Sustainable Non-Halogenated Flame Retardant TPU Solutions

LUBRIZOL ENGINEERED POLYMERS

ADVANCING MATERIALS. ELEVATING PERFORMANCE.

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AGENDA

- Lubrizol Overview
- What is TPU?
- Non-Halogenated TPU FR Grades
- Application Examples: Hydraulic Fracturing and EV Charges

THE LUBRIZOL CORPORATION

A Berkshire Hathaway company

- Chairman & CEO Warren E. Buffett
- Portfolio of more than 60 businesses

The Lubrizol Corporation, established 1928

- A global specialty chemical company
- Headquartered in Cleveland, OH
- 2020: Over 8,800 employees
- Serves customers in over 100 countries from a well-networked global structure

Employees Globally	Labs/Technical Facilities	Manufacturing Sites	Sales Offices
8,800	39	58	48

LUBRIZOL ADVANCED MATERIALS

Global Business Units

- Engineered Materials
  - **Engineered Polymers**
  - Performance Coatings
  - CPVC Piping Systems
- Lubrizol Life Science
  - Beauty and Personal Care
  - Home Care
  - Health

- **Create** proprietary, high-performance materials for customers in a wide range of industries
- **Apply** core polymer and surface active chemistries and formulations know-how
- **Accelerate** development cycles and customer success through collaboration, strategic partnerships and a well-networked global team

At work… at home… Anywhere you are!

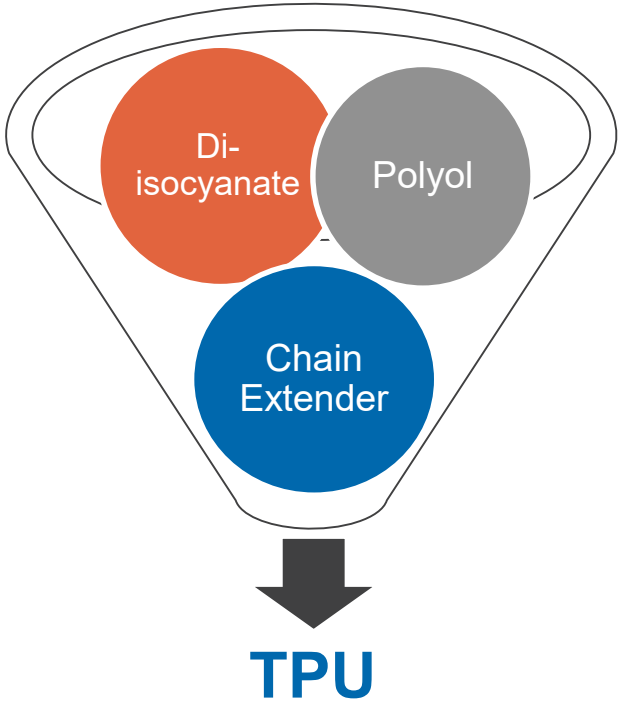
TPU CHEMISTRY

Diisocyanate, Polyol, Chain extender (diol)

Diisocyanate + Chain extender → hard segment

Diisocyanate + Polyol → soft segment

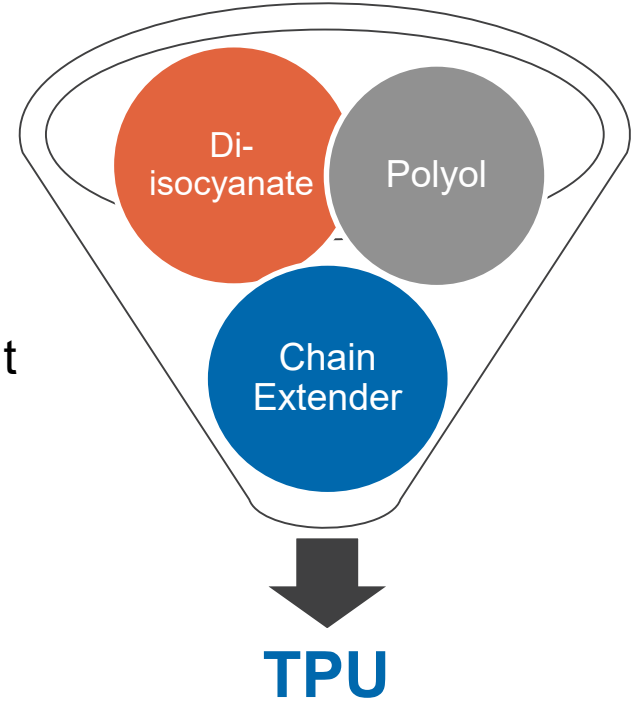
Ratio of hard to soft segments determines basic properties within a given family



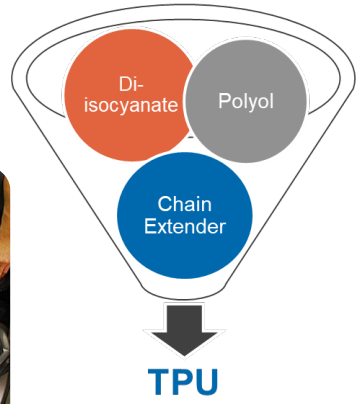
Lubrizol (back then BF Goodrich) invented TPU in 1959

POLYOL CHEMISTRIES

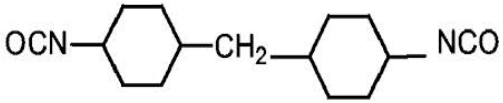
- ***Polyester-based***: Excellent oil, fuel, chemical and abrasion resistance; good adhesion and barrier properties
- ***Polyether-based***: Excellent low temperature, hydrolysis and abrasion properties; improved UV and fungal resistance (over aromatic esters) without additives
- ***Polycaprolactone-based***: Bridge gap between polyesters and polyethers
- ***Polycarbonate-based***: Higher performance compared to polyesters and polyethers



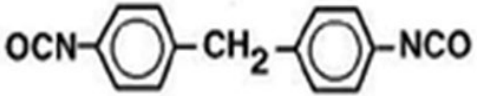
Di-isocyanate: Aliphatic / Aromatic TPU



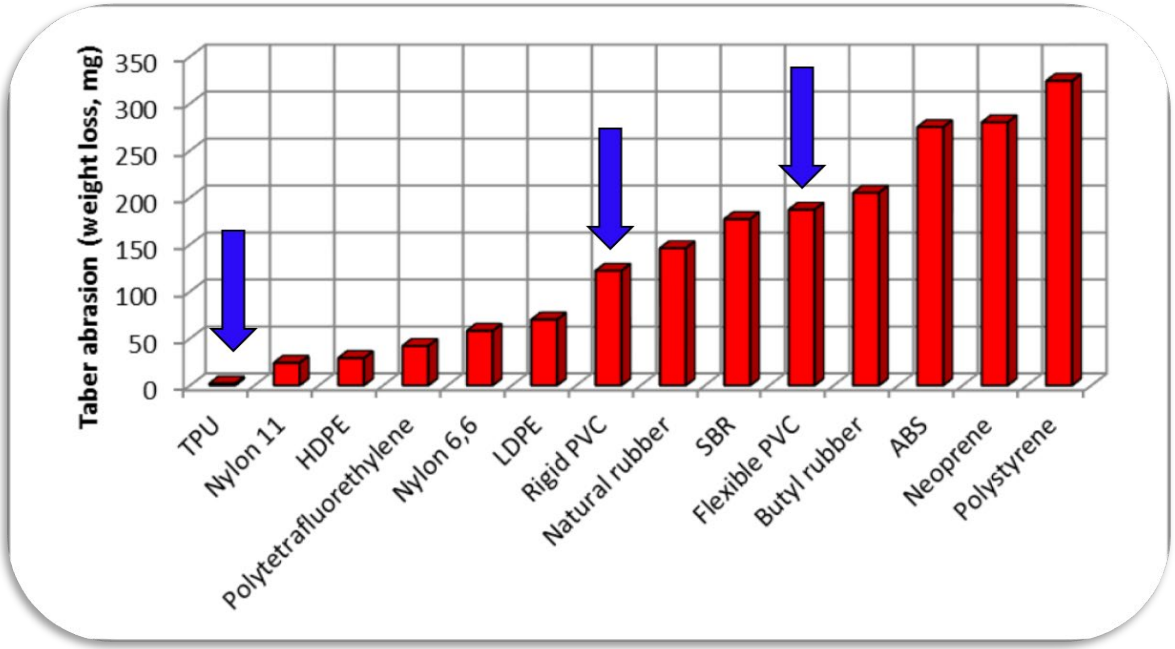
Aliphatic – excellent UV resistance in optically clear products, abrasion resistance and outdoor durability for decades



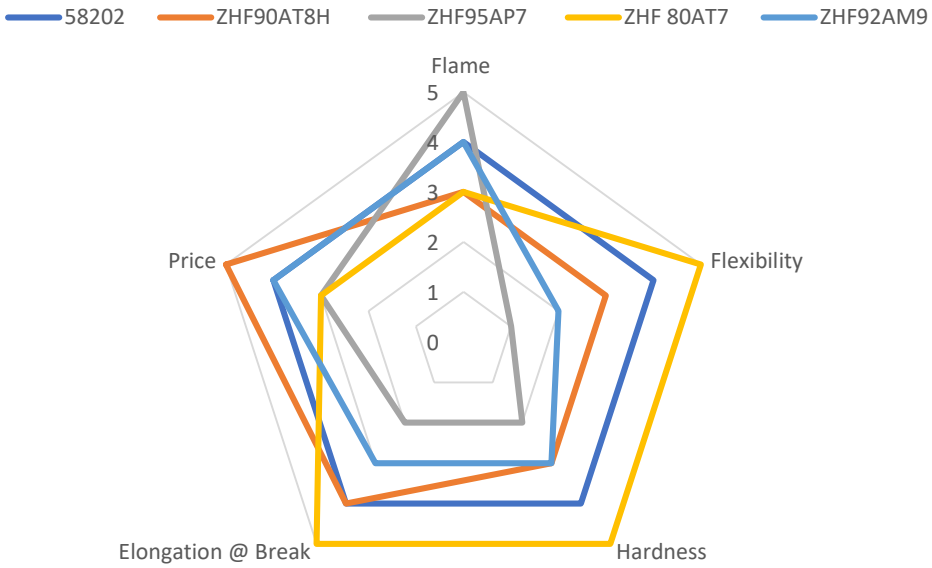
Aromatic – excellent chemical, abrasion and puncture resistance.



EXCELLENT ABRASION



NHFR Grades Comparison – Key Attributes

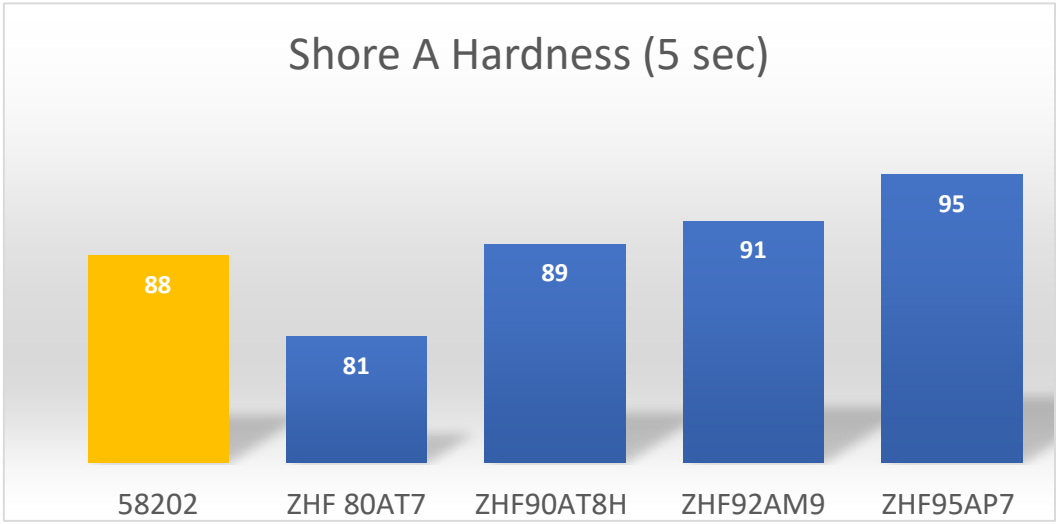


Benchmarking Tests Performed

- Tests to measure flexibility/low temperature performance
  - Hardness
  - Stress @ 100% elongation
  - Glass transition temperature Tg
  - DMA storage modulus at low temperature
- Other important tests
  - Elongation @ Break, UL 94 flame test

All the tests in this presentation were conducted by the same test method/same specimen preparation method/at the same location.

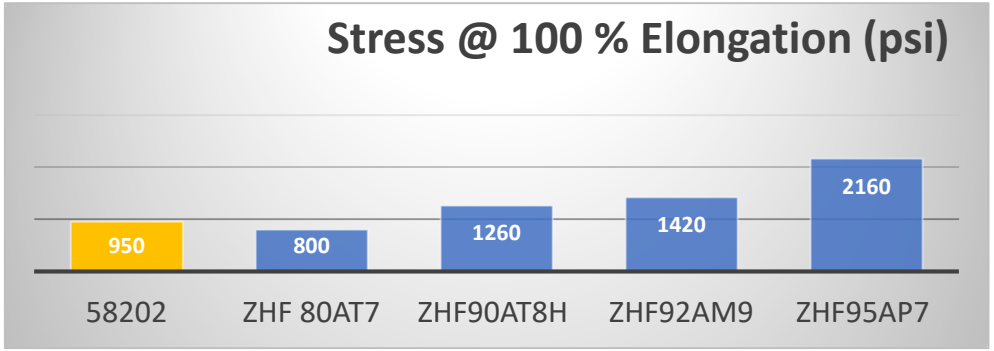
Shore A Hardness



The lower the number, the better for cable jacketing materials.

- Although this is not a good objective property to compare materials, the wire and cable industry uses this widely and this is among the first properties being looked at on a TDS.

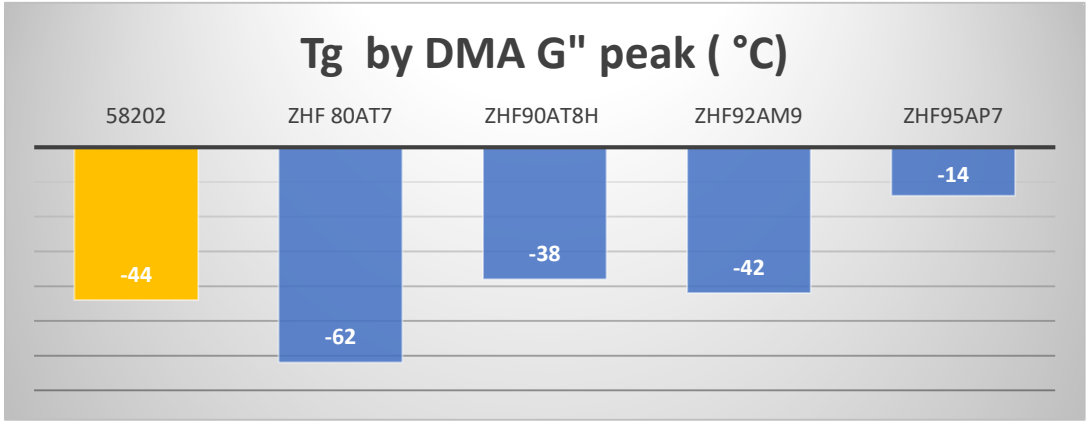
Stress @ 100% Elongation for Ambient Flexibility



- The lower the number, the better it is for room temperature flexibility.
- Helps to gauge subjective “hand feel” of cable product.

- Stress @ 100% elongation is an indirect measure of flexibility. Some cable designers uses it to get a rough indication of relative flexibility of the material by comparing this property for different elastomers.

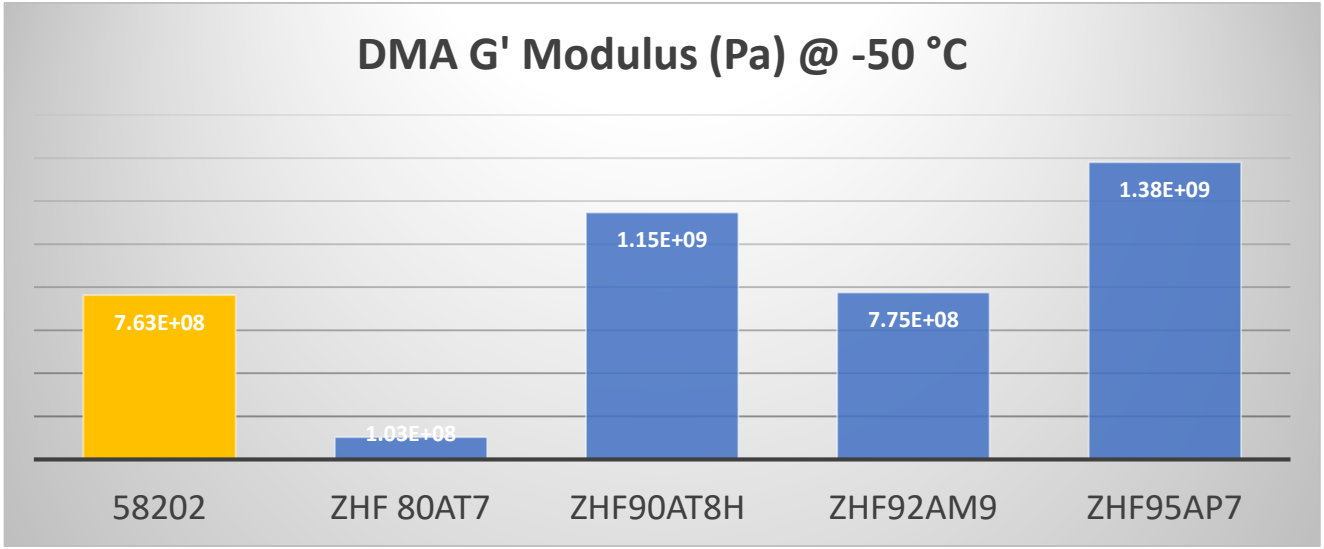
Glass Transition Temperature (Tg) for Low Temperature Performance



- The lower the number, the better low temperature performance for cable jacketing materials.
- Helps to gauge cold impact performance of cable.

- The Tg of jacketing material is a very important property for cable manufacturers as it helps them compare low temperature properties between different jacketing compounds in standardized material tests.

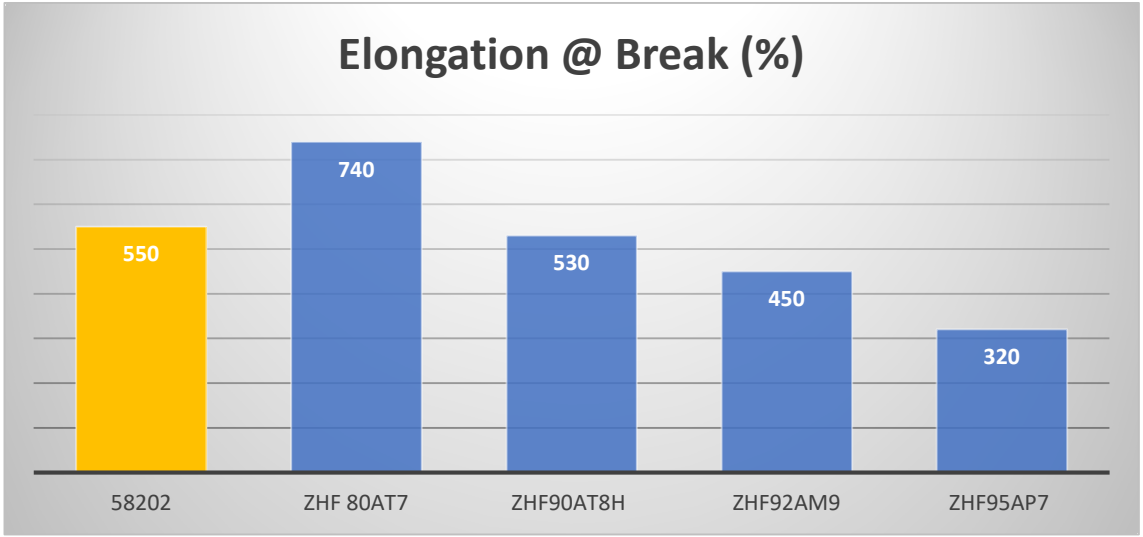
DMA G' Modulus at -50°C for Low Temperature Flexibility



- The lower the number, the better for low temperature flexibility for cable jacketing materials.
- Helps to gauge relative cold bend performance.

- The lower modulus value means it takes less force to bend the material. This is important for cable designers as most of the resistance to bending is related to the cable jacketing material.

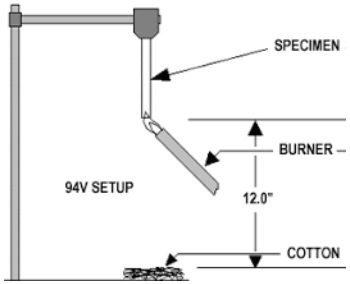
Elongation @ Break



- The higher the number, the better the performance of the cable jacketing material.
- The single most important property for jacketing material to ensure continued functioning of cable whether it is for power or optical.

- Loss of elongation results in the failure (tear/crack) of cable jackets exposing the underlying cable materials to the environment. It's like going to -40° C weather with torn/holes in jacket.

Self Extinguishing (V0) as per UL 94 Vertical Burn Test



	V0	V1	V2
Flaming combustion time after either application of flame for each specimen	≤ 10 sec	≤ 30 sec	≤ 30 sec
Total flaming combustion time for all 5 specimens	≤ 50 sec	≤ 250 sec	≤ 250 sec
Flaming drips	NO	No	Yes

What does self extinguishing (UL94- V0) mean?

The material does not continue to burn after ignited and it does not spread fire to the surrounding area by flaming droplets.

- Performance is dependent on thickness of specimen tested. The lower the thickness the more difficult it is to obtain V0 rating. UL lists products up to **13 mm** thickness.
- V0 is self-extinguishing V1 and V2 are not self-extinguishing. There is a big difference in performance from V0 to V2.

UL94 Vertical Burn Test Results

	ZHF 80AT7	58202	ZHF90AT8H	ZHF95AP7	ZHF92AM9
at 75 mil (1.9 mm)	V2	V0	V0	V0	V0
at 125 mil (3.2 mm)	V0	V0	V0	V0	V0

- Self-extinguishing performance achieved by ESTANE® ZHF80AT7 should be sufficient for the majority of the TPU applications.
- For applications requiring stringent flame requirement performance like UL 1061 and higher, ESTANE® ZHF92AM9 or ESTANE® ZHF95AP7 should be considered.

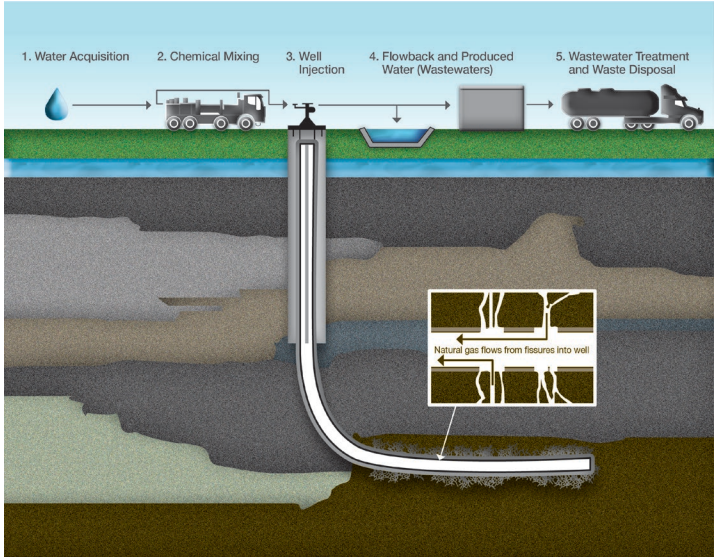
Summary

- Our Non-Halogenated Flame Retardant portfolio provides a wide range of high performing grades to target different applications and markets
  - ESTANE® ZHF80AT7 provides better flexibility/low temperature performance than any of our commercial flame retardant grades including legacy ESTANE® 58202
  - ESTANE® ZHF92AM9 provides improved flame retardancy over ESTANE® ZHF80AT7 and ESTANE® ZHF90AT8H, and it should be considered for higher level cable flame test requirements
  - ESTANE® ZHF90AT8H provides a good balance of properties at a competitive cost
  - ESTANE® ZHF95AP7 is the highest flame performance grade among the portfolio

Hydraulic Fracturing / Oil& Gas

Challenging requirements for cable jacketing material:

- High mechanical properties to withstand high pressure and loads
- Exceptional abrasion resistance to abrasive fracking environment (Proppant – silica, quartz sand)
- Higher temperature resistance
- Chemical resistance to drilling fluids-mud
- Resistance to corrosive gases (H_2S)

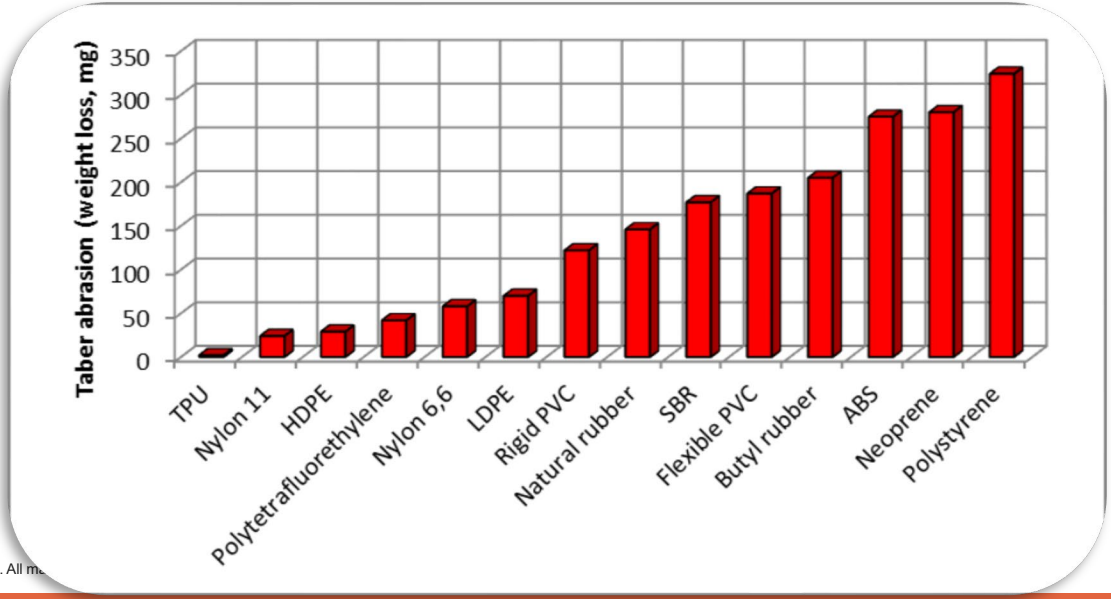


ESTANE® TS92AP7
Elastomer with High Mechanical Properties

	TPU C
Tensile Strength (MPa)	65
Ultimate Elongation (%)	360

ESTANE® TS92AP7
Exceptional Abrasion Resistance

Taber Abrasion Weight loss (H-18 wheel, 1000g)	**40 mg/1000 rev**



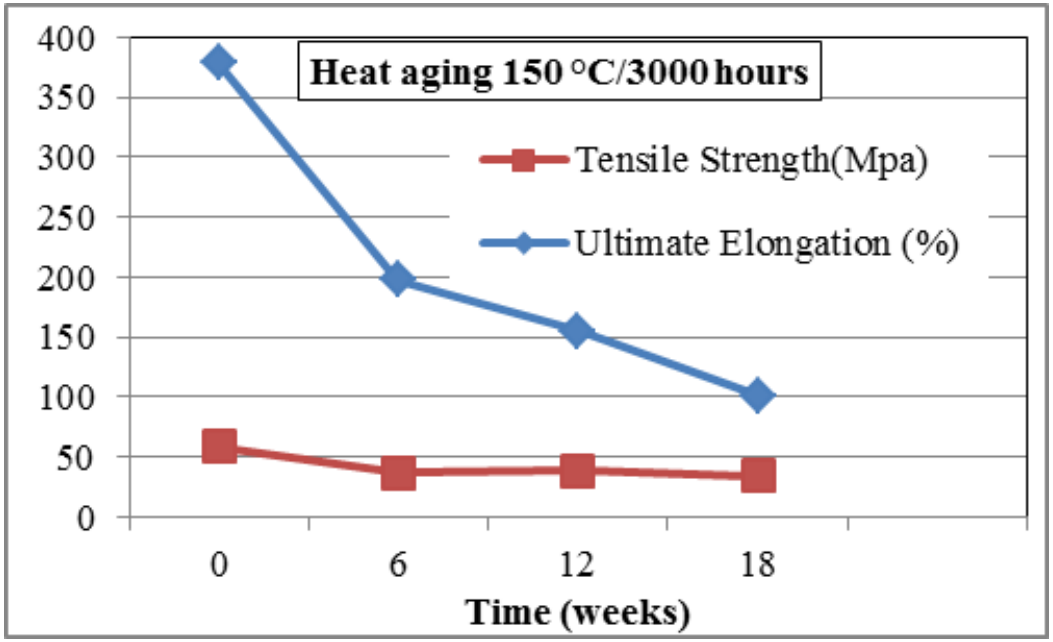
CS-17 wheel

ESTANE® TS92AP7
125 ° C High Temperature Resistance

Aging temperature: 158°C
Aging Time: 168 h

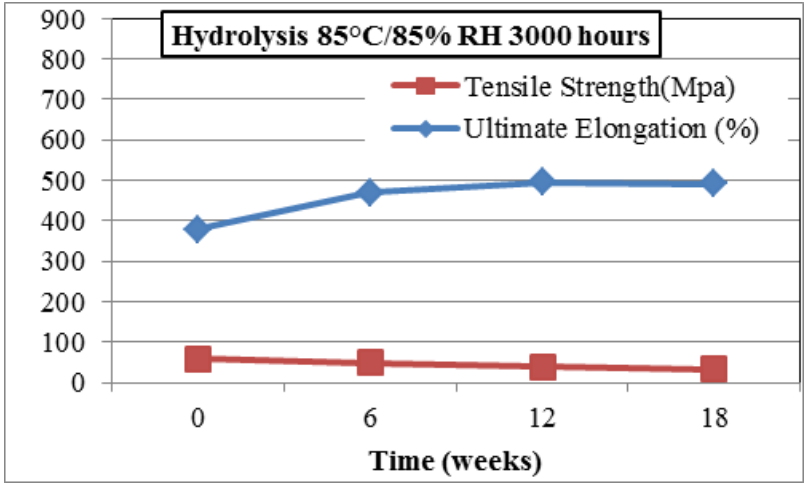
	TPU C
Unaged Tensile Strength (MPa)	65
Unaged Ultimate Elongation (%)	360
% retention of Unaged TS	82
% retention of Unaged UE	100

ESTANE® TS92AP7
Long Term Heat Aging Performance



ESTANE® TS92AP7 Drilling Fluid Resistance

Long term Hydrolysis Performance



IRM 902 Oil aging 100 °C for 1 Week

Tensile strength retention (%)	95
Ultimate Elongation retention (%)	105

ESTANE® TS92AP7
Resistance to Corrosive Gases

Bio-Gas

Carbon dioxide	32.8%
Methane	65.6%
Nitrogen	0.82%
Hydrogen sulfide	0.3%
Toluene	0.46%

ESTANE® TPU-C after Biogas Exposure at 70 °C

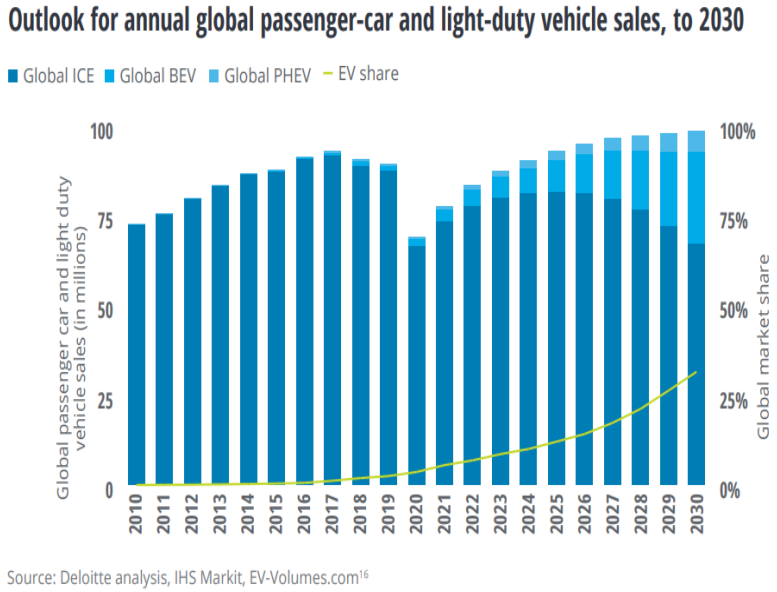
	Tensile Strength (psi)	Elongation @ Break (%)	Surface Cracking	GPC (Mw) % of original
Original	8500	360	None	100
90 days	8500	360	None	116

EV Charging Cables and TPU

Main CTQ's for TPU

- In the EN 50620 and IEC 62893 standards, the main requirements for TPU sheathing are:
  - Tensile strength >20 Mpa for EVM-1
  - Fire-test is to be according to IEC 60332-1-2
  - Assessment of halogens for all non-metallic materials
    - pH value of **>4,3**
    - Gas conductivity
      - **<40 µS/mm for EN 50620***
      - **<35 µS/mm for IEC 62893***

      *(*amended from Annex A of IEC 60754-2: 2011)*

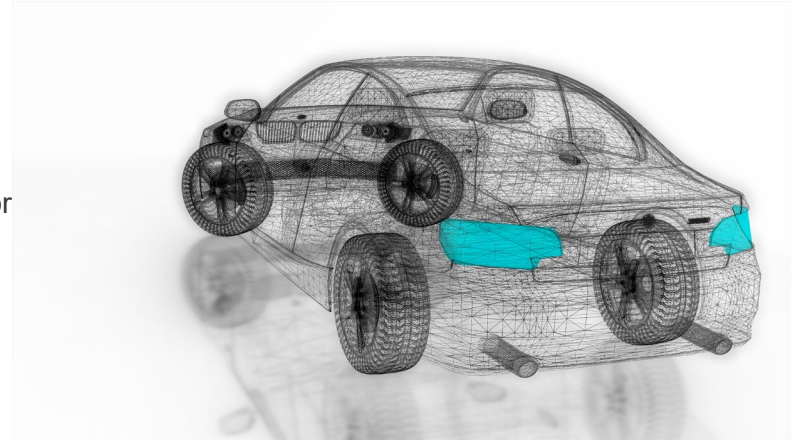


Source: Deloitte analysis, IHS Markit, EV-Volumes.com[16]

EV Charging Cables and TPU

What else is important?

- Safety
  - All our grades are non-SVHC
- Global compliance
- No or low smell and volatiles
  - Not mentioned in the standards
  - Becoming a barrier to entry for some OEM's
  - No plasticizers and 'clean' formulations give an advantage
- Color / Esthetics
  - Cables used directly by consumers with high sensitivity to color stability/esthetics especially with lighter colors
  - Use of certain additives could lead to discoloration
- Processability
- Performance/price balance

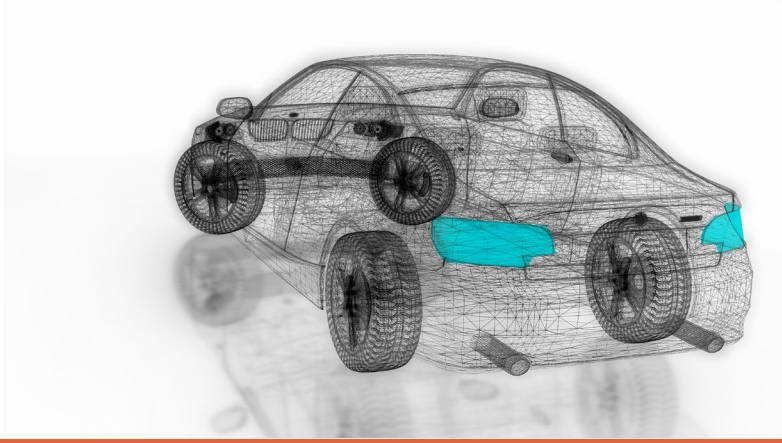


ESTANE® ZHF for EV Charging Cables

Physical property	Unit	ESTANE® ZHF 58202 NAT 02	ESTANE® EV 90AT2 NAT 01	ESTANE® EV 88AT2 NAT 01	ESTANE® ZHF 58370 NAT 01
Feature		**Differentiated Halogen-free FR**	**Halogen-free FR**	**Halogen free FR**	**Differentiated Halogen-free FR**
Hardness	Shore A	91	90	89	86
Specific Gravity	g/cm^3	1.23	1.19	1.18	1.20
Tensile at break	MPa	28	29	34	31
Elongation at break	%	632	523	529	653
Abrasion resistance	mm^3	65	46	45	91
Oxygen Index	%	25	22	22	23
Vertical Burn test	Rating	V-2 @ 1.9 mm	V-2 @ 1.9 mm	V-2 @ 1.9 mm	V-2 @ 1.9 mm
pH value		8.1	8.5	8.9	7.3
Gas conductivity	µS/mm	<35	<40	<35	<10
IEC 60332-1-2	/	PASS	PASS	PASS	PASS*
IEC62893/EN50620 compliance		IEC62893/ EN50620	EN50620	IEC62893/ EN50620	IEC62893/ EN50620

**Dependant on cable construction*

Table 1: Overview of new halogen-free, flame retardant grades for EV charging cables



Thank you
Any Questions?

From the invention of ESTANE® TPU through our newest innovations, we improve lives and deliver success by helping customers solve problems they once thought impossible. We bring together the people, ideas and technologies that can enable new designs, better performing products and more sustainable outcomes. We're proud to be part of The Lubrizol Corporation, a Berkshire Hathaway company. Lubrizol combines market insights, chemistry and application capabilities to deliver efficiency, reliability and wellness in global transportation, industrial and consumer markets.

To learn more, visit www.lubrizol.com

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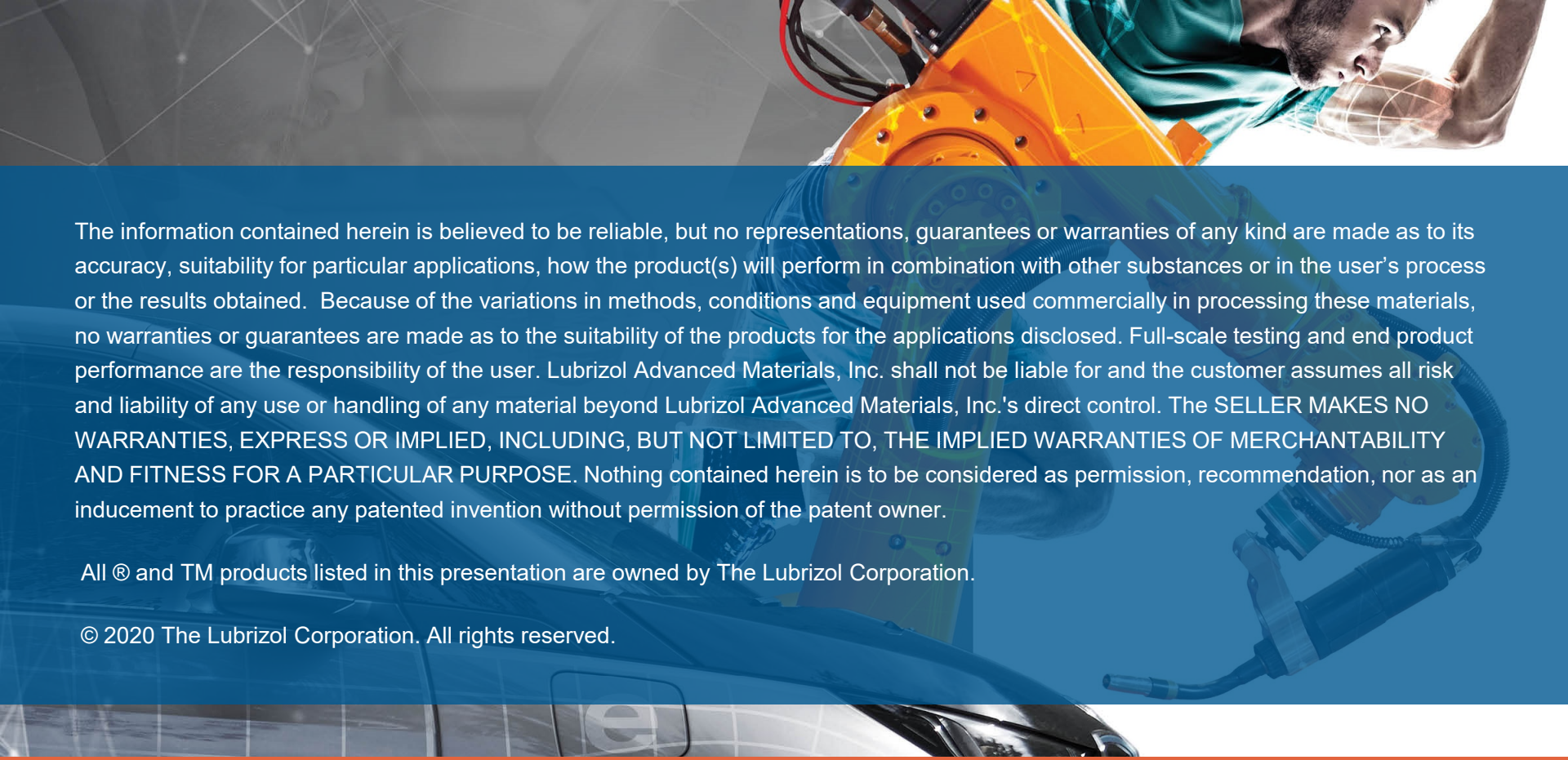

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