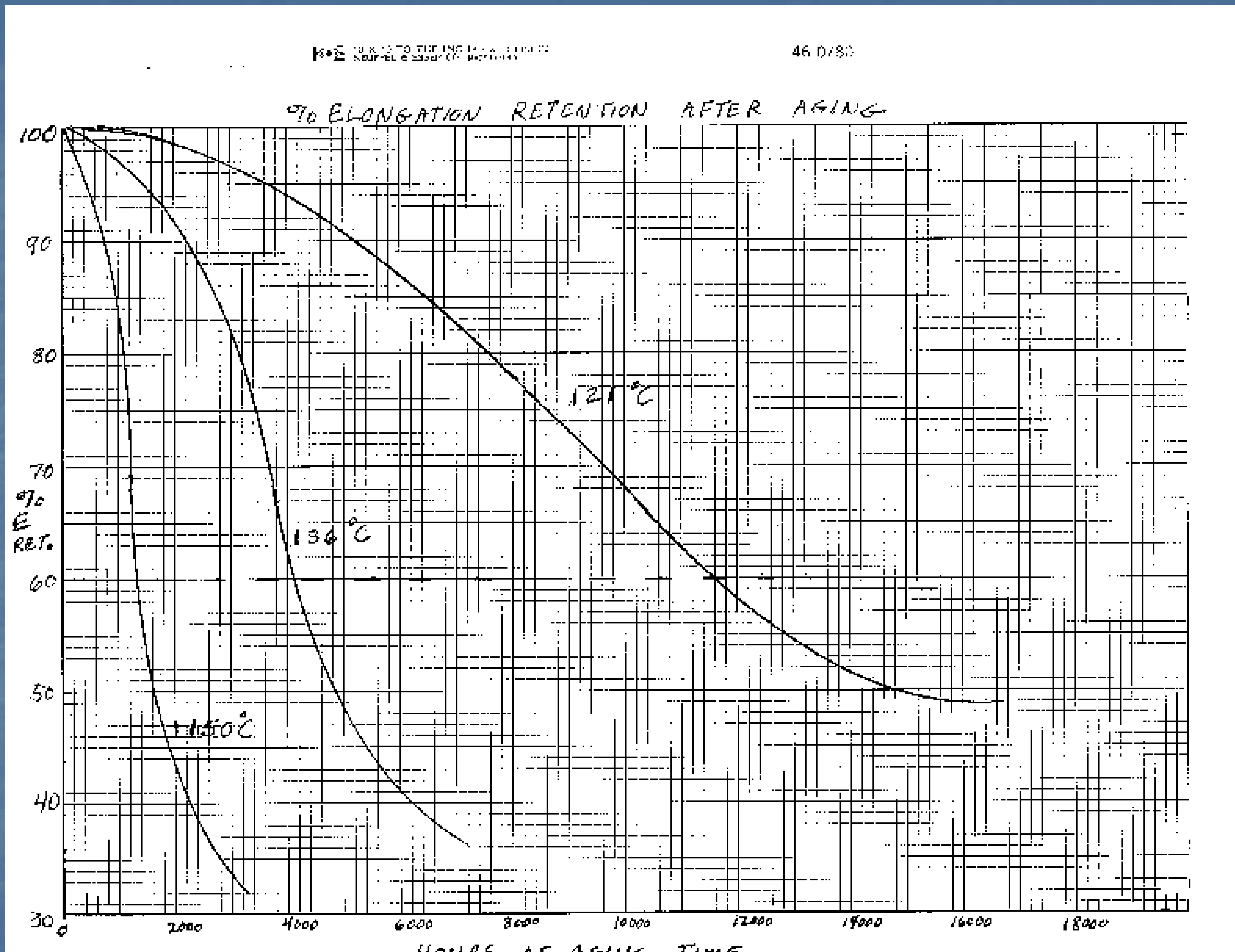
- RSCC-proprietary Silicone polymer (peroxide crosslinked) provides 40year life at 125°C
- Unique polymer required to survive pre LOCA exposure to 200 Mrad Gamma
- Most silicone rubber compouns available will not survive the aging and irradiation above

Cable requirements for new plants in 21st Century

- IEEE 323 and 383 published in 2004 with many changes
- LOCA profile and length of test not yet established
- Generally accepted that 60 year life at 90°C will be required for insulations
- Flame test requirement has become more severe. IEEE383 tray burn replaced by IEEE1202
- This uses an angled burner and allows significantly less burn length
- "Insulating" jackets on shielded cables will need to be qualified as well

Arrhenius Aging Rules

- At least three temperatures
- At least 10°C between aging temperatures
- Shortest time to end of life > 100 hours
- One point for end of life >5000 hours
- Selection of end point ????


% ELONGATION RETENTION AFTER AGING
100
90
80
70
60
50
40
30
% E RET.
121°C
136°C
150°C
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
HOURS OF AGING TIME

Arrhenius Aging

Arrhenius

Life (hours)= A exp(B/T)

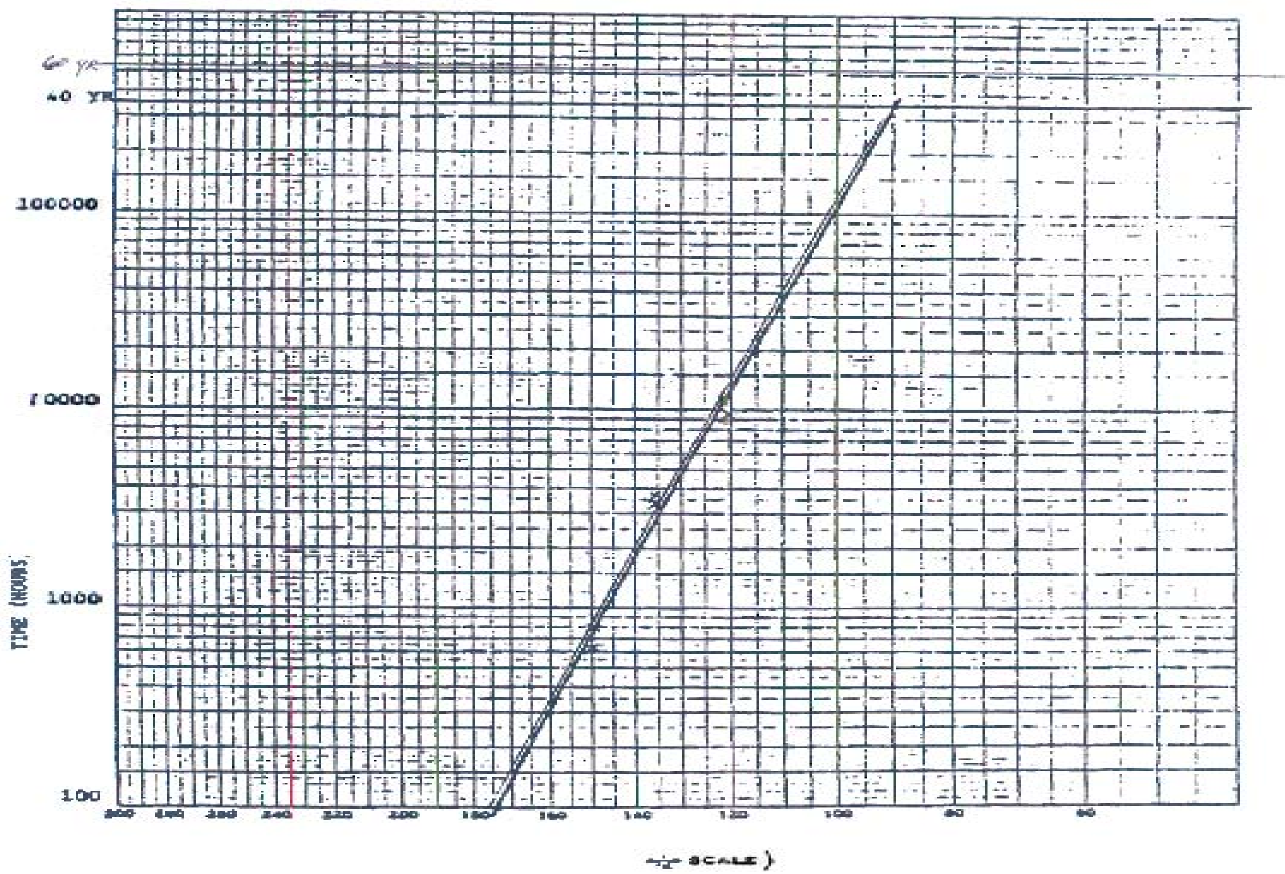
ln(hours)= ln A + B/T

A = intercept

B = slope

Arrhenius Aging

- The log of time to end point is plotted against the inverse of absolute temperature and the best fit straight line is extended to 40 years. This will serve as the basis for determining pre-LOCA aging of the wire.


60 yr
40 YR
100000
10000
1000
100
TIME (HOURS)
160
140
120
100
80
60
SCALE)

RSCC Arrhenius parameters

- RSCC uses 60 % retention of elongation as end point
- All Arrhenius aging samples are 0.030” wall insulation removed from 14 awg wire to provide a representative sample for life prediction
- To achieve 60 or 80 year life prediction at 90°C with standard insulating materials (XLPE or EPR) is challenging
- With scrupulous adherence to aging rules, unique formulations need to be developed.

Impact of Halogens on Equipment and People

- Early PVC use was viewed as a mistake after a fire in a nuclear plant caused significant damage to the facility (produces hydrochloric acid)
- Transition to brominated FR was effective due to lower halogen concentration as well as increased stability of the halogen source compared to chlorine in PVC
- Halogen/antimony oxide system functions as a gas phase flame retardent as well as good char producing system in a fire scenario.

Low Smoke Zero Halogen Technology

- Flame retardent based on LSZH depends on the addition of hydrated aluminum or magnesium to a polyolefin resin.
- These products release water of hydration when exposed to flame.
- This cools the substrate due to the evaporation and helps to extinguish the flame.
- The remaining charred substrate will no longer support a fire due to the non flammable char.

LSZH cont.

- For LSZH system to be affective, it need to be highly filled with this hydrated mineral (>60%)
- Physical and electrical performance are negatively affected by the high filler levels
- Current technology has minimized the negative attribute and current compounds are acceptable for use.
- These are primarily used as jackets but we now have an insulation system that will be evaluated for this application.

Thin wall/High temp. materials

- ECTFE (Halar) to be evaluated as thin wall LOCA rated at 150°C
- PEEK to be evaluated at >150°C thin wall needs to be carefully controlled during extrusion to insure stable crystalline structure. If amorphous, this material will be more flexible but will form micro cracks in use due to additional crystallization due to thermal cycling.