Thermal Aging of TPUs for Cable Applications

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Outline

- TPU basics
- Motivation for current work
- Long term Aging of TPUs
- Summary

The Lubrizol Corporation

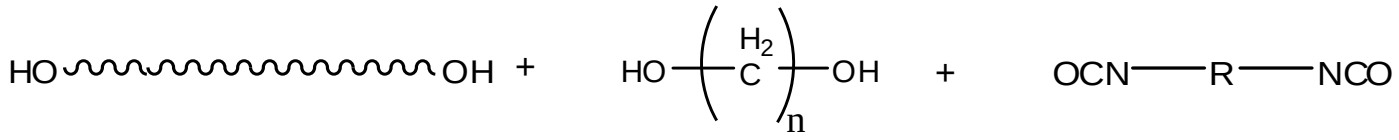
- Specialty chemical company
- ~1600 active patents
- 7000 employees
- Operations in 27 countries
- Wholly owned Subsidiary of Berkshire Hathaway Inc

Lubrizol acquired Estane® Engineered Polymers business in 2004 as part of Noveon acquisition

What is TPU?

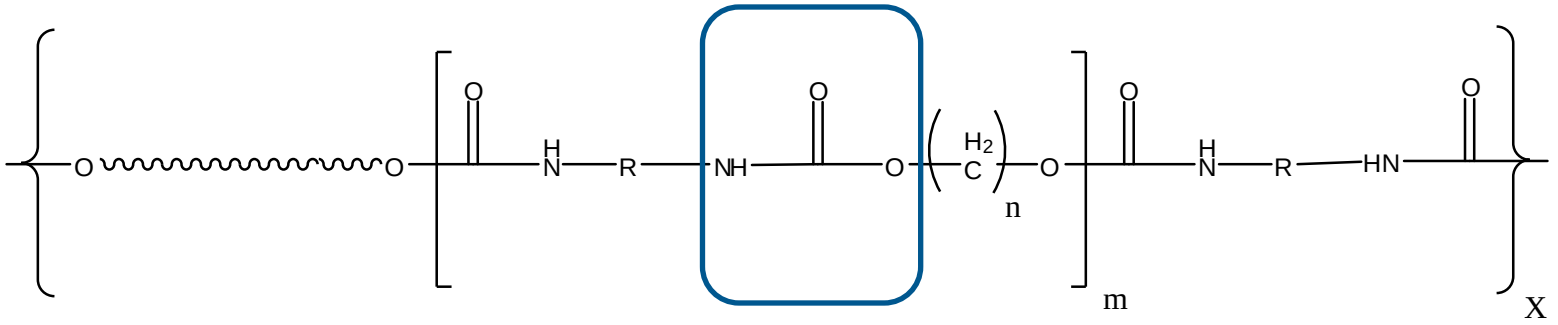
- Linear polymer with alternating hard and soft segments (like a block copolymer)
- Thermoplastic- no permanent crosslinking; can be re-melted

TPU Chemistry



Polyol **Chain extender** **Diisocyanate**

(catalyst)

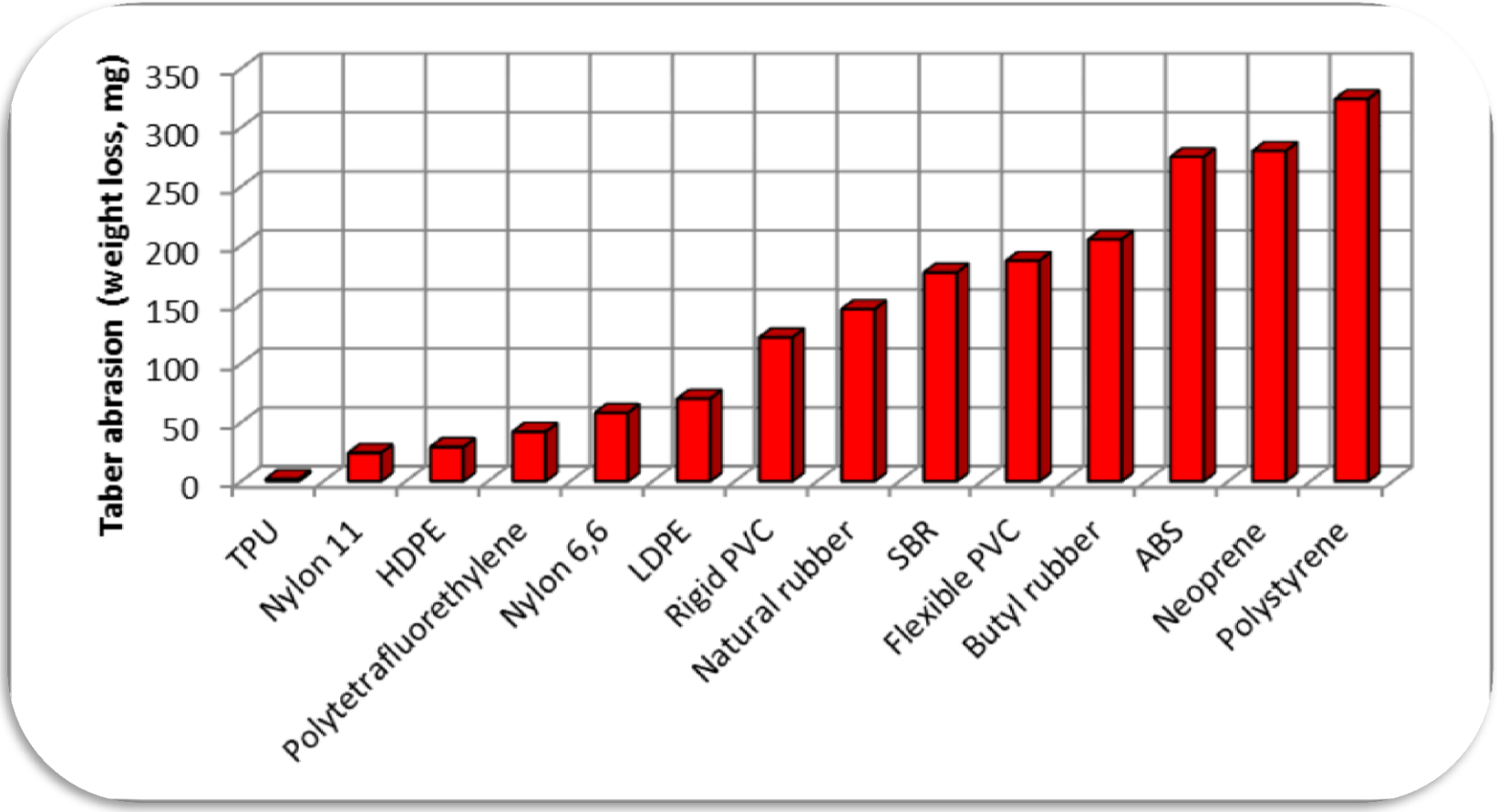


Urethane block

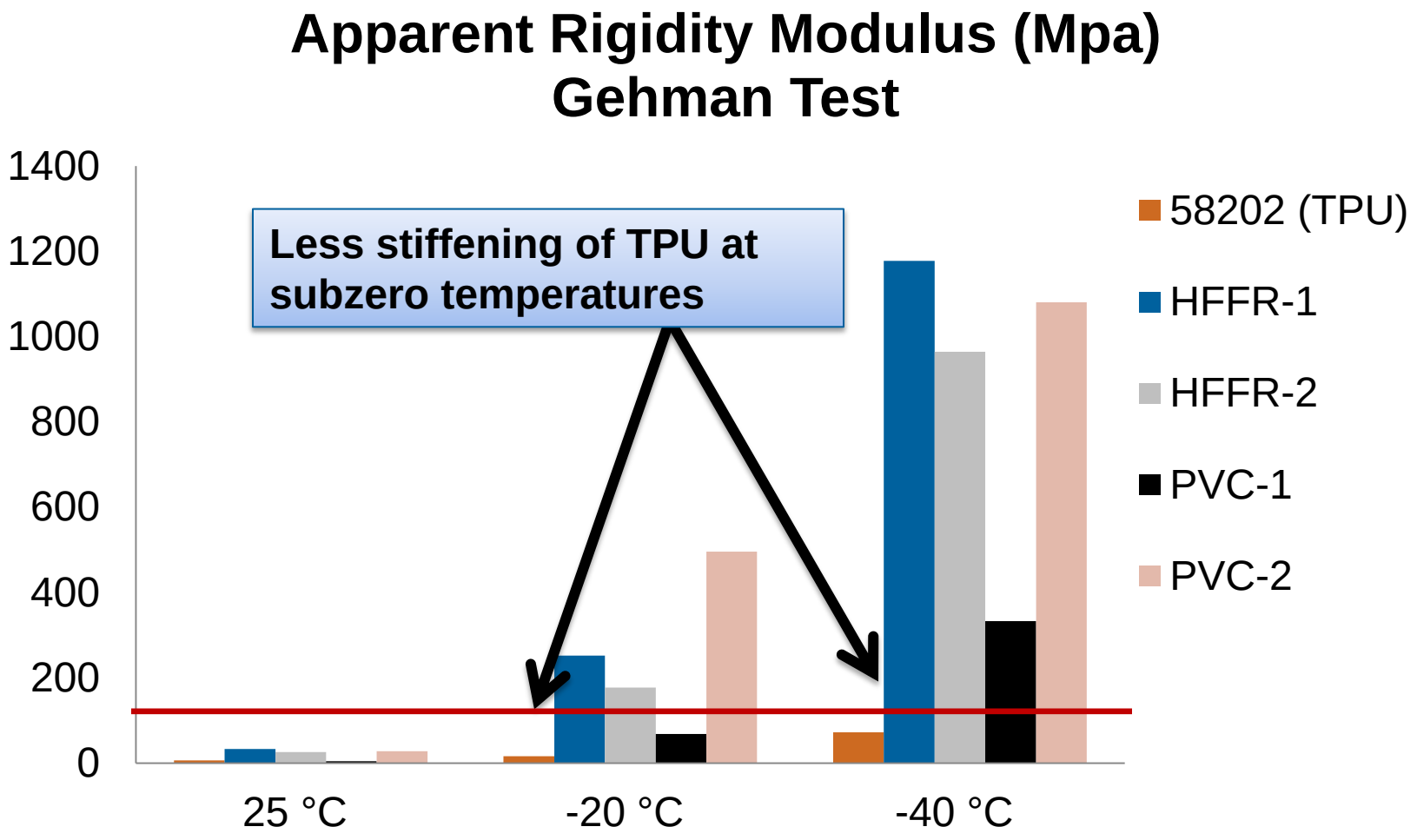
TPUs in Cable Applications

- Started in early 1960s as solution coating of polyester type TPUs
- Mostly polyether type currently
  - Hydrolytic stability
  - Inherent microbial resistance
  - Excellent low temperature flexibility
- Common characteristics:
  - Used in physically aggressive environments (oils, outdoors, low temp, abrasive dragging)
  - constant motion (high flex life w/o cracking)

Why use TPU ?



Why use TPU ?



Motivation for doing Current Work

- Generate long term aging data to demonstrate capability of standard TPUs for 90 °C and 105 °C rating
- Work on having short term aging tables included for TPUs

Temperature rating of TPUs as per UL 1581

- Table 50.227 for TPUs
  - Maximum of 80 °C rating possible

- Table 50.223 (105 °C) and 50.224(90 °C) for TPEs
  - Age time: 7 days (168 h)
  - Aging temperature:
    - 121 °C for 90 °C rating 136 °C for 105 °C rating
  - Requirements
    - 75 % retention of original Tensile strength and Elongation

TPUs under TPEs category via Short Term Aging

Problem

- 90 °C rating results are not reproducible for most W&C grades
- 105 °C rating is not possible for most W&C grades

Alternative Approach: Long term Aging

- UL 1581 (UL 2556) Long term Aging :
  - Test specimens for 90, 120 and 150 days and use data generated to calculate properties at 300 days as per formula provided
  - Test temperature

    $T_{test} = 1.02 \times (373.15 + T_{rating\ (°C)}) - 273.15$

For 90 °C test temperature is 97 °C

For 105 °C test temperature is 113 °C

Calculations

$$U_{(t)} = U_{(90)} \text{ X } e^{-R(t-90)}$$

Where

$U_{(t)}$ = Ultimate Elongation %, or tensile strength, Mpa

$U_{(90)}$ = regression constant (Calculated at 90 d)

R= Decay constant to be calculated from long term data

t = time in days

Converting to linear form

$$Y = B + RT$$

Where

$Y = \ln [U_{(t)}]$, $B = \ln [U_{(90)}]$, $T = (t-90)$

Calculations continued

$$Y = B + RT$$

Constants B and R to be determined by least square linear regression analysis

Requirement:

Tensile Strength $_{300\ d}$ > 4 MPa (for Jacketing material)

Ultimate elongation $_{300\ d}$ > 50 %

Experimental

- Grades Tested
  - Estane® TPU 58315
    - 85 A Polyether TPU
    - non-FR TPU
  - Estane® TPU 58202
    - 85 A Polyether TPU
    - flame retardant
  - Estane® TPU ZHF90AT2
    - 90 A Polyether TPU
    - Halogen free flame retardant

Experimental continued

- Specimen preparation
  - Die cut from extruded 30 mil thick sheet on 1” single screw extruder
- Oven Aging
  - Forced Air-ciruculated Oven
- Tensile testing
  - as per ASTM D-412
  - @ 500 mm/min crosshead speed
  - Data reported are average of five specimens

Estane® TPU 58315
Testing for 90 °C rating

Days	Test Temp (°C)	Tensile Strength (psi)		Ultimate Elongation %	
90	97	Avg.	5780	Avg.	645
		S.D.	263	S.D.	21
120	97	Avg.	5450	Avg.	685
		S.D.	300	S.D.	28
150	97	Avg.	5000	Avg.	683
		S.D.	114	S.D.	28

- Ultimate elongation $_{300\ d}$ = 796 %
- Tensile Strength $_{300\ d}$ = 24 MPa

58315 gets 90 °C rating

Estane® TPU 58315
Testing for 105 °C rating

Days	Test Temp (°C)	Tensile Strength (psi)		Ultimate Elongation %	
90	113	Avg.	2260	Avg.	714
		S.D.	23	S.D.	16
120	113	Avg.	2230	Avg.	639
		S.D.	51	S.D.	8
150	113	Avg.	2100	Avg.	543
		S.D.	312	S.D.	95

- Ultimate elongation $_{300\ d}$ = 276 %
- Tensile Strength $_{300\ d}$ = 12 MPa

58315 gets 105 °C rating

Estane® TPU 58202
Testing for 90°C rating

Days	Test Temp (°C)	Tensile Strength (psi)		Ultimate elongation %	
90	97	Avg.	3160	Avg.	705
		S.D.	100	S.D.	12
120	97	Avg.	3050	Avg.	692
		S.D.	100	S.D.	14
150	97	Avg.	2760	Avg.	678
		S.D.	57	S.D.	20

- Ultimate elongation $_{300\ d}$ = 615 %
- Tensile Strength $_{300\ d}$ = 14 MPa

58202 gets 90 °C rating

Estane® TPU 58202
Testing for 105 °C rating

Days	Test Temp (°C)	Tensile Strength (psi)		Ultimate elongation %	
90	113	Avg.	1140	Avg.	446
		S.D.	116	S.D.	69
120	113	Avg.	1050	Avg.	392
		S.D.	89	S.D.	47
150	113	Avg.	1180	Avg.	385
		S.D.	72	S.D.	26

- Ultimate elongation $_{300\ d}$ = 262%
- Tensile Strength $_{300\ d}$ = 9 MPa

58202 gets 105 °C rating

Estane® TPU ZHF90AT2
Testing for 90°C rating

Days	Test Temp (°C)	Tensile Strength (psi)		Elongation at Break %	
90	97	Avg.	2880	Avg.	524
		S.D.	298	S.D.	33
120	97	Avg.	3140	Avg.	523
		S.D.	118	S.D.	13
150	97	Avg.	2790	Avg.	515
		S.D.	186	S.D.	21

- Ultimate elongation $_{300\ d}$ = 494 %
- Tensile Strength $_{300\ d}$ = 18 MPa

ZHF90AT2 gets 90 °C rating

Estane® TPU ZHF90AT2
Testing for 105 °C rating

Days	Test Temp (°C)	Tensile Strength (psi)		Ultimate Elongation %	
90	113	Avg.	2070	Avg.	495
		S.D.	112	S.D.	26
120	113	Avg.	1990	Avg.	476
		S.D.	131	S.D.	21
150	113	Avg.	2030	Avg.	425
		S.D.	255	S.D.	31

- Ultimate elongation $_{300\ d}$ = 294%
- Tensile Strength $_{300\ d}$ = 13 MPa

ZHF90AT2 gets 105 °C rating

Summary

- No short term aging guideline exist for TPUs for 90 °C and 105 °C rating in UL 1581
- TS and TE retention requirement for TPEs in UL 1581 Tables are not suitable for TPUs
- Based on longer term aging Polyether based TPUs are suitable candidate for 90 °C and 105 °C temperature rating.
- Short term aging tables to obtain 90 °C and 105 °C rating for TPUs should be included in UL1581

Lubrizol

ESTANE® TPU

Thank you for your attention!

QUESTIONS…….