Study of Pulling Lubricant Interaction with LSZH Jacket Materials

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Hydro Plant LSZH Jacket Failure

- Generator lead cables at a hydro plant
- 2000 kcmil, 15 kV, EPR/LSZH cables (two per phase)
- Cables rise ~100 feet to cable spreading room
- Supported at top by wire grip (improperly sized and applied)
- Short sections of tray before exiting to switchyard
- Wood spacer blocks in tray (improperly sized)
- Conduit on both sides of tray results in pulling lubricant residue
- Failure observed in tray and at grip

Hydro Plant LSZH Jacket Failure

- Cable spacer block grabs cable jacket
- Tension introduced by close proximity cable hang

Hydro Plant LSZH Jacket Failure

- Jacket under stress from hanging grip
- Lubricant residue from pulls into duct banks on both sides

LSZH Jacket Failure Observations

- Jacket under stress where it tore
- No extraordinary environmental conditions
- Cable under electrical load – warm
- Not contained in conduit – so cables were dry – no lubricant "reflux"
- Tension on jacket estimated at 500 to 1000 psi
- IEEE 1210 testing of actual lubricant used on failed cables showed aged tensiles of 800 to 1000 psi and low elongations of 20 to 30%
- LSZH jackets have been pulled into conduit for many years without significant problems – physical stress on jacket produced this failure

IEEE 1210 – 2004

Table 1

Properties	Low Smoke Halogen Free		
	Thermoplastic Type 1	**Thermoset Type 1**	**Thermoset Type 2**
Immerse at (°C ± 1 °C)	**100**	**121**	**121**
Immerse for (hours)	**168**	**168**	**168**
Retained tensile strength, % minimum of unimmersed and unaged comparison	**75**	**75**	**85**
Retained elongation at rupture, % minimum of unimmersed and unaged comparison	**60**	**60**	**75**
Retained tensile strength and elongation at rupture, % minimum of immersed in water/air and heat-aged comparison	**85**	**85**	**85**
After immersion test at 50 °C ± 1 °C for 30 days Retained tensile and elongation at rupture, % minimum of immersed in water/air and heat-aged comparison	**85**	**85**	**85**

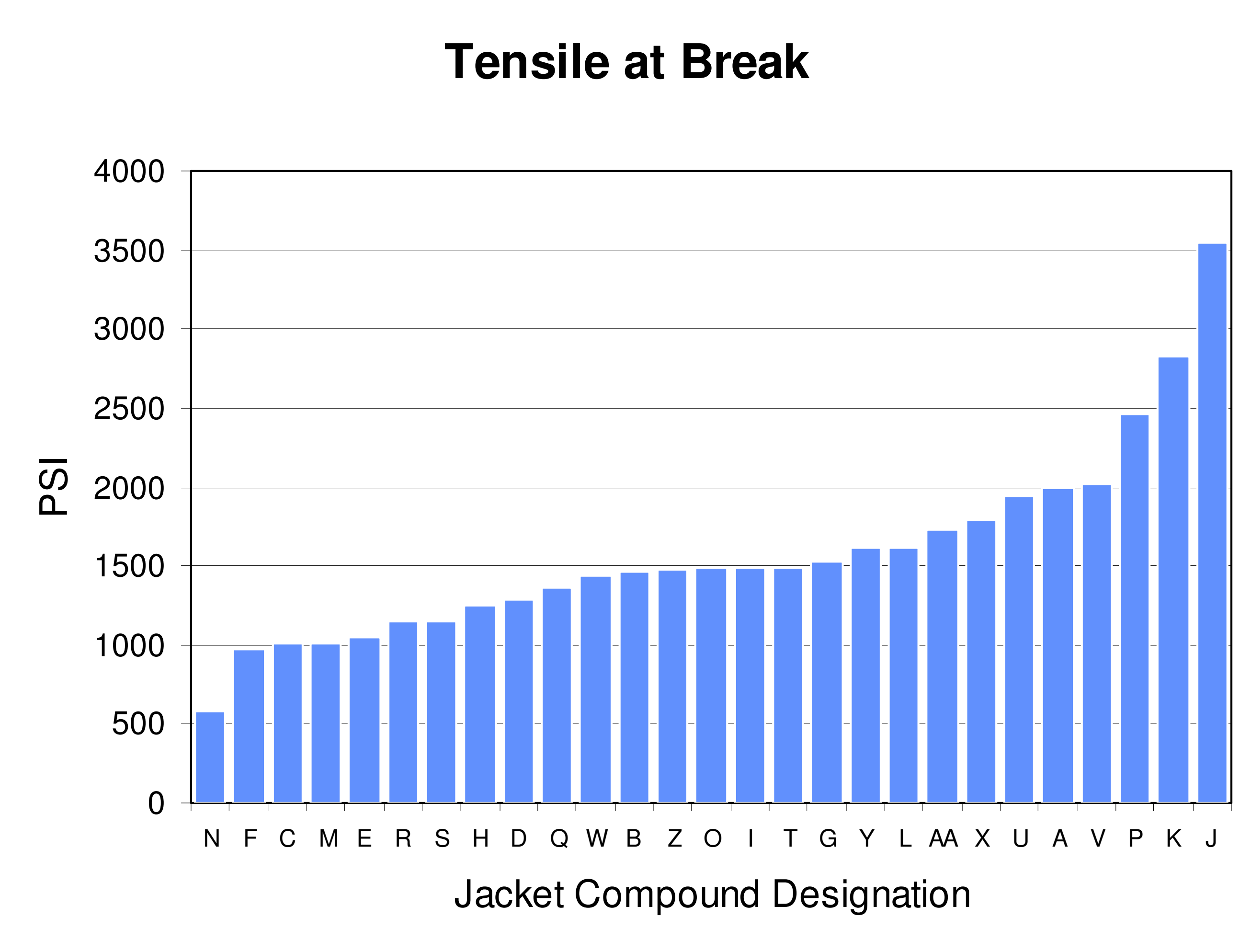
IEEE 1210 Tests

1. ICEA/NEMA jacket aging requirements
2. Test “refluxes” jacket in lubricant
3. Secondary lower-temperature, longer-aging test
4. Water vs air-aged control
5. Sample pulling speed – 50 mm/min vs 500 mm/min
6. 100° C vs 121° C
7. Reflux test of jacket in lubricant - more severe than conditions where actual failure occurred.
8. Physical strength focus seems right based on nature of field failure.

LSZH Jacket Study to IEEE 1210

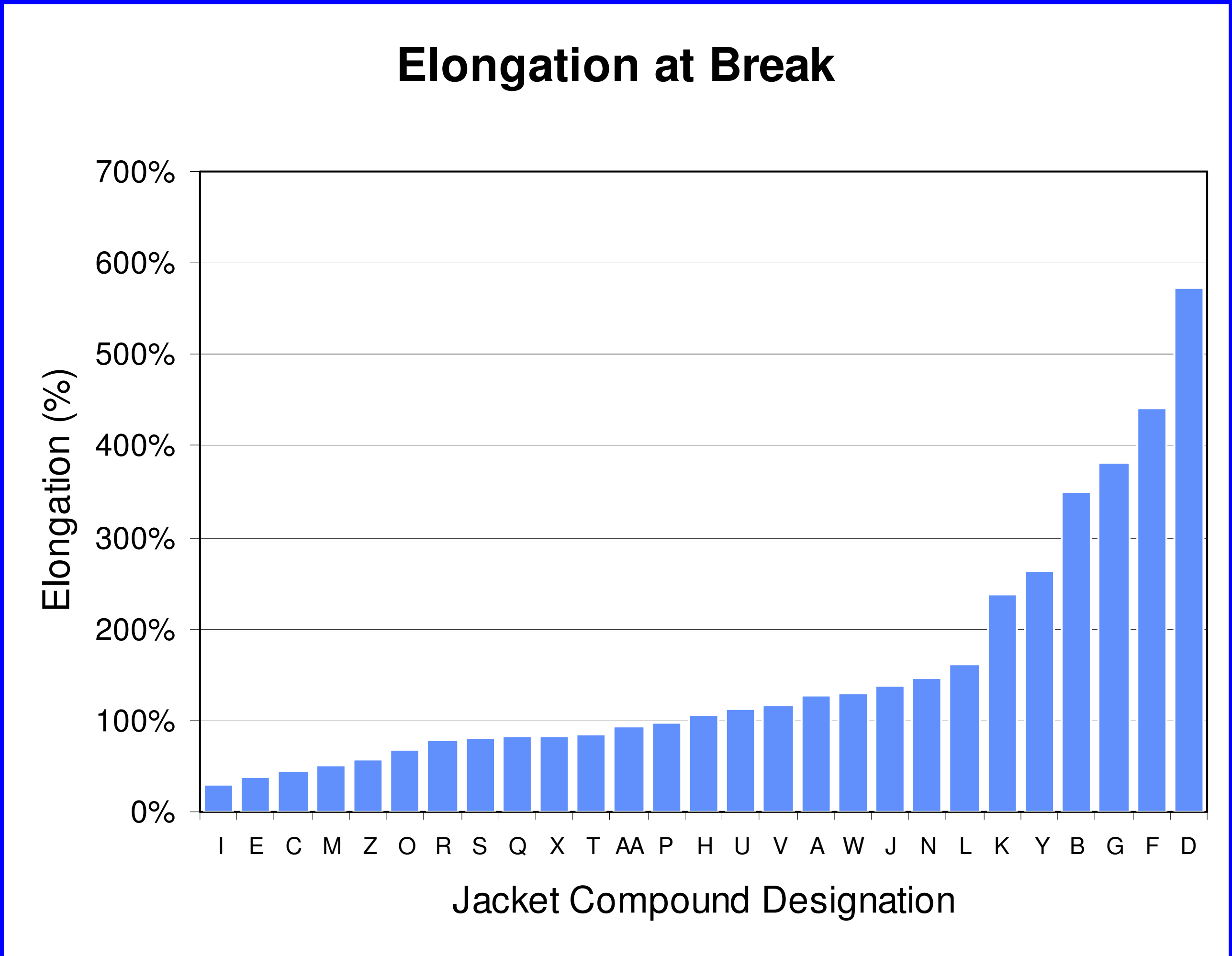
- 27 jackets designated A to AA
- 17 plaques, 7 tapes, 3 Jackets
- 20 thermoplastic, 7 thermoset
- Primarily inorganic hydrate loaded types
- All pulled at 50 mm/min
- Data presented are for a water-aged comparison sample
- Plaque sample variability based on preparation

Non-Aged Sample Tensiles



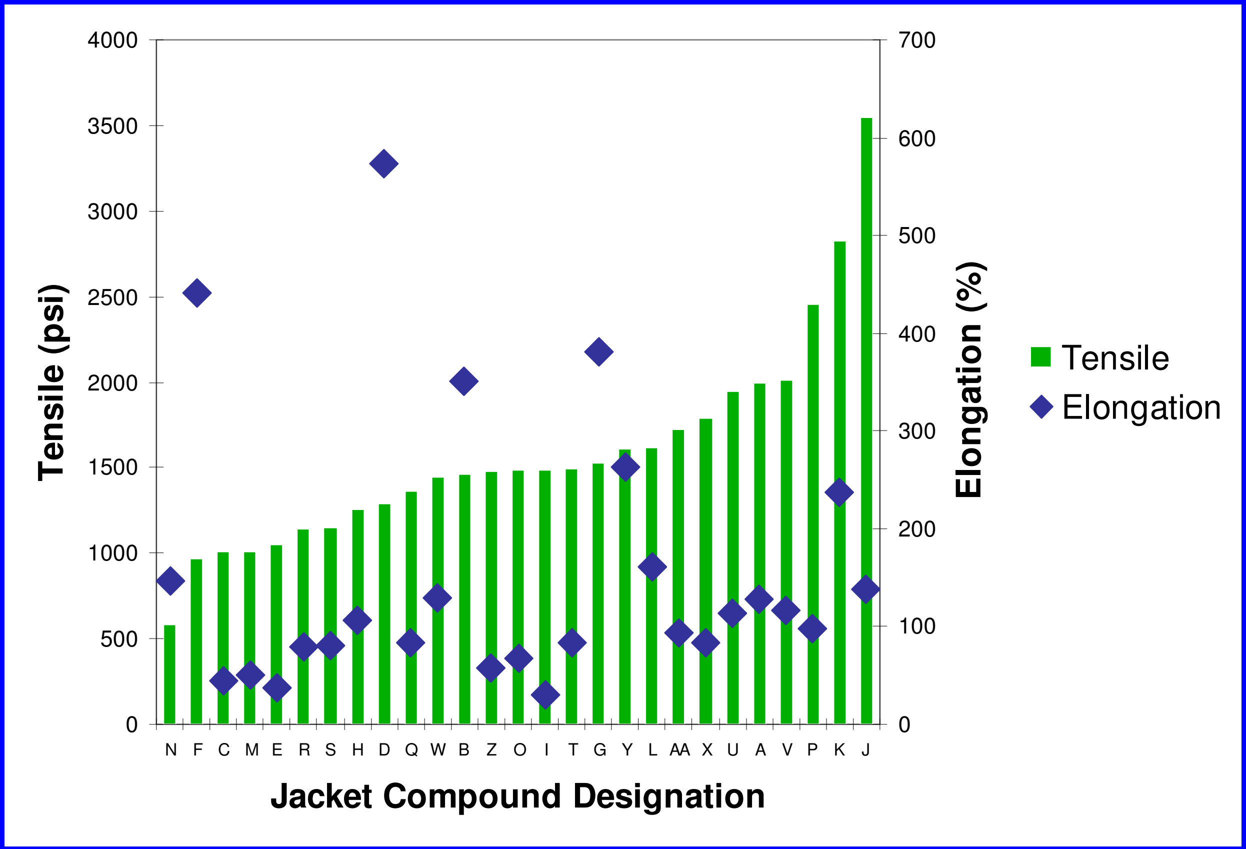
- Samples had non-aged tensile from 600 to 3500 psi (4 to 24 Mpa)
- Sample ave tensile of 1582 psi (10.9 Mpa)

Non-Aged Sample Elongations



- Samples had non-aged elongations from 30% to 575%
- Sample ave elongation of 155%

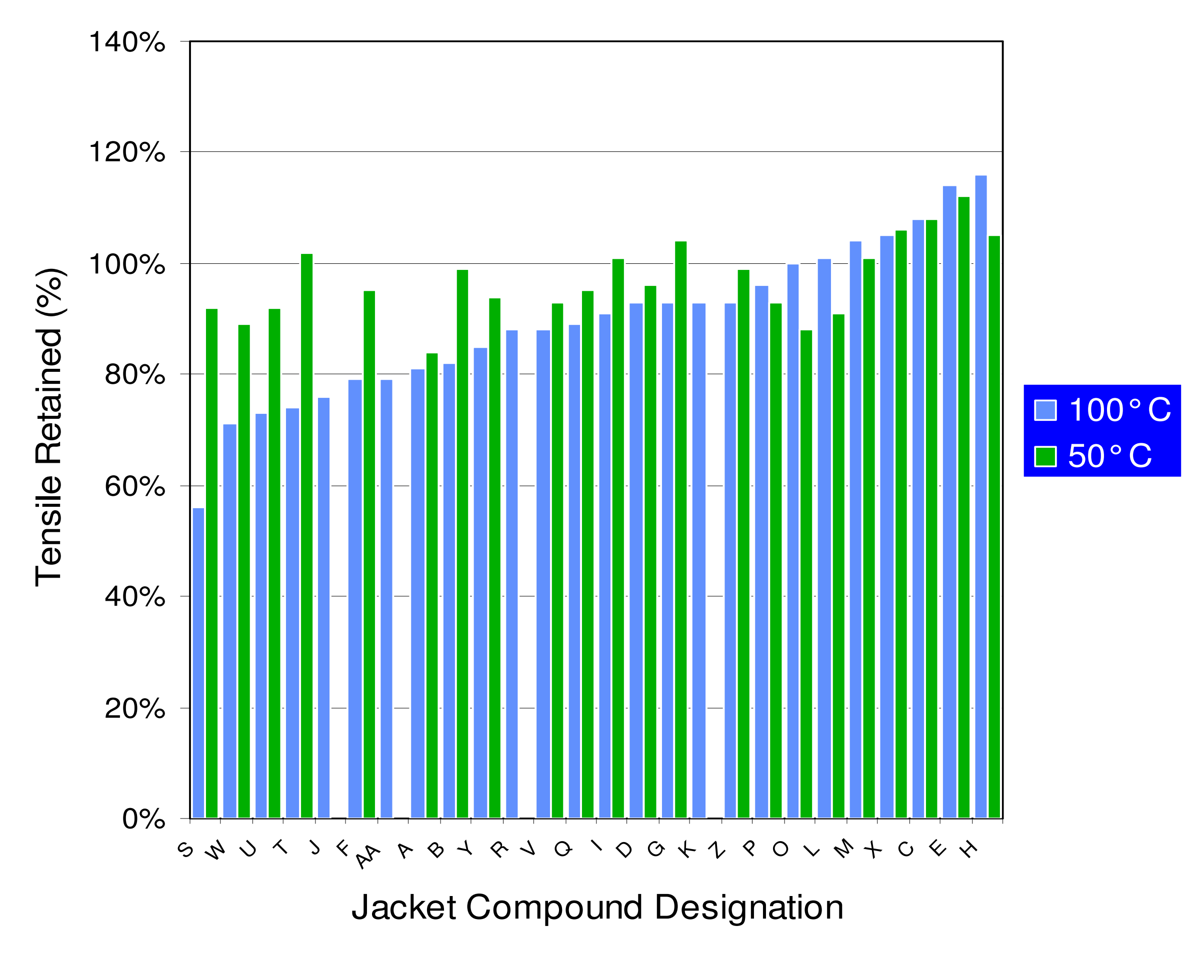
Sample Tensile / Elongation Comparison



- Elongation and tensile not correlated
- Elongation property shows greater variability

Sample Tensile Retention (vs Non-Aged)

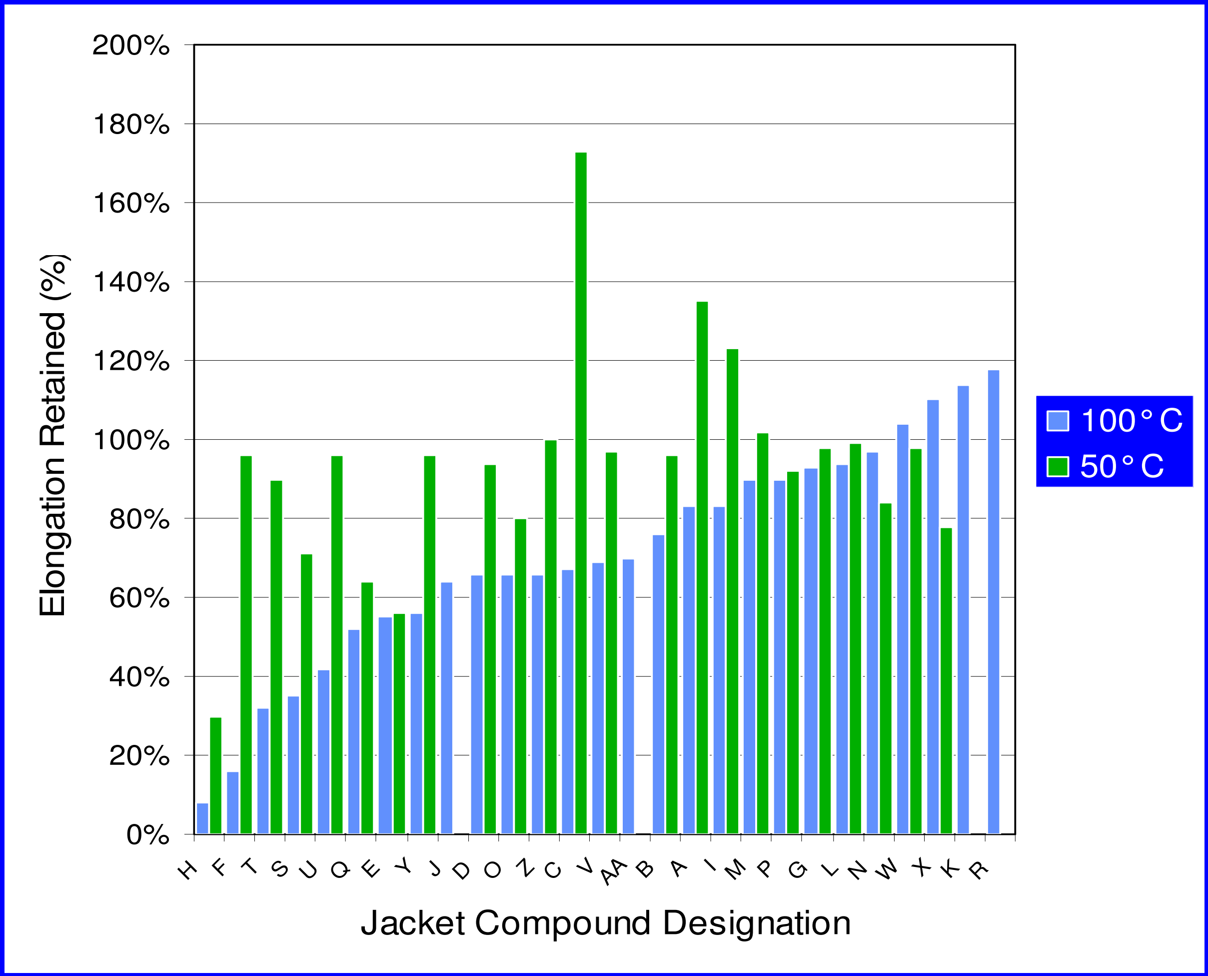
Water-Aged (7 day @ 100° C & 30 day @ 50° C)



- At 100° C - Ave tensile retention of 91% - range from 56% to 125%
- At 50° C - Ave tensile retention of 98% - range from 84% to 118%
- Less robust samples in 100° C water are less affected by 50° C

Sample Elongation Retention (vs Non-Aged)

Water-Aged (7 day @ 100° C & 30 day @ 50° C)



- At 100° C - Ave elongation retention of 71% - range from 8% to 118%
- At 50° C - Ave elongation retention of 93% - range from 30% to 173%
- Larger changes than tensile

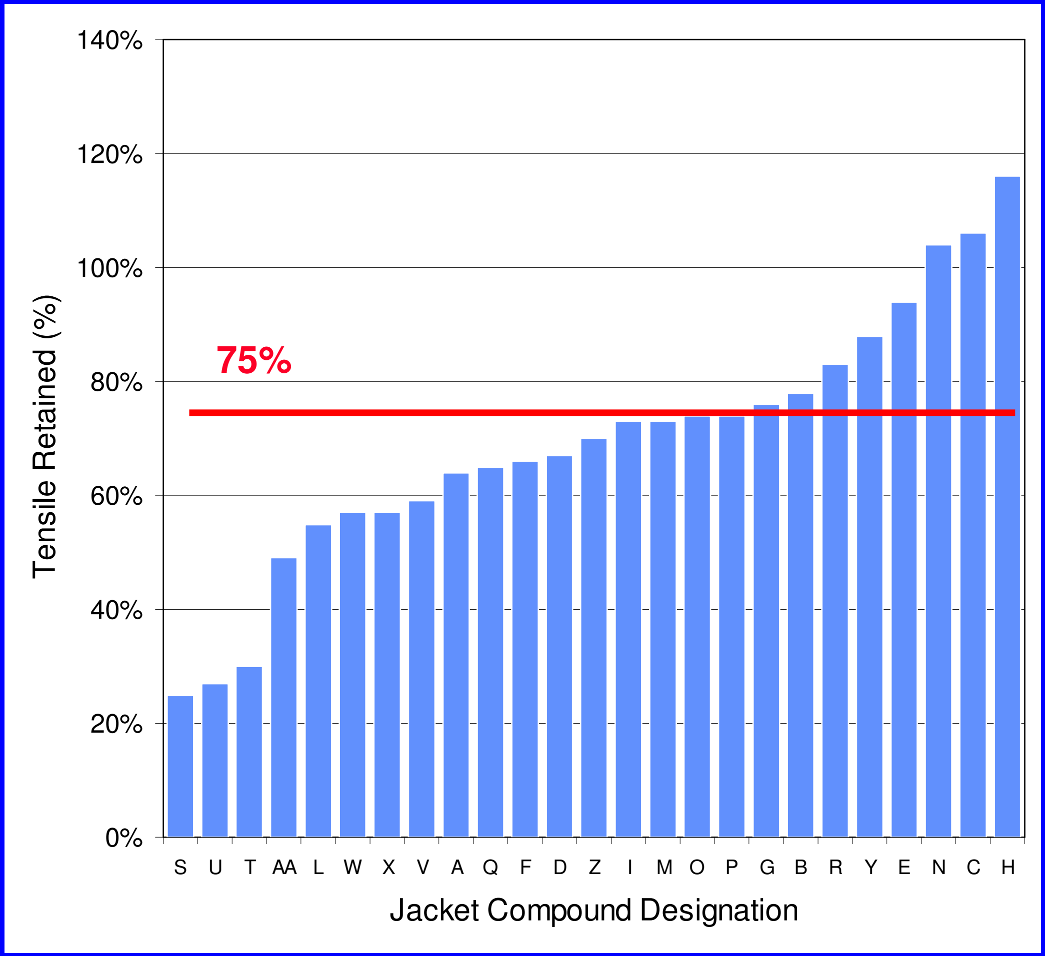
Observations – Control Samples

1. There is no typical "LSZH" jacket.
2. There are significant differences in base physical properties and temperature / water resistance of these materials.
3. Some samples notably more robust in 100° C water-aging. Differences not as great at 50° C.

Some lubricants severely affected jackets materials. Continued testing was only done on lubricants that maintained enough jacket integrity to support testing

Tensile Retention Comparison

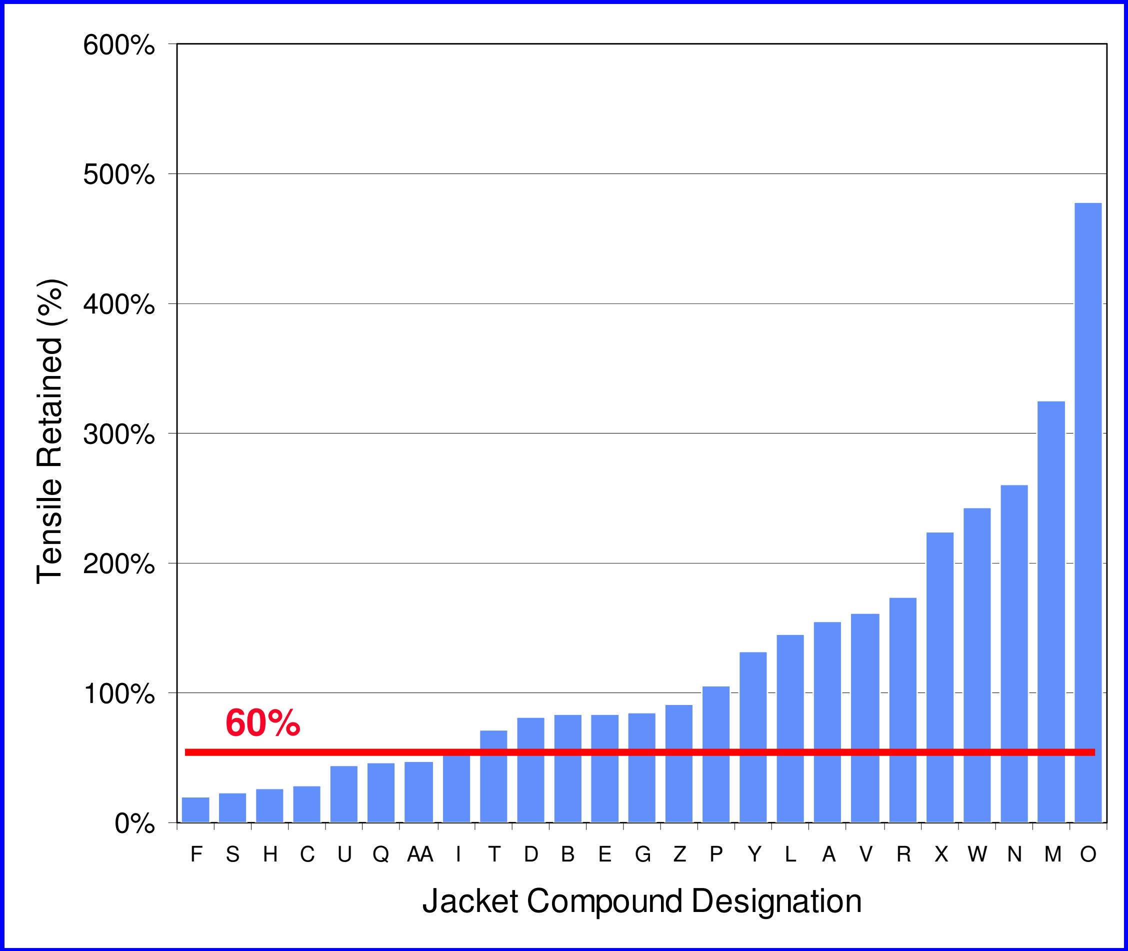
Lubricant A (7 day @ 100° C) vs Non-Aged



- Lubricant A (100° C) – 8 out of 25 specimens met 75% retention
- Lubricant A (100° C) - Ave tensile retention of 69% - range 25% to 116%

Elongation Retention Comparison

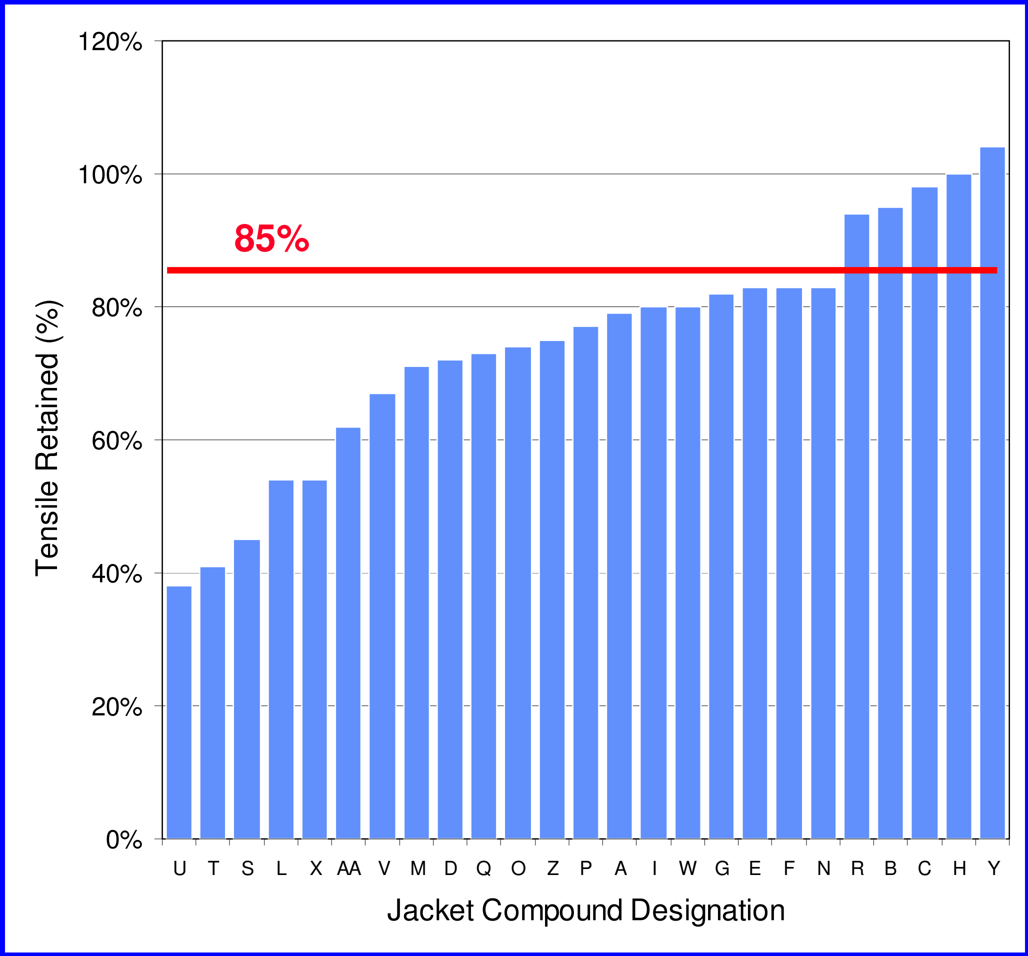
Lubricant A (7 day @ 100° C) to Non-Aged



- Lubricant A (100° C) - 17 out of 25 specimens met 60% retention
- Lubricant A (100° C) - Ave elongation retention of 128% - range 20% to 478%

Tensile Retention Comparison

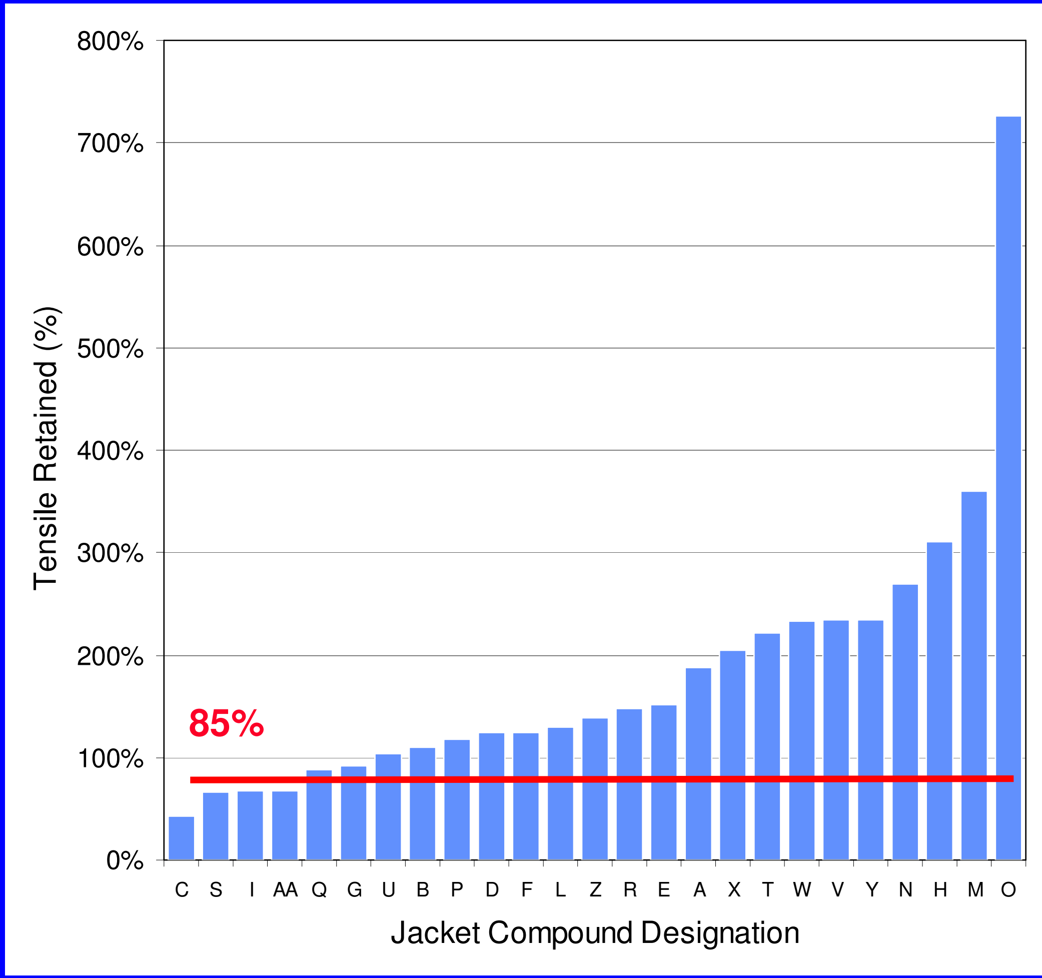
Lubricant A (7 day @ 100° C) to Water-Aged (7 day @ 100° C)



- Lubricant A (100° C) – 5 out of 25 specimens met 85% retention
- Lubricant A (100° C) - Ave tensile retention of 75% - range 38% to 104%

Elongation Retention Comparison

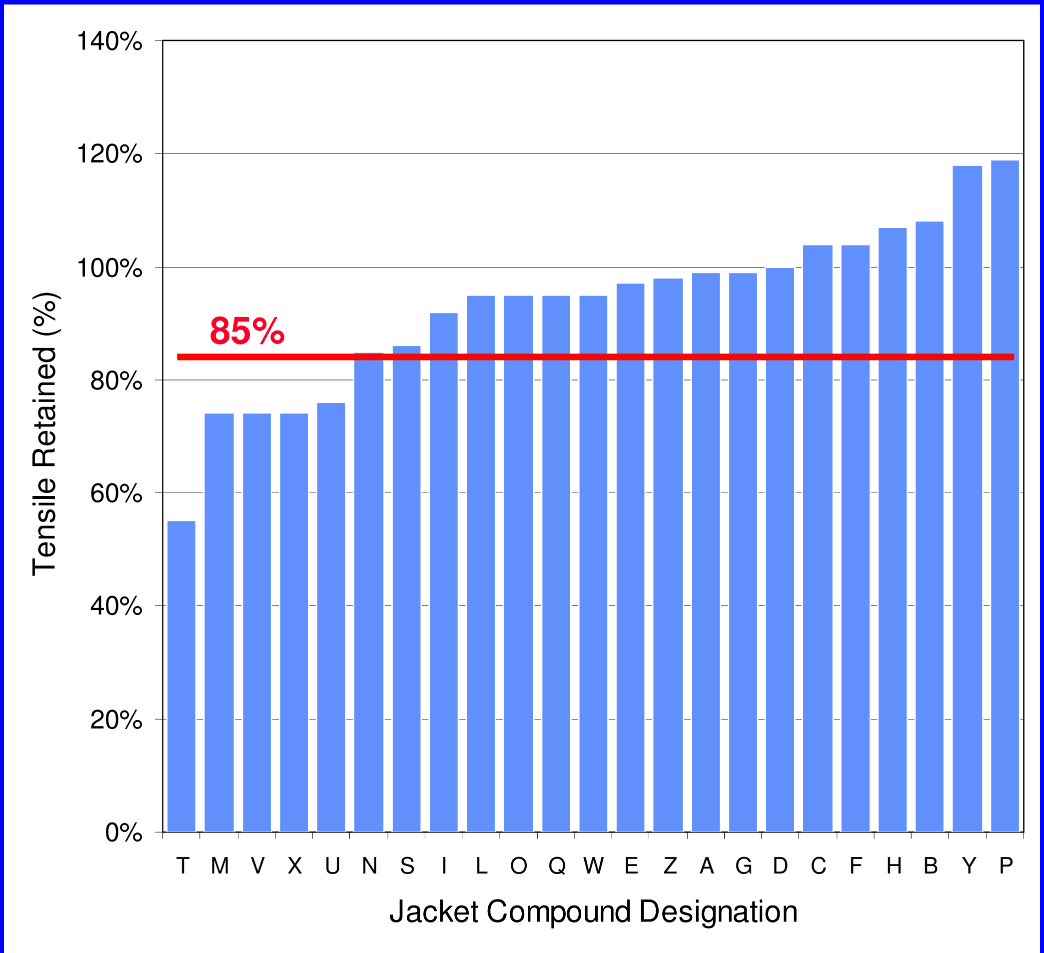
Lubricant A (7 day @ 100° C) to Water-Aged (7 day @ 100° C)



- Lubricant A (100° C) - 21 out of 25 specimens met 85% retention
- Lubricant A (100° C) - Ave elongation retention of 182% - range 43% to 726%

Tensile Retention Comparison

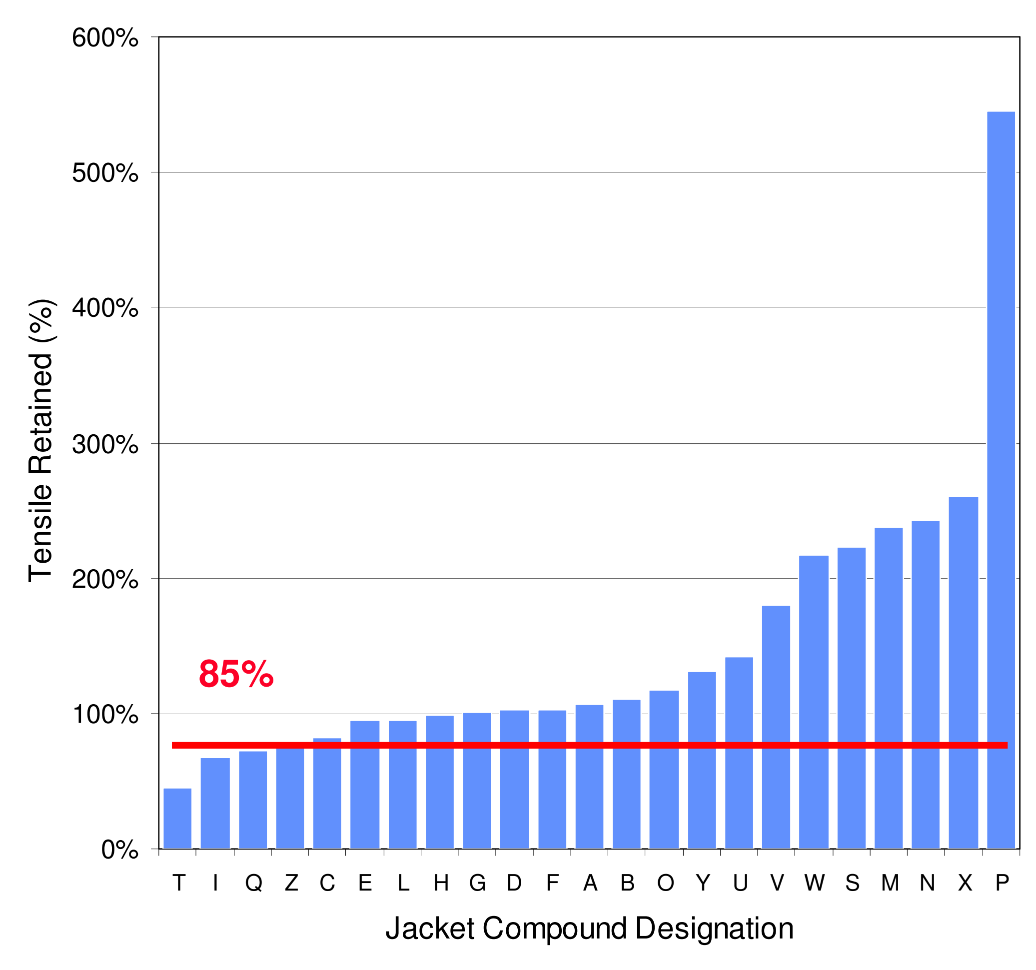
Lubricant A (30 day @ 50° C) to Water-Aged (30 day @ 50° C)



- Lubricant A (50° C) – 18 out of 23 specimens met 85% retention
- Lubricant A (50° C) - Ave tensile retention of 93% - range 38% to 104%

Elongation Retention Comparison

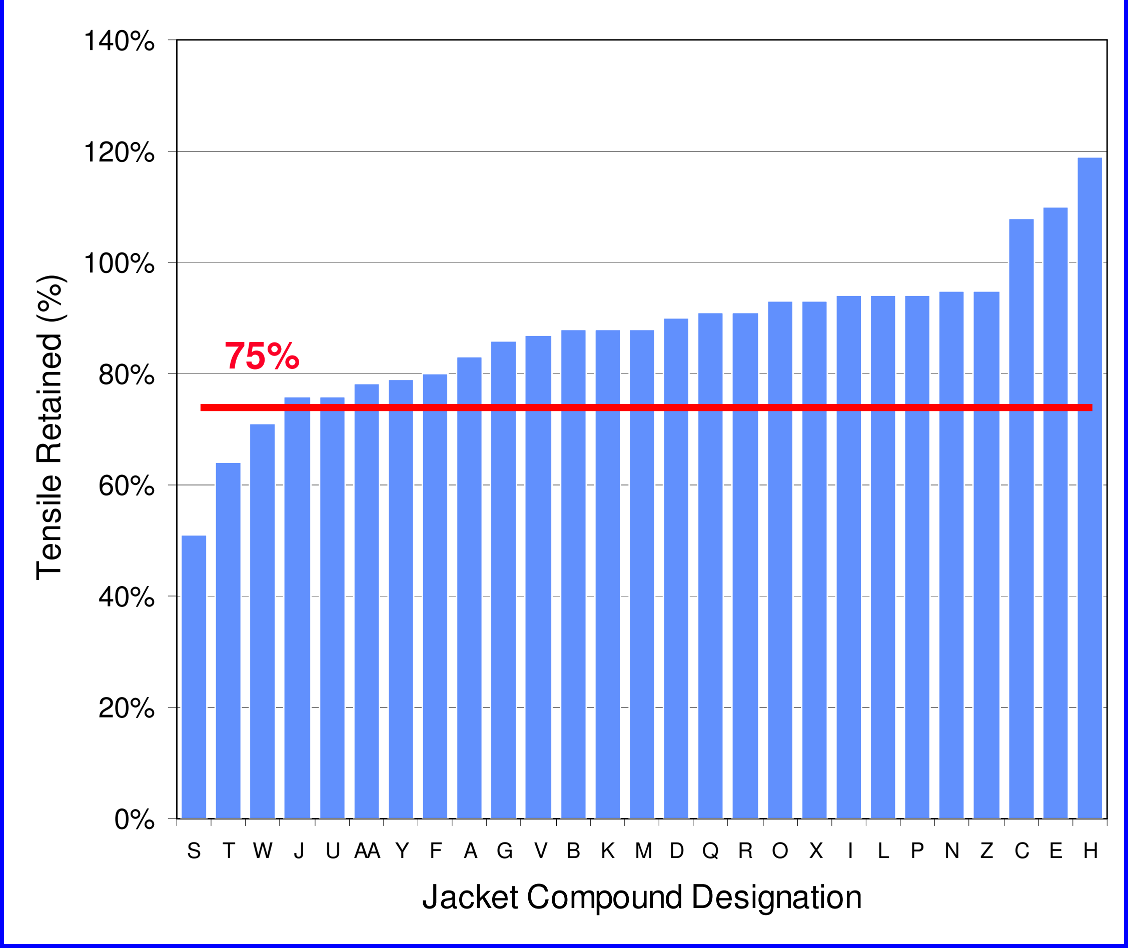
Lubricant A (30 day @ 50° C) to Water-Aged (30 day @ 50° C)



- Lubricant A (50° C) - 18 out of 23 specimens met 85% retention
- Lubricant A (50° C) - Ave elongation retention of 150% - range 45% to 545%

Tensile Retention Comparison

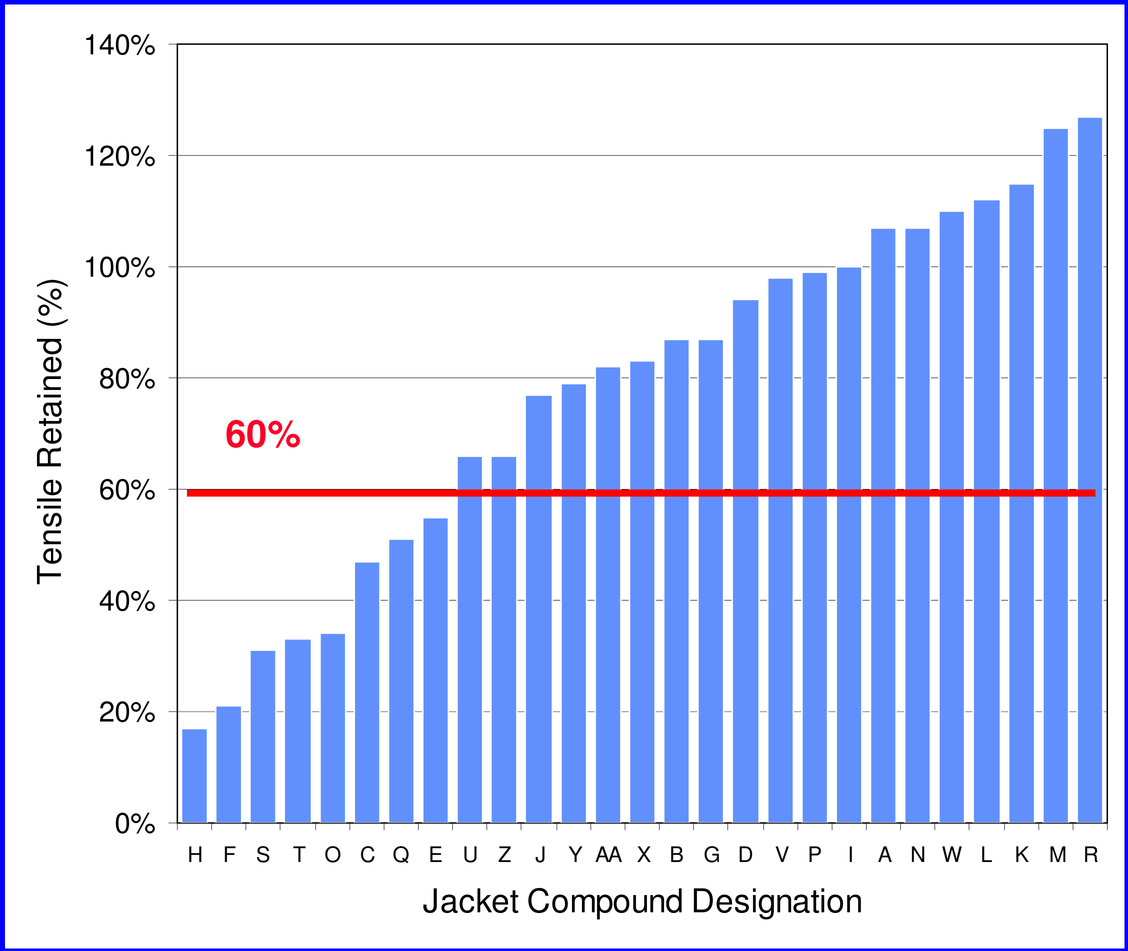
Lubricant B (7 day @ 100° C) to Non-Aged



- Lubricant B (100° C) – 24 out of 27 specimens met 75% retention
- Lubricant B (100° C) - Ave tensile retention of 87% - range 51% to 119%

Elongation Retention Comparison

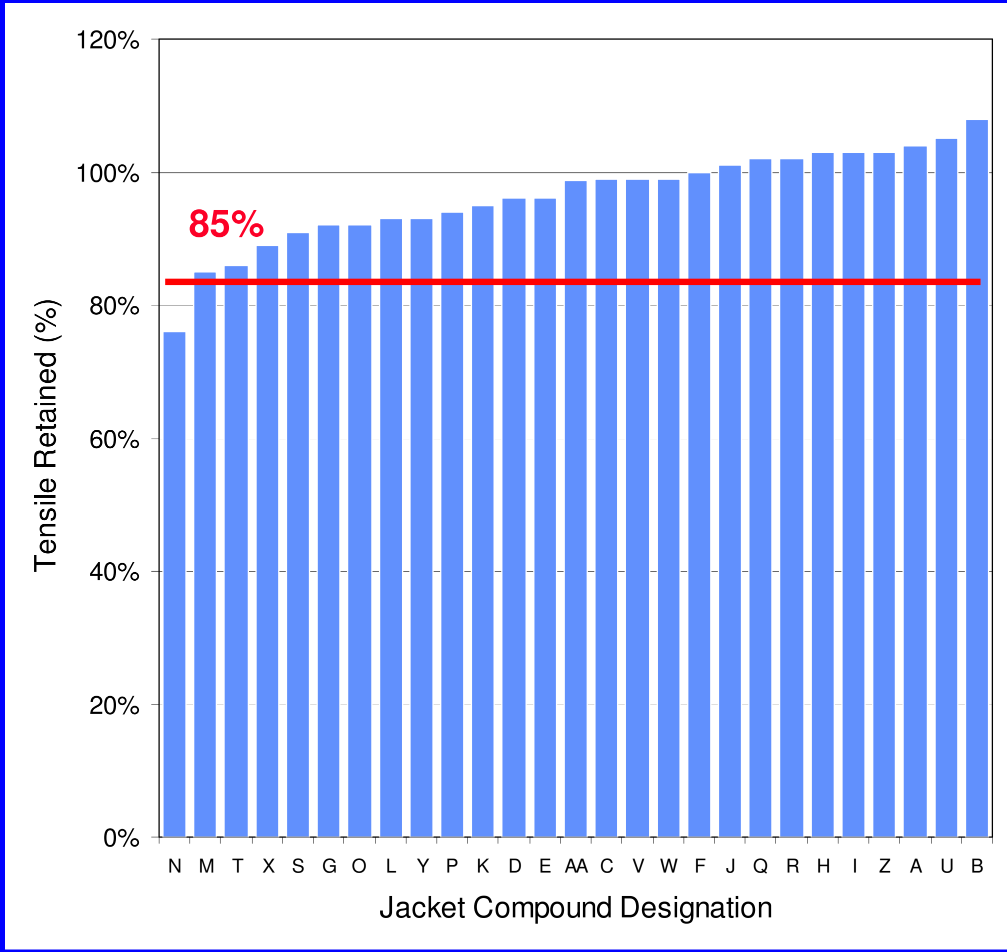
Lubricant B (7 day @ 100° C) to Non-Aged



- Lubricant B (100° C) - 19 out of 27 specimens met 60% retention
- Lubricant B (100° C) - Ave elongation retention of 78% - range 17% to 127%

Tensile Retention Comparison

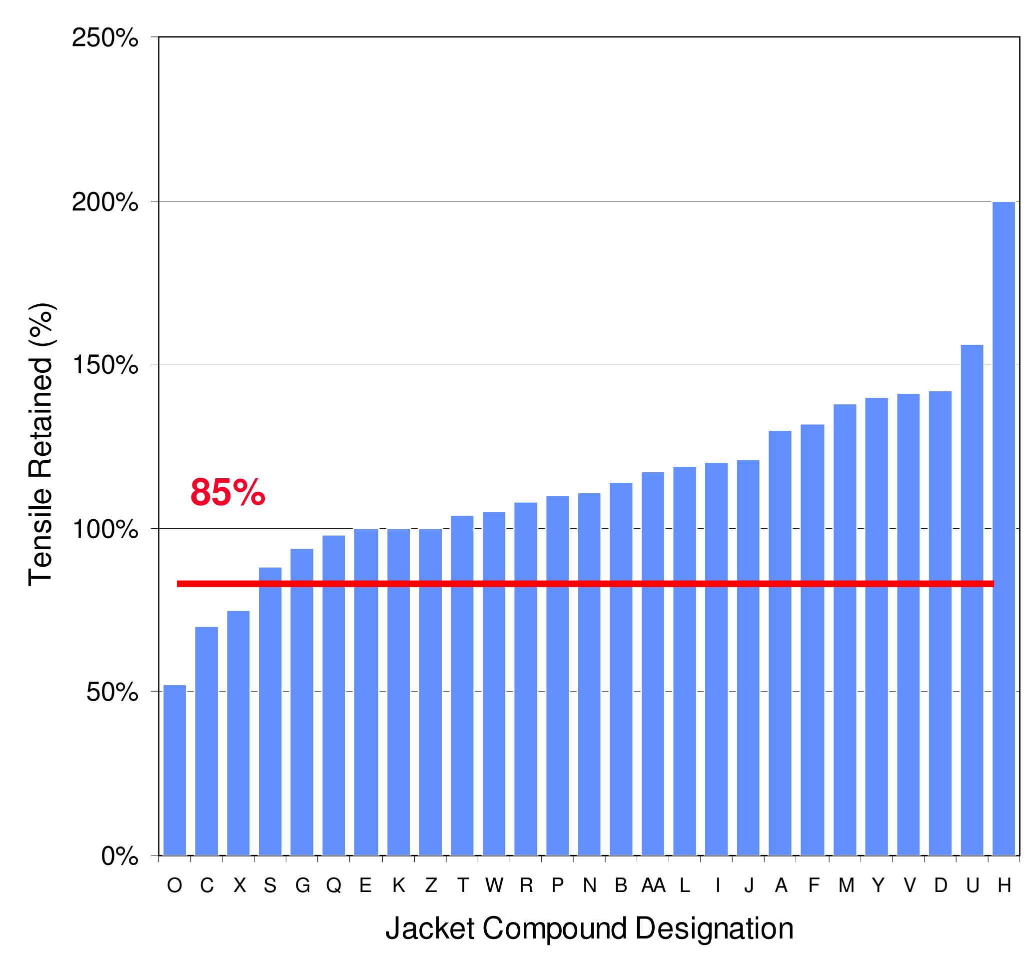
Lubricant B (7 day @ 100° C) to Water-Aged (7 day @ 100° C)



- Lubricant B (100° C) – 26 out of 27 specimens met 85% retention
- Lubricant B (100° C) - Ave tensile retention of 96% - range 76% to 108%

Elongation Retention Comparison

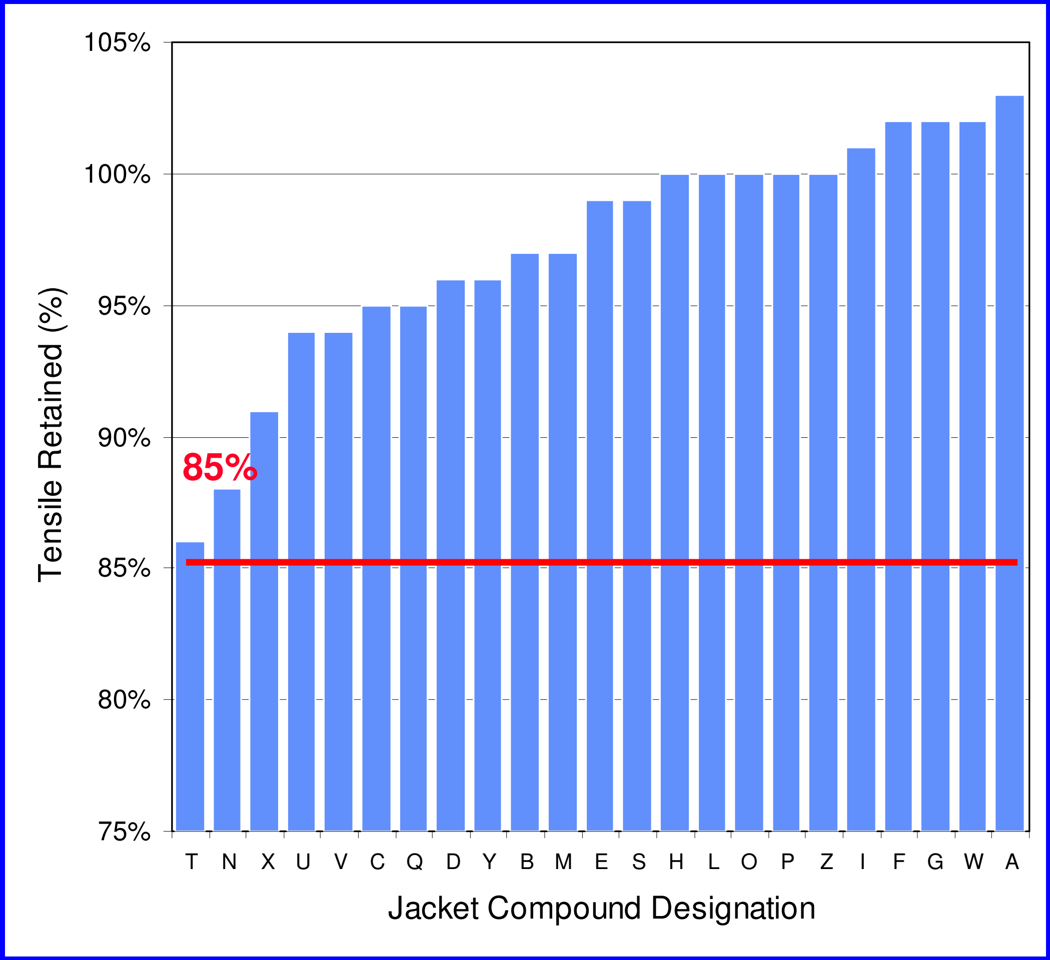
Lubricant B (7 day @ 100° C) to Water-Aged (7 day @ 100° C)



- Lubricant B (100° C) - 24 out of 27 specimens met 85% retention
- Lubricant B (100° C) - Ave elongation retention of 114% - range 52% to 200%

Tensile Retention Comparison

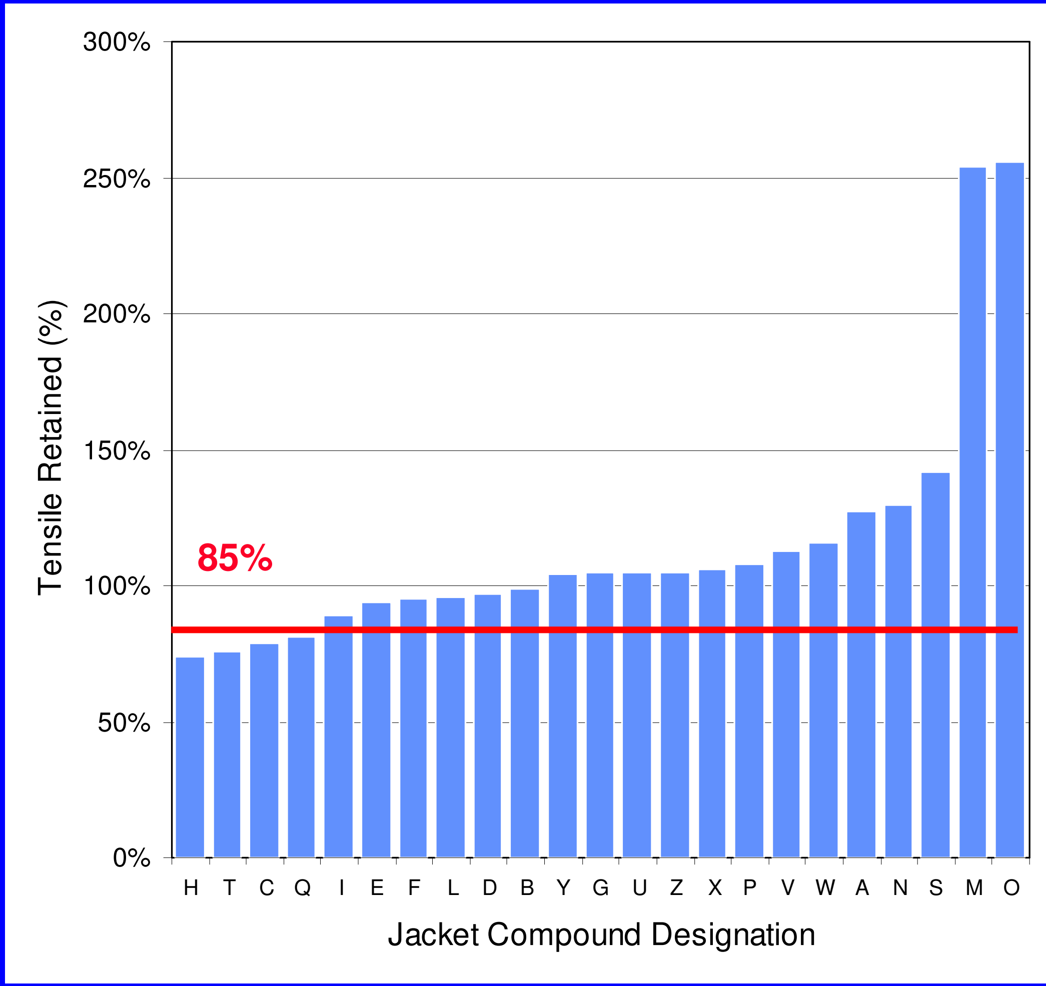
Lubricant B (30 day @ 50° C) to Water-Aged (30 day @ 50° C)



- Lubricant B (50° C) – 23 out of 23 specimens met 85% retention
- Lubricant A (50° C) - Ave tensile retention of 97% - range 86% to 103%

Elongation Retention Comparison

Lubricant B (30 day @ 50° C) to Water-Aged (30 day @ 50° C)



- Lubricant B (50° C) - 19 out of 23 specimens met 85% retention
- Lubricant A (50° C) - Ave elongation retention of 115% - range 74% to 256%

Observations – Lubricant Aging Tests

1. Water-based pulling lubricants can affect the physical properties of the hydrate loaded jackets.
2. Not all lubricants are the same, with some lubricant formulations apparently more suitable than others.
3. Lubricant B had less effect on these jackets than lubricant A. But lubricant B did not test compatible on the jackets most affected by water.
4. When a jacket is significantly affected by heat and/or water, water-based lubricants will not test well on it, especially at the at 100° C aging tests.
5. 50° C aging, even at the longer exposure, affects physical properties less than the 100° C aging.
6. Elongation aging changes were, on the average, greater than tensile changes.

Summary

1. Today's LSZH jackets can be affected by commercially available pulling lubricants.
2. The only known field jacket failure was associated with significant physical stress on the jacket.
3. Universal lubricant compatibility with all tested LSZH jackets has not been shown, although compatibility has been shown with the more robust jackets.
4. Specific testing (jacket and lubricant) should be done to insure compatibility.
5. Studies are continuing to define the lubricant ingredients most suitable for use on LSZH materials.