March 18, 2019

LUBRIZOL ENGINEERED POLYMERS | **ADVANCING MATERIALS. ELEVATING PERFORMANCE.**

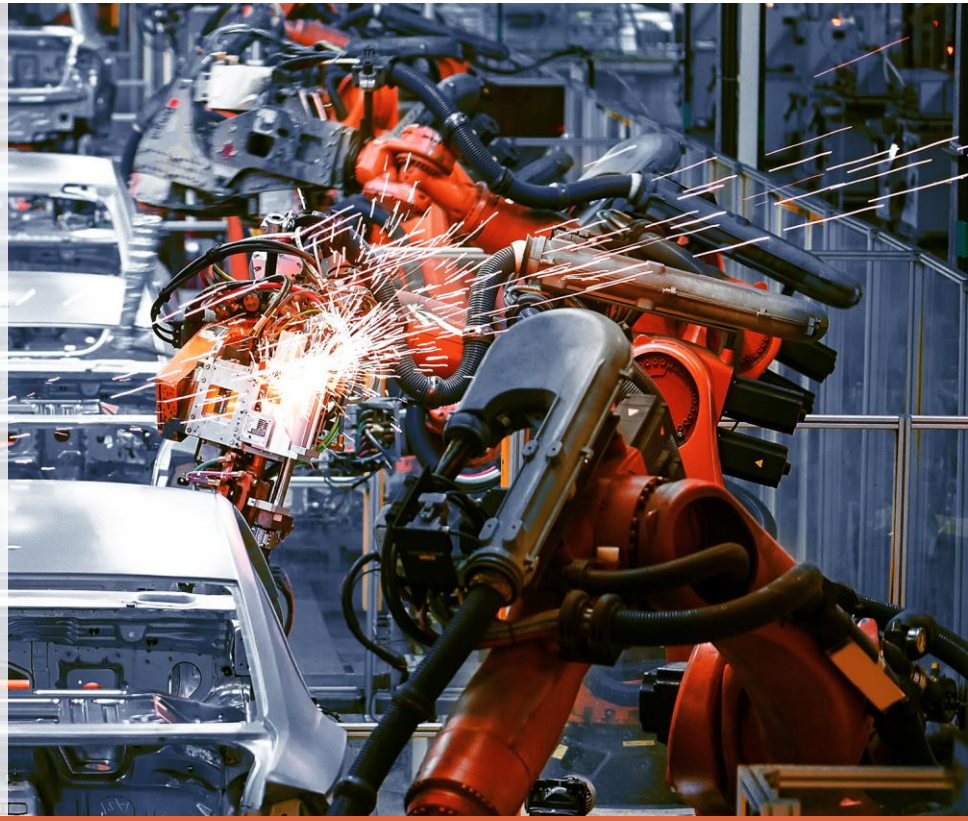
ESTANE® ZHF solutions

Want to get effective flame retardancy with no halogens in your wire and cables?

Fabio Morelli
New Business Dev. Manager EMEA
The Lubrizol Corporation

Agenda

- About Lubrizol Engineered Polymers
- ZHF Market trends & Products
- New developments in ESTANE® NHFR TPU
- EV Charging Cables
- ESTANE® grades



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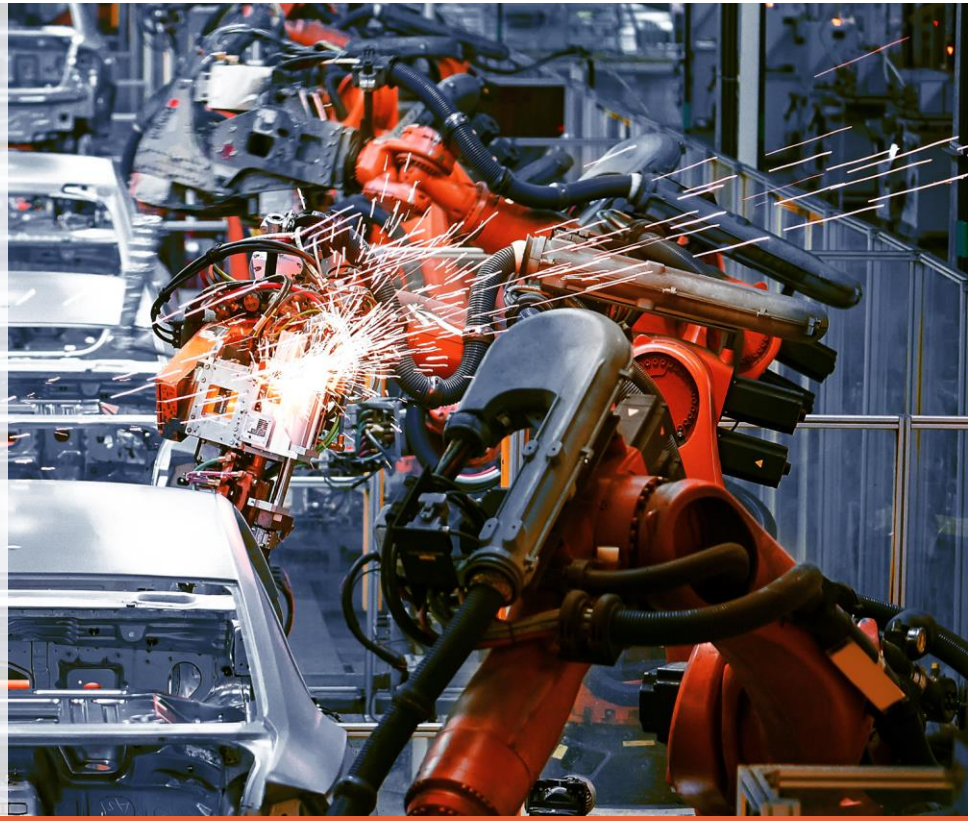
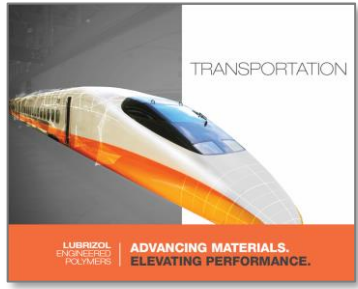


Engineered Polymers

- Inventor of TPU in 1959 – Acquired by Lubrizol in 2004
- **ESTANE®** brand TPU globally recognized as the benchmark for performance and quality
- Extensive portfolio of specialty polymers that bridge the gap between flexible rubber and rigid plastics
- Locally present, globally networked for full support



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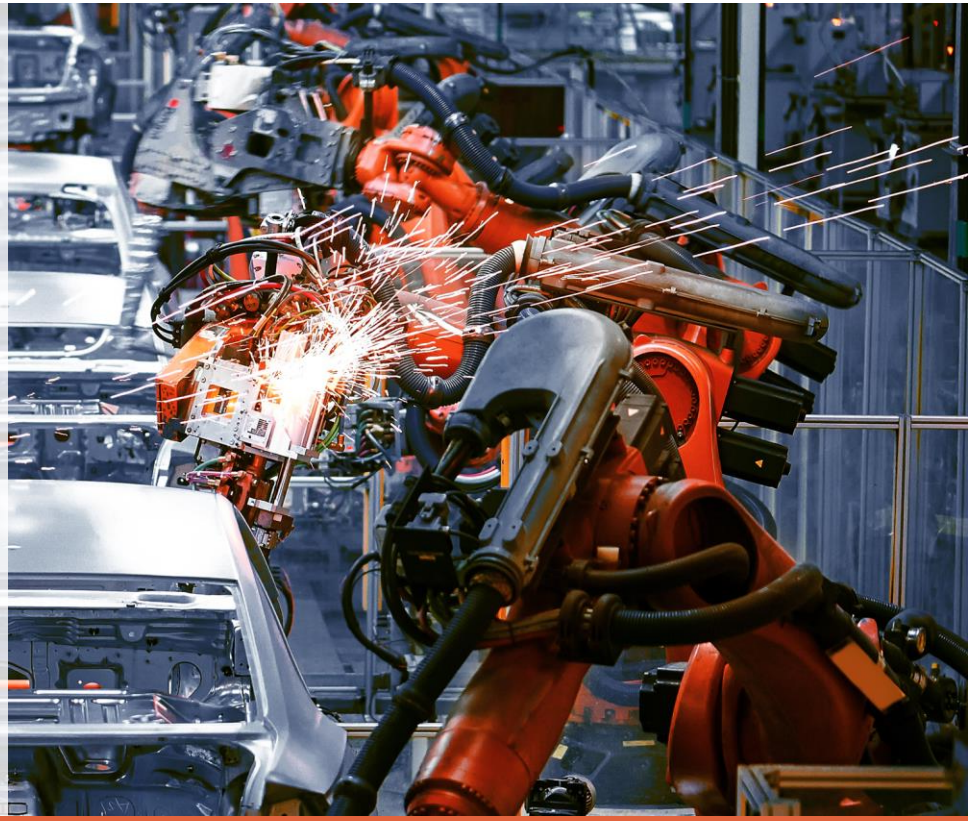
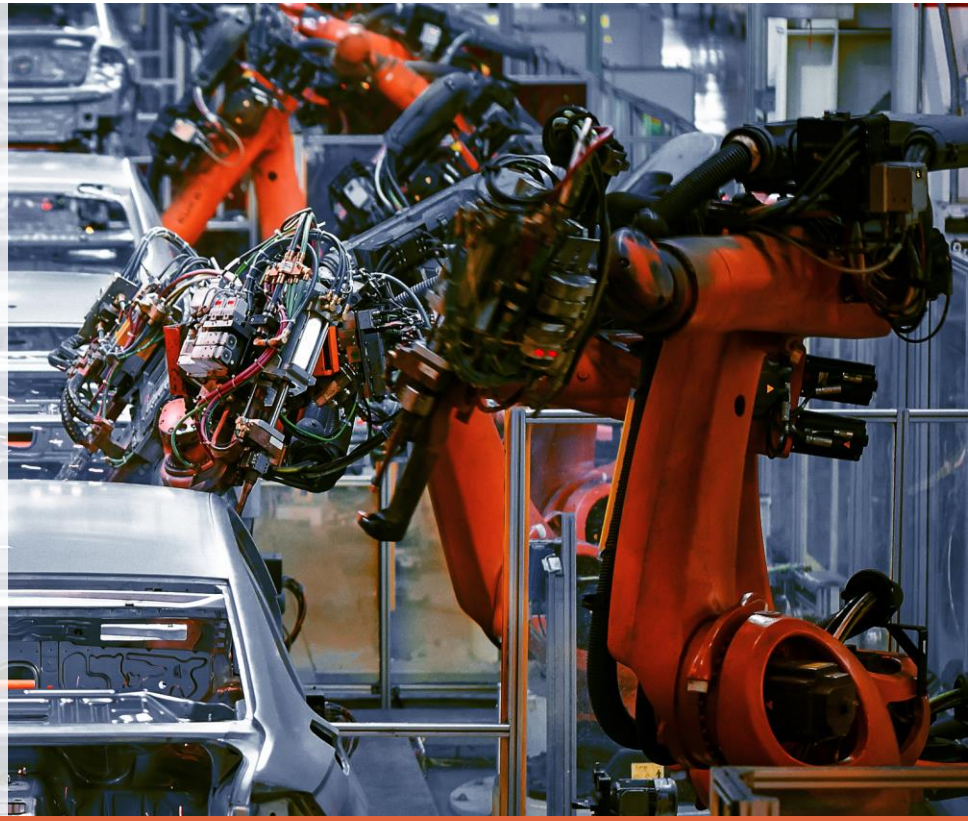


NHFR Market Trends

- Main drivers for growth
  - Industry 4.0
  - Car Electrification – EV C-Cables
  - Building (CPR)
- Competitive trends
- Technical streams
  - SVHC constraints
  - Stringent CPR and Railways Standards



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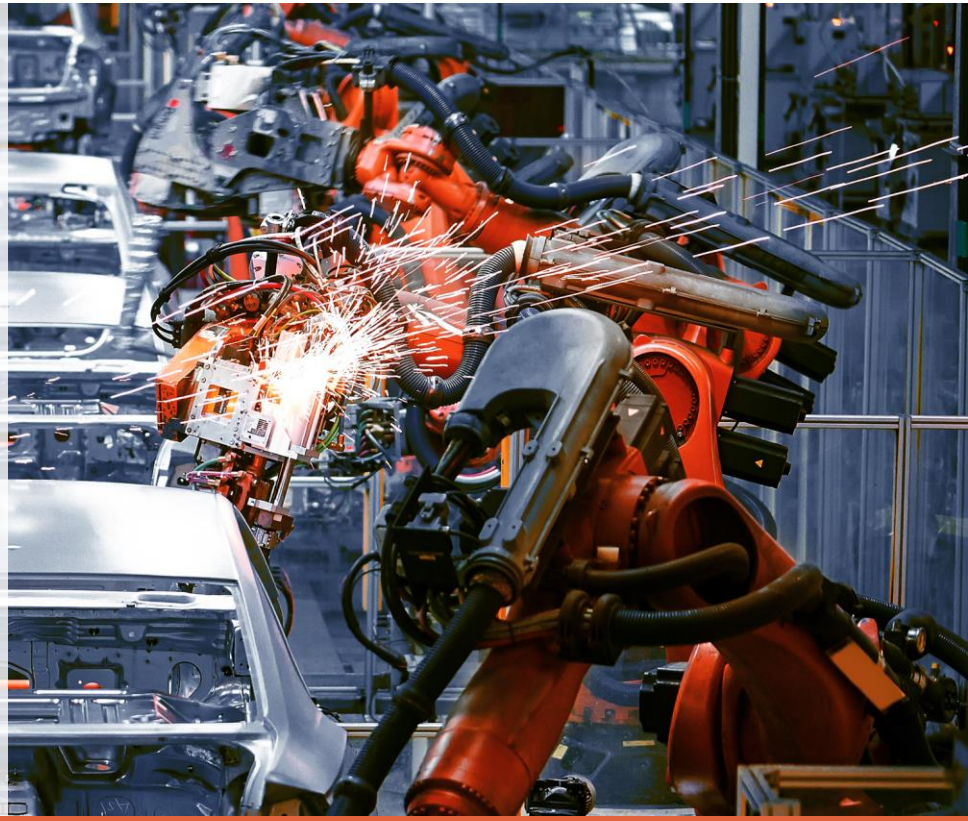
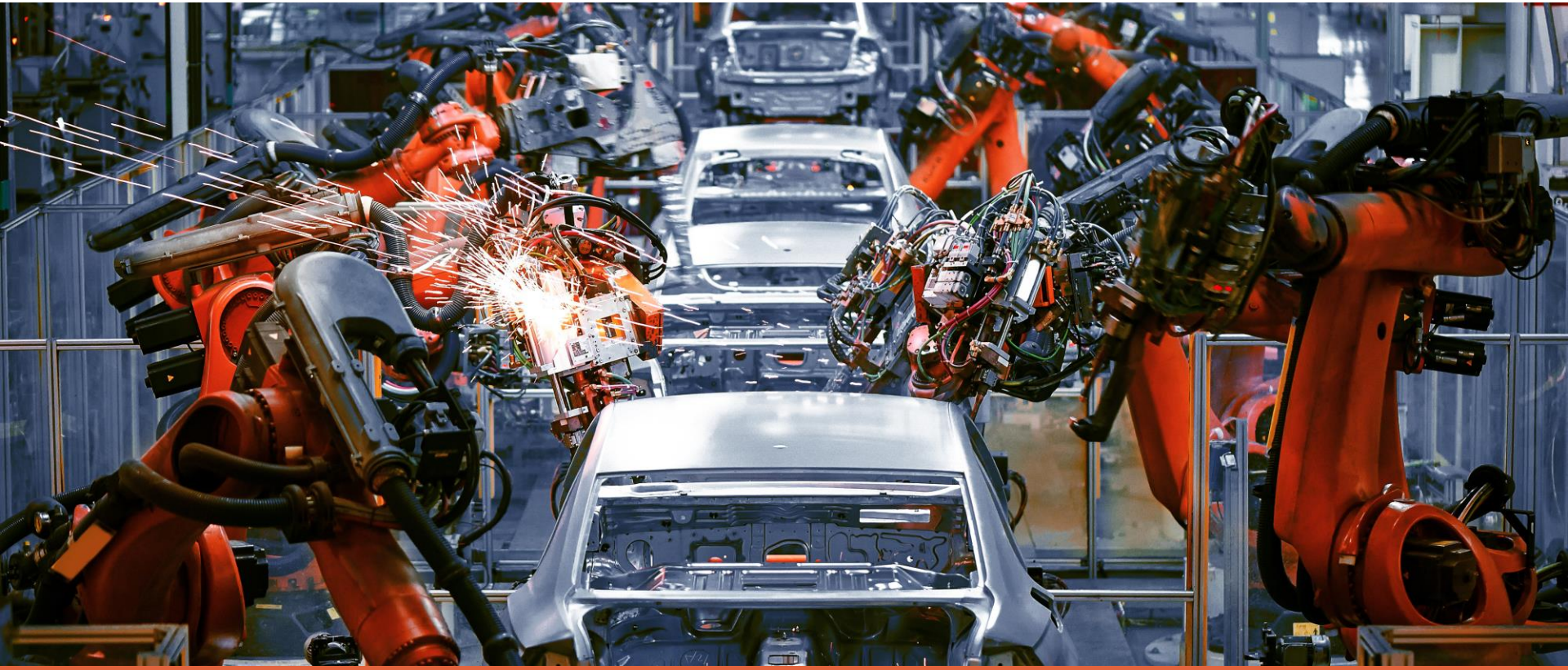


ESTANE® ZHF TPU



LUBRIZOL
ENGINEERED
POLYMERS

ADVANCING MATERIALS.
ELEVATING PERFORMANCE.

Lubrizol

ESTANE®
FEATURED GRADES

- ✓ ZHF 85 AT8 MATT
- ✓ ZHF 90 AT8 H
- ✓ EV 90 AT2
- ✓ ZHF 92 AT*
- ✓ ZHF 58202 & ZHF 58370
- ✓ ZHF 58211
- ✓ TS 92 AP7

* Still in Development

ESTANE® ZHF 85 AT8 & 90 AT2 grades

Physical property	Unit	ZHF 85AT8 MATT 01	ZHF 90AT2 NAT 055	EV 90AT2 NAT 055
FEATURE		ISO 6722 UL 1581	UL 1581 IEC 60332	UL 1581 IEC 60332 EN 50620 IEC 62893
Hardness	Shore	84 A	91 A	90 A
Tensile at break	MPa	50	22	28
Elong. at break	%	550	459	520
Tear Strength	kN/m	55	72	85
Abrasion	mm^3	40	49	38
Oxygen Index	%	24	24	23
Vertical Burn test		V-2	V-2	V-2
Yellow card		/	/	/

ESTANE®
ZHF 85AT8 MATT 01

- ✓ UL 94-V2
- ✓ Pass ISO 6722 Flame test*
- ✓ UL 90°C rating
- ✓ Nice matt aspect
- ✓ UV-stabilized
- ✓ Good abrasion
- ✓ High tensile strength
- ✓ Lower density

* Depending on cable construction

ESTANE®
ZHF 90AT2 NAT 055

- ✓ IEC 60332-1-2*
- ✓ UL 1581 FT-1 & VW1*
- ✓ Consistent FT-2 for thin cables
- ✓ UL 90°C rating
- ✓ Forms compact crust
- ✓ UV-stabilized
- ✓ No plasticizers

* Depending on cable construction

UL 1581 and VDE compliant ESTANE® ZHF 90AT8

Physical property	Unit	ZHF 90AT2 NAT 055	ZHF 90AT8 NAT 02	ZHF 90AT8H NAT 02
FEATURE		UL 1581 IEC 60332	UL 1581 IEC 60332	UL 1581 IEC 60332
Hardness	Shore	91 A	89 A	87 A
Tensile at break	MPa	22	29	25
Elong. at break	%	459	512	524
Tear Strength	kN/m	72	55	53
Abrasion	mm^3	49	38	36
Oxygen Index	%	24	24	25
Vertical Burn test		V-2	V-2/0*	V-0
Yellow card		/	Y	Y

* Depending on cable construction

ESTANE®
ZHF 90AT8(H) NAT 02

- ✓ Complies with VDE 282-10 (T.S. >25 MPa)
- ✓ Low abrasion
- ✓ UL 94 V-0 rating (as of 0,8 mm for the ‘H’)
- ✓ IEC 60332-1-2*
- ✓ UL 1581 S.1080 (VW1) & S.1060 (FT-1)*
- ✓ UL 1581 S.1061*
- ✓ UL 105°C rating
- ✓ UV-stabilized
- ✓ Available in different versions

* Depending on cable construction

High-performance ZHF 92AT* ESTANE® TPU

Physical property	Unit	ZHF 90AT2 NAT 055	ZHF 90AT8H NAT 02	ZHF 92AT*	58244	ZHF 95AT3 NAT 055
FEATURE		UL 1581 IEC 60332	UL 1581 IEC 60332	UL 1581 IEC 60332	Differentiated Smoke Data	UL 1581 IEC 60332
Hardness	Shore	91 A	87 A	92 A	92 A	95
Tensile at break	MPa	22	25	17	14/28	15
Elong. at break	%	459	524	500	580	370
Tear Strength	kN/m	72	53	53	56	66
Abrasion	mm^3	49	36	99	97	142
Oxygen Index	%	24	25	31,5	28	37
Vertical Burn test		V-2	V-0	V-0	V-0	V-0
Yellow card		/	Y	/	Y	/

*Still in Development

ESTANE® ZHF 92AT**

- ✓ UL 94 V-0 rating
- ✓ IEC 60332-1-2*
- ✓ UL 1581 S.1080 (VW1) & S.1060 (FT-1)*
- ✓ UL 1581 S.1061*, consistent for thin cables, smaller than 7mm OD
- ✓ UL 90°C rating
- ✓ UV-stabilized

- *Depending on cable construction
- **Still in Development

Low smoke & toxicity ESTANE® ZHF TPU

Physical property	Unit	ESTANE® ZHF 58370 NAT 01	ESTANE® ZHF 58202 NAT 02	ESTANE® ZHF 58211 NAT 01
Feature		Differentiated Halogen-free FR	Differentiated Halogen-free FR	Differentiated Halogen-free FR High Heat
Hardness	Shore	86	91A	94A
Specific Gravity	g/cm^3	1,20	1.23	1.26
Tensile at break	MPa	31	28	25
Elongation at break	%	650	632	380
Abrasion resistance	mm^3	91	65	90
Oxygen Index	%	24	25	25
Vertical Burn test	Rating	V-2 @ 1,9 mm	V-0 @ 1,9 mm	V-0 @ 1,9 mm

ESTANE®
ZHF 58202 NAT 02

- ✓ Very low conductivity + pH (EN 50620 + IEC 62893)
- ✓ Low smoke toxicity/density
- ✓ UL 1581 Sec. 1061*
- ✓ IEC 60332-1-2*
- ✓ VDE compliant
- ✓ UL 105°C rating
- ✓ UL 94 V-0 rating
- ✓ Plasticizer-free + UV-stabilized
- ✓ Low abrasion

* Depending on cable construction

ESTANE®
ZHF 58370 NAT 01

- ✓ Best low conductivity + pH (EN 50620 + IEC 62893)
- ✓ Low smoke toxicity/density
- ✓ IEC 60332-1-2*
- ✓ VDE compliant
- ✓ UL 90°C rating
- ✓ UL 94 V-2 rating
- ✓ Plasticizer-free + UV-stabilized
- ✓ Low abrasion

* Depending on cable construction

ESTANE®
ZHF 58211 NAT 01

- ✓ Superior Heat Resistance (ISO 6722)
- ✓ Very low conductivity + pH (EN 50620 + IEC 62893)
- ✓ Low smoke toxicity/density
- ✓ UL 1581 Sec. 1061*
- ✓ IEC 60332-1-2*
- ✓ VDE compliant
- ✓ UL 90°C rating
- ✓ UL 94 V-0 rating
- ✓ Plasticizer-free + UV-stabilized

* Depending on cable construction

HIGH HEAT ESTANE® TPU

Physical property	Unit	ESTANE® ZHF 58211 NAT 01	ESTANE® TS 92AP7 NAT 055
Feature		Differentiated Halogen-free FR High Heat	High heat
Hardness	°Shore	94A	92A
Specific Gravity	g/cm^3	1.26	1.21
Tensile at break	MPa	25	55
Elongation at break	%	280	400
Tear Strength	kN/m	116	80
Abrasion resistance	mm^3	90	40
Oxygen Index	%	25	24
Vertical Burn test	UL 94	V-0	V-2
UL Yellow card		NO	YES

ESTANE®

TS 92AP7 NAT055

- ✓ UL 125°C rating
- ✓ Higher Durability at elevated temperatures:
  - ✓ Automotive Class D requirements
    - ✓ – 40°C cable bending
    - ✓ Passing 3000hrs / 85°C & 85% relative humidity
    - ✓ Passing 150°C / 3000 hrs
    - ✓ Passing 175°C / 240 hrs
- ✓ RTI 95°C
- ✓ Photovoltaic cables EN 60216-1 up to DC 1,8 kV testing: Passing 120°C / 20.000 hrs
- ✓ Inherently UL 94 V-2 rating (halogen-free)
- ✓ Excellent Chemical resistance
- ✓ Very high mechanicals and abrasion resistance

ESTANE® ZHF TPU for EV C-CABLES

- EV Market
- C-cables Value Chain
- TPU in C-cables
- Portfolio

$300 Billions

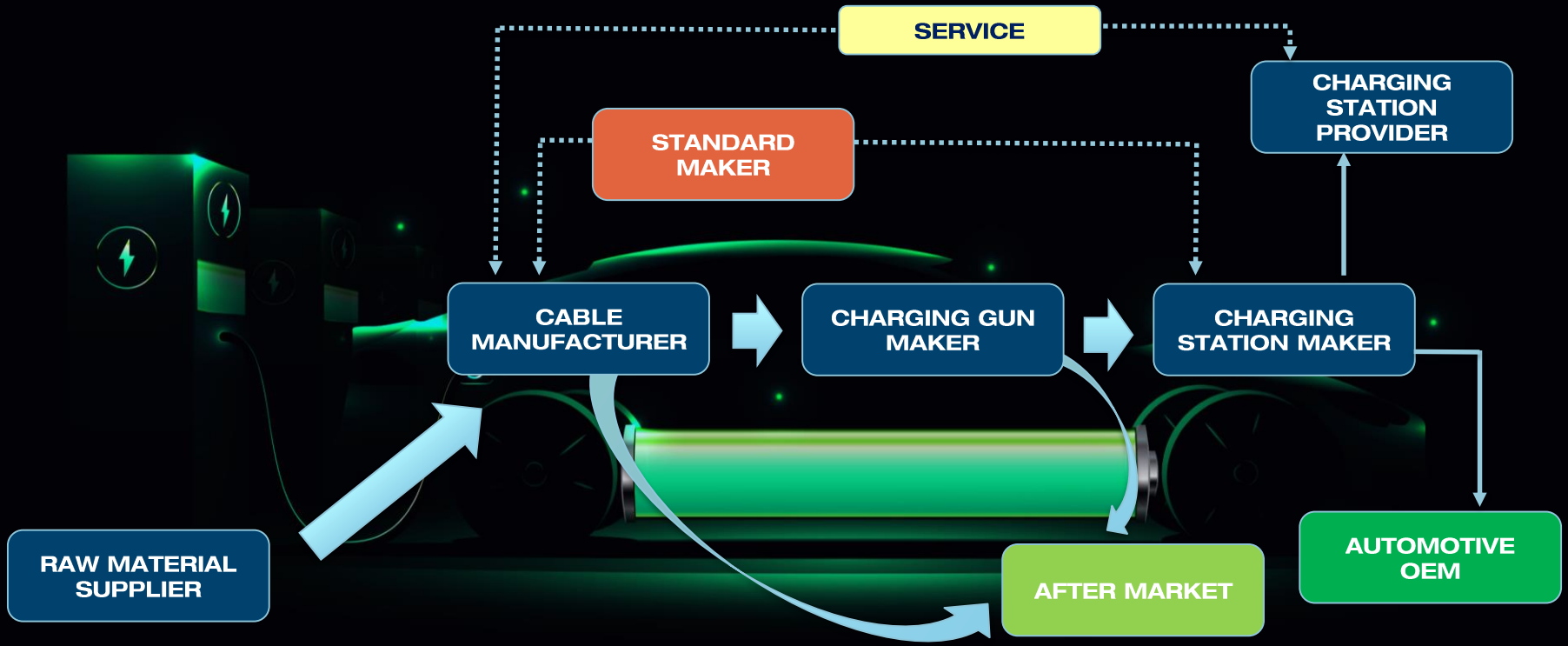
Source: REUTERS 2019

Investments in EV developments in the next 5 to 10 years will be made by car manufacturers ONLY

- About the half will be spent in China
- Not including Services & Infrastructures

More than 220 EV models available in Europe by 2021

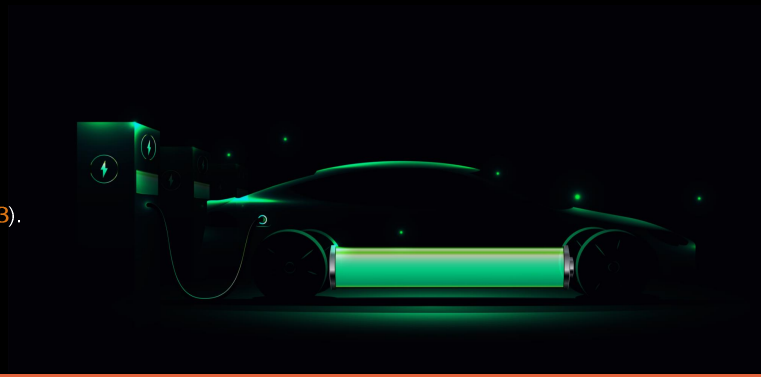
EV C-Cables Value Chain



EV Charging Cables and TPU

- As of end 2017, Europe decided to use halogen-free materials with the adoption of **EN 50620** *(Electric cables – Charging Cables for Electric Vehicles)* standard. It foresees charging modes 1 to 3.
- The international **IEC 62893** *(Charging cables for electric vehicles of rated voltages up to and including 0,6/1 kV)* standard also provides insulation materials containing halogens because of the Japanese and US influence. It also includes charging mode 4
- China uses the EN standard as a guide

- In the **EN 50620** standard, the main requirements for TPU sheathing are listed in Table 3.
- Fire-resistance test is to be according to IEC 60332-1-2
- Another very important aspect is the assessment of halogens for all non-metallic materials (Table 5, sec. 15)
  - The recommended compliance criteria given in the Annex A of IEC 60754 - 2: 2011 is a ***pH value of greater than 4.3*** and ***conductivity value of less than 10 µS/mm*** (this value has been amended to **<40 µS/mm for EN 50620** and **<35 µS/mm for IEC 62893**).



ESTANE®
EV 90AT2 NAT 01

- ✓ Low conductivity + pH (EN 50620 + IEC 62893)
- ✓ IEC 60332-1-2*
- ✓ UL 90°C rating
- ✓ Forms compact crust
- ✓ UV-stabilized
- ✓ No plasticizers

* Depending on cable construction

ESTANE® ZHF TPU for EV C-Cables

ESTANE® ZHF 58202 NAT 02

- ✓ Conductivity: 14 µS/mm
- ✓ pH value: 8,14

ESTANE® ZHF 58370 NAT 01

- ✓ Conductivity: 4 µS/mm
- ✓ pH value: 7,28

ESTANE® ZHF 58211 NAT 01 & 02

- ✓ Conductivity & pH expected similar to ZHF 58202 NAT 02 (similar chemistry)

ESTANE® EV 90AT2 NAT 01

- ✓ Conductivity: 23 µS/mm
- ✓ pH value: 8,5

- The recommended compliance criteria given in the Annex A of IEC 60754 - 2: 2011 is a pH value of >4.3 and conductivity value of <10 µS/mm (this value has been amended to <40 µS/mm for EN50620 and <35 µS/mm for IEC 62893).

Why ESTANE® ZHF grades?

- ✓ Unique and Innovative ZHF range
- ✓ Most complete portfolio for EV Charging Cables
- ✓ Fast developments
- ✓ Open to directly cooperate with Customers
- ✓ Global presence, Local contacts

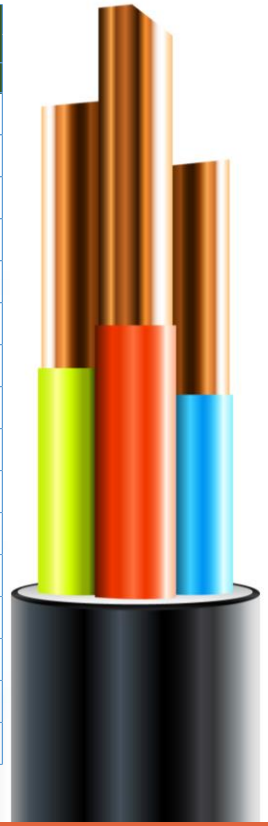
ESTANE® ZHF portfolio for the W&C Market

ESTANE® grade	Hardness	AVAILABLE	MAIN APPLICATIONS				UL-94 RATING	VDE Pass	UL TEMP RATING			
			Robotic Automation	Industrial Cables	High Heat Cables	EV Charging Cables			80°C	90°C	105°C	125°C
ZHF 58370 NAT 01	82A	YES	Y			Y	V2	Y	Y	Y		
ZHF 58202 NAT 02	89A	YES	Y			Y	V0	Y	Y	Y	Y	
ZHF 58202H NAT 02	89A	DEV	Y				V0	Y	Y	Y	Y	
ZHF 58211 NAT 01	94A	YES	Y			Y	V0	Y	Y	Y		
ZHF 58211 NAT 02	91A	DEV	Y		Y	Y	V0	Y	Y	Y		
ZHF 90AT2 NAT 055	91A	YES	Y				V2		Y	Y		
ZHF 90AT8 NAT 02	87A	YES	Y				V0	Y	Y	Y	Y	
ZHF 90AT8H NAT 02	87A	YES	Y				V0	Y	Y	Y	Y	
ZHF 90AT8L NAT 02	87A	DEV	Y				V2	Y	Y	Y	Y	
ZHF 92AT (EC14-89-x)	92A	DEV	Y				V0		Y	Y		
ZHF 85AT8 NAT 01	83A	YES		Y			V2		Y	Y		
ZHF 85AT8 MATT 01	83A	YES	Y	Y			V2	Y	Y	Y		
EV 90AT2 NAT 01	88A	DEV	Y	Y		Y	V2	Y	Y	Y		
TS 92 AP7 NAT 055	92A	YES	Y	Y	Y		V2	Y	Y	Y	Y	Y
ZHF 95AT3 NAT 055	95A	YES	Y	Y			V0		Y	Y		
58244 NAT 032	92A	YES	Y	Y			V0		Y	Y		

* Depending on cable construction

ESTANE® ZHF portfolio for the W&C Market

ESTANE® grade	Hardness	AVAILABLE	ISO 6722 CLASS	FLAME TESTS ON CABLES								EV- CHARGING CABLES			
				VDE	IEC 60332		UL 1581				UL 1666				
					IEC 60332-1 & -2	IEC 60332-3	1060 FT1	FT2	1080 VW-1	1061 CFT	RINSER	EN 50620	IEC 62893	IEC 60754-1	IEC 60754-2
ZHF 58370 NAT 01	82A	YES		Y	Y		Y	Y				Y	Y	Y	Y
ZHF 58202 NAT 02	89A	YES		Y	Y		Y	Y	Y	Y		Y	Y		Y
ZHF 58202H NAT 02	89A	DEV		Y	Y		Y	Y	Y	Y					
ZHF 58211 NAT 01	94A	YES	C	Y	Y		Y	Y	Y	Y		Y	Y		Y
ZHF 58211 NAT 02	91A	DEV	C	Y	Y		Y	Y	Y	Y		Y	Y		Y
ZHF 90AT2 NAT 055	91A	YES			Y		Y	Y		Y*					
ZHF 90AT8 NAT 02	87A	YES		Y	Y		Y	Y	Y*	Y*					
ZHF 90AT8H NAT 02	87A	YES		Y	Y		Y	Y	Y	Y					
ZHF 90AT8L NAT 02	87A	DEV		Y	Y		Y*	Y							
ZHF 92AT (EC14-89-x)	92A	DEV			Y	Y*	Y	Y	Y	Y					
ZHF 85AT8 NAT 01	83A	YES	B/C	Y	Y*			Y*							
ZHF 85AT8 MATT 01	83A	YES	C	Y	Y		Y*	Y							
EV 90AT2 NAT 01	88A	DEV		Y	Y		Y	Y		Y*		Y	Y		Y
TS 92 AP7 NAT 055	92A	YES	D	Y	Y		Y	Y							
ZHF 95AT3 NAT 055	95A	YES			Y	Y	Y	Y	Y	Y	Y				
58244 NAT 032	92A	YES			Y		Y	Y	Y	Y					



* Depending on cable construction

ESTANE® ZHF portfolio for the W&C Market

Very broad NHFR portfolio

Grades	Hardness (Shore A/D) ISO 868	Key benefits	Tensile Strength (MPa) ISO 527-2/5A/500	Elongation at break ISO 527-2/5A/500	Tear Resistance kN/m ISO 34-1B	Minimum Extrusion Temperature °C	Abrasion Resistance A/B method	Main Applications
ESTANE® ZHF 85AT8 NAT 01	82 A	Halogen-free flame retardant / Glossy surface / High mechanical properties	45	530	49	205	36 (A)	Sensors and power tools
ESTANE® ZHF 85AT8 MATT 01	84 A	Halogen-free flame retardant / Matt surface / High mechanical properties	50	550	55	190	40 (A)	Automation, sensor, power tools, drag chain and robotic cables
ESTANE® ZHF 58370 NAT 01	86 A	Halogen-free flame retardant / Hydrolysis resistance / Low Smoke / Low toxicity	31	653	49	185	91 (A)	Electric vehicles (EV) charging cables
ESTANE® ZHF 58202 NAT 02	89 A	Halogen-free flame retardant / Hydrolysis resistance / Low smoke / Low toxicity	28*	600*	55	190	65 (A)	Railway cables
ESTANE® ZHF 58202H NAT 02	91 A	Halogen-free flame retardant / Hydrolysis resistance / Low Smoke / Low toxicity	20	536	76	190	100 (A)	Automation, sensor, drag chain and robotic cables
ESTANE® ZHF 90AT8 NAT 02	89 A	Halogen-free flame retardant / Hydrolysis resistance / UV stabilized	28*	500*	54	190	38 (A)	Automation, sensor, drag chain and robotic cables
ESTANE® ZHF 90AT8H NAT 02	87 A	Halogen-free flame retardant / Hydrolysis resistant / UV stabilized	27	524	53	190	36 (A)	Automation, sensors, drag chain and robotic cables
ESTANE® ZHF 90AT0 NAT 055	90 A	Hydrolysis resistance / Halogen-free flame retardant / Transparency	58*	410*	70	190	24 (A)	Industrial cables
ESTANE® ZHF 90AT2 NAT 055	91 A	Halogen-free flame retardant / Hydrolysis resistance / Low smoke	24*	460*	72	190	49 (A)	Automation cables
ESTANE® 58244 NAT 032	92 A	Halogen-free flame retardant / Hydrolysis resistance / Low smoke	28*	580*	56	180	97 (B)	Automation and airplane cables
ESTANE® ZHF 58211 NAT 01	94 A	Halogen-free flame retardant / Heat & hydrolysis resistance / Low smoke/toxicity	25	381	100	195	90 (A)	Heat-resistant cables, Automotive Class C
ESTANE® ZHF 58211 NAT 02	92 A	Halogen-free flame retardant / Heat & hydrolysis resistance / Low smoke/toxicity	28	471	84	200	88 (A)	Heat-resistant cables, Automotive Class C
ESTANE® TS 92AP7 NAT 055	93 A	Long term high heat stability, Hydrolytic stability	60	375	103	200	39 (B)	Automotive and downhole cables
ESTANE® ZHF 95AT3 NAT 055	95 A	Halogen-free high flame retardant, Hydrolysis resistance	15*	370*	66	180	142 (A)	Data cables
ESTANE® EV 90AT2 NAT 02	90 A	Halogen-free high retardant, Hydrolysis resistance	28	520	85	200	38 (A)	Electric vehicles (EV) charging cables, Automation, Robotic cables

For more information:

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New video available from our web site:
www.lubrizol.com/Engineered-Polymers/Applications/Wire-and-Cable

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