Flame Retardant Thermoplastics '101' Webinar

Tuesday, September 20, 2022

Presented By: Cliff Watkins & Jeremy Bland

Flame Retardant Thermoplastics ‘101’ Webinar

- 41-Year Plastics Industry Veteran
- Past Owner of Custom Compounder TP Composites
- Ph.D. Chemistry
- 14 Years with PPG Fiber Glass

Cliff Watkins PhD
Direction, Application Development
(302) 528-2036 / cliff@polysource.net

- 24-Year Plastics Industry Veteran
- Pittsburg State University-Plastics
- Process Engineering Expertise
- Six Sigma Black Belt

Jeremy Bland
Materials Technology Manager
(515) 782-2056 / jeremy@polysource.net

The PolySource Webinar Series

HOW TO SURVIVE THE STRUCTURAL PA66 SHORTAGE

HOW TO IMPROVE YOUR MATERIAL SELECTION PROCESS

COMPARING NYLON-POLYAMIDES, INCLUDING SPECIALTIES

SELECTING THE RIGHT RESIN TO MEET YOUR APPLICATIONS REQUIREMENTS

RESOLVING PROCESSING AND PART PERFORMANCE ISSUES BY CHANGING MATERIALS

POLYKETONE (POK) – A MATERIAL OPTION VS EXPENSIVE AND SCARCE ENGINEERING THERMOPLASTICS

COMPARING RESIN MATERIAL TOUGHNESS AND HEAT RESISTANCE

MATERIAL OPTIONS VS SCARCE ENGINEERING THERMOPLASTICS

FLAME RETARDANT THERMOPLASTICS '101'

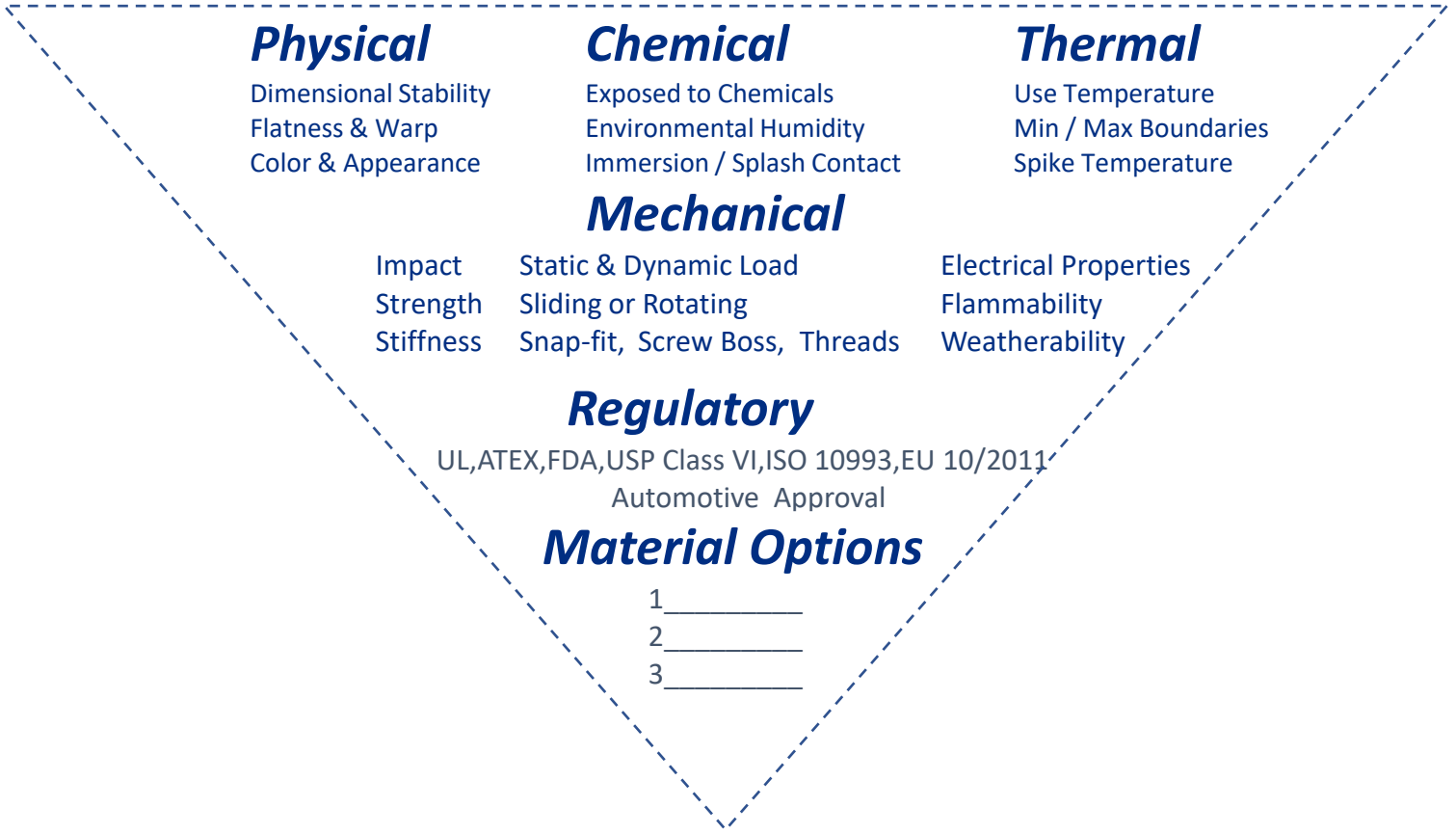
https://polysource.net/resources/?type=webinar.

Flame Retardant Thermoplastics ‘101’ Webinar

Agenda

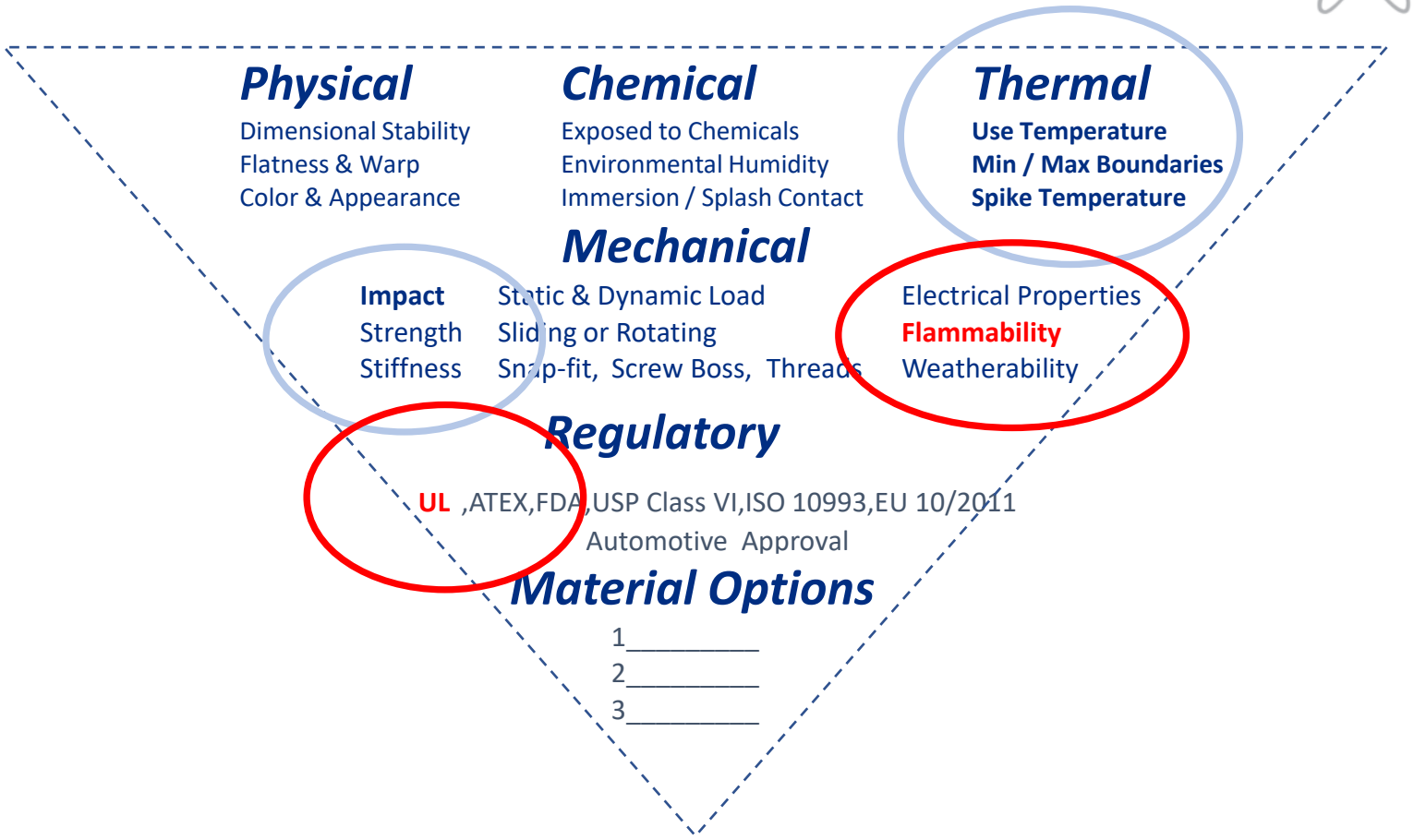
- Design / Material Selection / Processing / End Use Considerations
- Review of UL Yellow Card Ratings
- UL94 & UL 746 A Tests
- FR Additives Pros & Cons
- CA Prop 65, EU REACH, & RoHS Implications for FR Materials
- Processing Considerations for FR Resins & Compounds

The PolySource Design Funnel



Continuation of the use of ……”The PolySource Design Funnel”

The PolySource Design Funnel



Continuation of the use of ……”The PolySource Design Funnel”

UL Yellow Card Ratings

Flammability	Value	Test Method
Flame Rating		UL 94 IEC 60695-11-10, -20
1.5 mm, BG	V-0	
2.5 mm, BG	V-0, 5VA	
3.0 mm, BG	V-0, 5VA	
3.8 mm, BG	V-0	
Glow Wire Flammability Index (3.8 mm)	960 °C	IEC 60695-2-12
Glow Wire Ignition Temperature (3.8 mm)	775 °C	IEC 60695-2-13
Electrical	**Value**	**Test Method**
Hot-wire Ignition (HWI)		UL 746A
1.5 mm	PLC 3	
2.5 mm	PLC 3	
3.0 mm	PLC 2	
High Amp Arc Ignition (HAI)		UL 746A
1.5 mm	PLC 0	
2.5 mm	PLC 1	
3.0 mm	PLC 1	
Comparative Tracking Index (CTI)	PLC 2	UL 746A
Dielectric Strength	24 kV/mm	ASTM D149
High Voltage Arc Tracking Rate (HVTR)	PLC 3	UL 746A
Volume Resistivity	1.0E+15 ohms·cm	ASTM D257 IEC 60093
Arc Resistance	PLC 6	ASTM D495
Thermal	**Value**	**Test Method**
RTI Elec		UL 746B
1.5 mm	125 °C	
2.5 mm	125 °C	
3.0 mm	125 °C	
3.8 mm	125 °C	
RTI Imp		UL 746B
1.5 mm	115 °C	
2.5 mm	115 °C	
3.0 mm	115 °C	
3.8 mm	115 °C	
RTI Str		UL 746B
1.5 mm	125 °C	
2.5 mm	125 °C	
3.0 mm	125 °C	
3.8 mm	125 °C	
Deflection Temperature Under Load		ISO 75-2/A
1.8 MPa, Unannealed	137 °C	
Physical	**Value**	**Test Method**
Dimensional Change	0.0 %	ASTM D1042 ISO 2796
Outdoor Suitability	f1	UL 746C

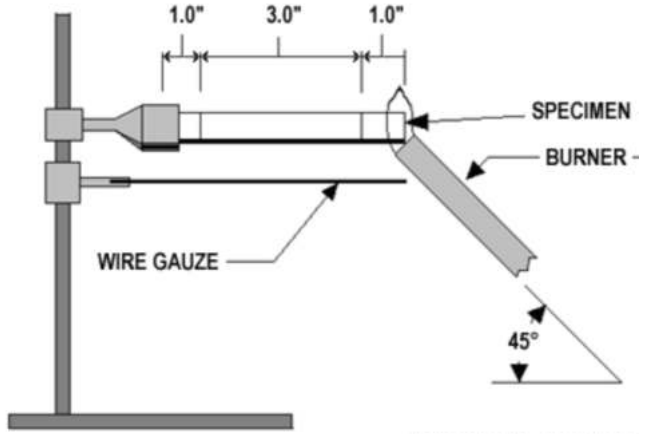
UL Testing & Ratings

- UL94 – Vertical & Horizontal Flame Tests
  - Short-term tests
  - Thickness dependent
- UL746 A – Electrical Energy Tests
  - Short-term tests
  - Some are thickness dependent
- UL746 B – Thermal Ratings (RTI's)
  - Long-term tests
  - For V rated grades, must retain V rating
  - Estimates 100,000 hr performance at elev. temperature
- UL746 C – UV Resistance
  - Long-term test
  - Estimates 5-year UV exposure
  - For V rated grades, must retain V rating

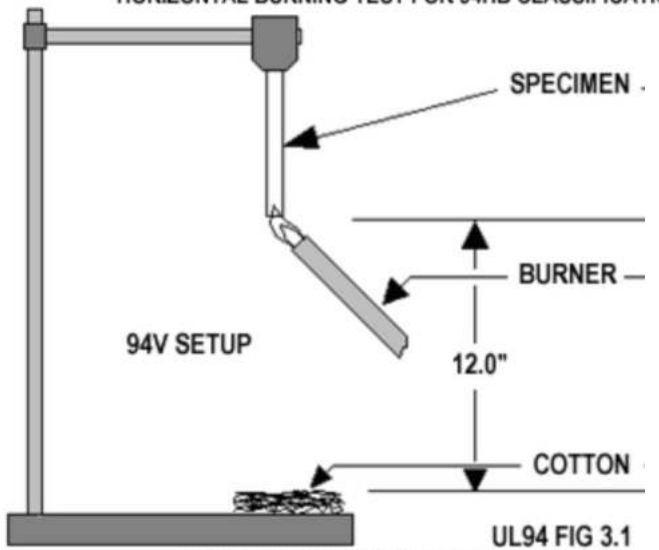
UL Ratings are A La Carte & the Costs Add Up

UL-94 / ASTM D635 / ISO 3795 / FMVSS302 Flame Ratings

Class	Orientation of Test Sample	Definition	Time of Burn Allowed	Particle Drop Allowed		plaque Holes
				Flaming	Non-Flaming	
UL 94 HB	Horizontal	Slow Burning	Burning rate of less than 76mm/min for a specimen less than 3mm thick and burning stops before 100mm			
UL 94 V-2	Vertical	Burning Stops	30 seconds	Yes	Yes	
UL 94 V-1	Vertical	Burning Stops	30 seconds	No	Yes	
UL 94 V-0	Vertical	Burning Stops	10 seconds	No	Yes	
UL 94 5VB	Vertical	Burning Stops	60 seconds	No	No	Yes
UL 94 5VA	Vertical	Burning Stops	60 seconds	No	No	No



HORIZONTAL BURNING TEST FOR 94HB CLASSIFICATION



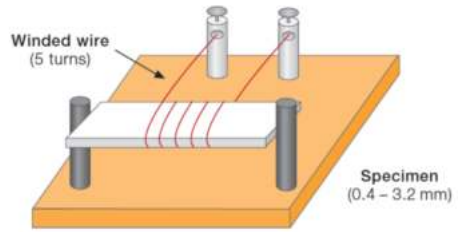
VERTICAL BURNING TEST FOR 94V

Flammability Resistance to an Open Flame

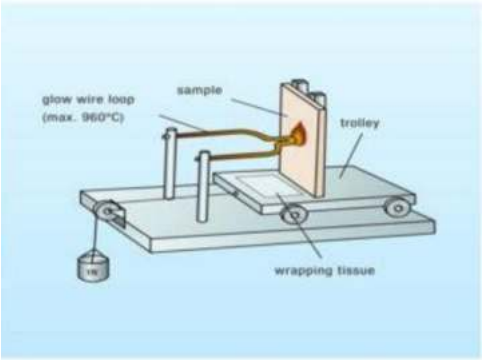
UL-746A Electrical Ratings

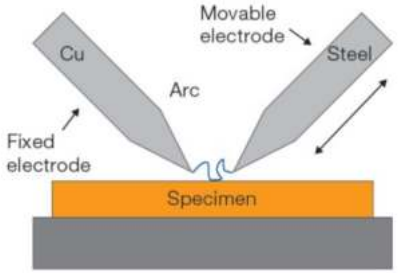
			Units
HWI	Hot Wire Ignition	# of seconds to ignite or burn through the sample	seconds
HAI	High Amp Arc Ignition	# of arc ruptures to ignite the sample	# of arcs
HVTR	High Voltage Arc Tracking Rate	rate at which a tracking path is created	mm/min
D-495	Arc Resistance	seconds of resistance to form a conducting path	seconds
CTI	Comparative Tracking Index	voltage which causes tracking	voltage
GWFI	Glow Wire Flammability Index	highest Temp after 30 seconds sample does not ignite	°C
GWIT	Glow Wire Ignition Temperature	Lowest Temperature at which the material ignites and burns > 5 seconds	°C

Not thickness dependent



Hot Wire Ignition Test (HWI)





Flammability Resistance to an Electric Arc or Heated Wire

UL-746A Performance Level Category (PLC) Ratings

PLC Ratings	Units	0	1	2	3	4	5	6	7
HWI	seconds	≥ 120	60 - 119	30 - 59	15 - 29	7 - 14	< 7		
HAI	# of arcs	≥ 120	60 - 119	30 - 59	15 - 29	< 15			
HVTR	mm/min	0 - 10	10.1 - 25.4	25.5 - 80	80.1 - 150	> 150			
D-495	seconds	≥ 420	360 - 419	300 - 359	240 - 299	180 - 239	120 - 179	60 - 119	< 60
CTI	voltage	≥ 600	400 - 599	250 - 399	175 - 249	100 - 174	< 100		

Lower PLC Ratings are Better

UL-746B Relative Thermal Index (RTI)

- RTI Ratings are Continuous Use Temperatures, at which a plastic is estimated to retain > 50% of initial values, after 100,000 hours (at that temperature), under zero load (stress, pressure, force etc.)

- Actual test times at UL range from 500 to 5000 hours, to collect the raw data

- Multiple temperature, linear regression analysis is used to plot the data to an extrapolated 100,000 hr result

- There are three (3) RTI values that can be assigned
  - RTI Electrical, retention of dielectric strength (electrical insulation)
  - RTI Impact, retention of either tensile impact or Notched Izod impact
  - RTI Strength, retention of tensile stress
  - FR materials must retain their V rating after the heat aging cycle

- A generic RTI is assigned to UL Listed materials, when long term testing has not been conducted

RTI's are VERY Expensive to Obtain, & Many Applications Don't Need Them

UL-746C Weathering: f1 and f2

- Simulated outdoor weathering is conducted using either a carbon electrode UV or Xenon arc UV source for 700-1000 hours
- Samples are then immersed in water for 168 hours at 70 ^{o}C
- FR performance, tensile stress and Notched Izod impact are measured before & after the exposure sequence
- An f1 rating is assigned when the mechanical & FR performance are retained after both UV & water immersion
- An f2 rating is assigned when either the UV or immersion performance is retained

Weathering Tests at UL Can Take as Long as 8-10 Months to Complete Due to Capacity Constraints

Three Main Categories for Flame Retardant Plastics:

- Inherently FR
- Halogenated
- Non-Halogenated

Lots of Choices with Plenty of Trade-Offs

Inherently FR

Pros

- PPS, PEI, Fluoropolymers, PPSU & certain PC's
- Do not require nor contain external FR additives
- Suitable for food contact
- These are ideal from a regulatory standpoint, for REACH and RoHS compliance
- Excluding PC, these are all low smoke generating materials too

Cons

- Cost per lb.
- They are a challenge to mold
- Most fluoropolymers require corrosion resistant metal alloys ($$$) for all surfaces in contact with the melt

Halogenated FR

REACH & RoHS

- EU regulators will likely ban all brominated FR additives when suitable non-hal options exist
- Brominated additives have been shifting to polymeric and oligomeric grades and away from ‘small molecule’ types

Pros

- Bromine and AO are extremely efficient
- REACH inadvertently pushed Bromine FR technology to better & better thermal resistance
- Diminished plate-out & blooming

Cons

- Significantly increase material density
- Mold corrosion & machine wear
- Smaller processing window

Non-Halogenated FR Additives

- Phosphate Esters
  - *FR PC/ABS*
- Alumino-Phosphate Salts
  - *Polyamides, Polyesters*
- Amino-Phosphate Blends
  - *Polypropylenes & Polyethylenes*
- Red Phosphorus
  - *Polyamides*
- Magnesium & Aluminum Hydroxides
  - *Polypropylenes & Polyethylenes*

Non-Halogenated FR Additives

Pros

- Lower material density in most cases
- Reduced concerns on machine corrosion
- Processing friendly

Cons

- Polyolefins require high loadings of non-hal which degrades mechanical & processing performance
- Supply constraints for multiple reasons
- Cost per lb. is generally higher

Flame Retardant Thermoplastics ‘101’ Webinar

PolySource

LATI | Flame retardant additives

DENSITY	**LOW**	HIGH	MEDIUM	MEDIUM	**LOW**
MECHANICAL PROPERTIES	**GOOD**	LOW	GOOD	MEDIUM	**GOOD**
LOI (%)	27 - 30	>35	24 - 30	**40 - 45**	**36-45**
ASPECT/COLOUR	**RED or DARK**	**EASY COLOURABLE**			+/-

RoHS COMPLIANT

REACH COMPLIANT

FR Options to Meet Most Designs

Flame Retardant Thermoplastics ‘101 Webinar

PolySource

LATI | **Comparing Flame retardant compounds solutions**

PROPERTIES				PA66 GF30	LATAMID 66 H2 G/25-V0		
					CT1	HF1	KB3
Density		ISO 1183	g/cm3	1,36	1,58	1,4	1,33
Shrinkage	**Longitudinal** **Transversal**	ISO 294-4	%	0,5/0,9	0,45 0,85	0,55 0,95	0,5 0,85
Charpy notched 23°C		ISO 179-1eA	kJ/m²	10	7	8	10
Tensile Strength at break		ISO 527 23°C	Mpa	185	135	140	135
Elongation			%	3,2	2,1	3	2,2
Modulus			Mpa	9 400	9 200	8 500	8 200
HDT 1,81 MN/m2		ISO 75	°C	245	240	235	225
Oxygen Index Limit		ASTM D2863	%	27	35	32	26
Flammability Rating		UL94-V0	mm	HB	0,4	0,75	1,5
GWFI		IEC-695-2-12	°C	-		960	
GWIT		IEC-695-2-13		-	900	775	-
Comparative Tracking Index		IEC 112	Volt	500	400	600	600

There’s No Free Lunch When Selecting FR & Electrical Performance

Regulatory Considerations for FR Plastics

REACH

- Targets specific chemicals, mixtures & compounds
- EU regulators will likely ban all brominated FR additives when suitable non-hal options exist
- Brominated additives have been shifting to polymeric and oligomeric grades & away from ‘small molecule’ types

RoHS

- Targets specific additives & chemicals used in Electrical & Electronic devices
- Aimed at end-of-line considerations and keeping hazardous materials out of landfills

CA Prop 65

- Antimony oxide is listed
- (so too, is “alcoholic beverages”, “Tamoxfen”, “Cisplatin”)

Lots of Choices with Plenty of Trade-Offs

Processing Considerations for FR Plastics

- Drying FR Polymers
- Thermal Stability Concerns
  - Halogenated/Non-Hal
  - Actual Melt Temperature vs. Non-FR Grades
  - Barrel Residence Time
  - Hot Runner Systems
  - Back Pressure
  - Screw Recovery
- Importance of Proper Venting in the Mold
  - Designed In, Not an Afterthought!
  - ½” Wide Every 2” of Parting Line
- Tooling, Screw & Barrel Materials / Coatings
  - General Purpose Design
  - Stainless Steel
  - Chrome Plating/Titanium Nitride Coatings (Mold)
  - Beryllium Copper
- Gates & Runners
- Mold Maintenance / Cleaning / Purging
- Regrind?

Lots of Choices with Plenty of Trade-Offs

Flame Retardant Thermoplastics ‘101’ Webinar

PolySource

ForTii in Internal Functional MCCB components Electrical & Electronics - F11

Customer needs and Market trends:

- ForTii F11 meets all the stringent requirements for tripping bars, tripping unit parts and chamber materials, where thermo-mechanical and electrical performance are essential

Key benefits of ForTii:

- Excellent dielectric aging performance at 150 °C
- High CTI values at 600 volts
- very high HDT and Hal Free V0 from 0,2mm onwards
- Improved surface aesthetics

Application	Internal Functional MCCB Components
Preferred ForTii (Ace) grades	F11, TX1

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

High Heat / High Voltage Resistance / Thick Wall Design

Flame Retardant Thermoplastics ‘101’ Webinar

Stanyl in E-motors
Automotive - TW241F6, TE250F6

Customer needs and Market trends:

- Increase Power density: High flow-thin wall, high toughness and High HDT-A
- Use/assembly: Snap fit designs, no flash, Good mechanics, High CTI
- Water cooled molds: Higher temperatures Class H (<180 °C) vs PA66 GF (Class F < 155 °C)
- Noise Reduction/Lifetime: Move from brushed to Brushless motors
- Lifetime: ATF Chemical Resistance/heat aging CUT at 160-180 °C (E vs W stabilized)

Key benefits of Stanyl:

- High Flow, High Toughness, ATF resistance
- Excellent High temperature and creep resistance
- UL1446 Class H at 0,35 mm thickness (HB & V0).
- High CTI > 500 V and best in class mechanics

Application	HB	V0	Super Flow	Stiffness
Preferred Stanyl grades	TW241F6, TW200F6, TE200F6	TE250F6	TW341, 46SF5030	TW241F10

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

PA4/6 Solutions in HB & V-0 Compositions

Flame Retardant Thermoplastics ‘101’ Webinar

PolySource

Akulon in MCB Housings/ Enclosures Electrical & Electronics - K-FKGV4

Customer needs and Market trends:

- Producers of low voltage switchgear (LVSG) are turning to more environmentally friendly solutions
- Halogen-free flame retardant Polyamide 6 (PA6).
- Laser Marking ability
- Solid state base circuit breakers

Key benefits of Akulon:

- 80% better flow*
- 25% reduced Injection molding cycle time*
- Lower process temperatures
- Halogen and Phosphorus free
- Meets UL94 VO

Application	MCB Housings/ Enclosures
Preferred Akulon grades	K-FKGV4

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Flame Retardant Thermoplastics ‘101’ Webinar

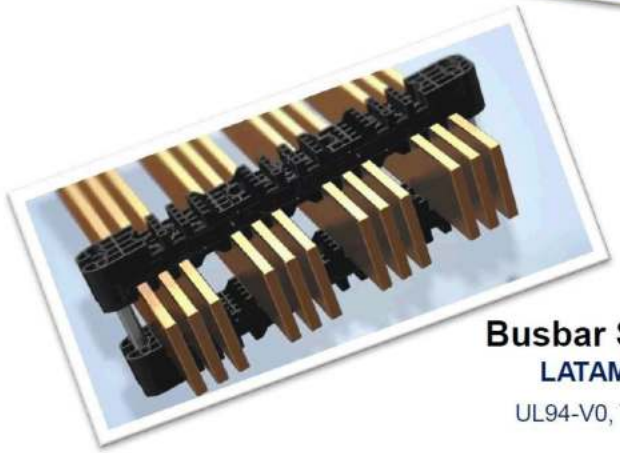
PolySource

LATI | PAs - E&E

Cover NH-Disconnector
LATAMID 66 H2 G/25-V0KB3
UL94-V0 1,5mm, Yellow card
GWFI 960°C

High voltage switch
LATAMID 66 H2 G/50-V0HF1
UL94-V0
Dimensional stability
High stiffness
Halogen free
CTI 600V

Motor brush rod
LATAMID 66 H2 G/50-GWHF1
GWFI 960°C
Dimensional stability
High stiffness
Halogen free



Busbar Support System
LATAMID 6 H2 G/30-V0HF1
UL94-V0, Yellow card, GWFI 960°C
Flowability
Halogen free
CTI 600V

Different FR Technologies to Deliver the Best Design Solution

Flame Retardant Thermoplastics ‘101’ Webinar

PolySource

LATI | PBT - Industrial switches

Switch
LATER 4 G/30-V0HF1

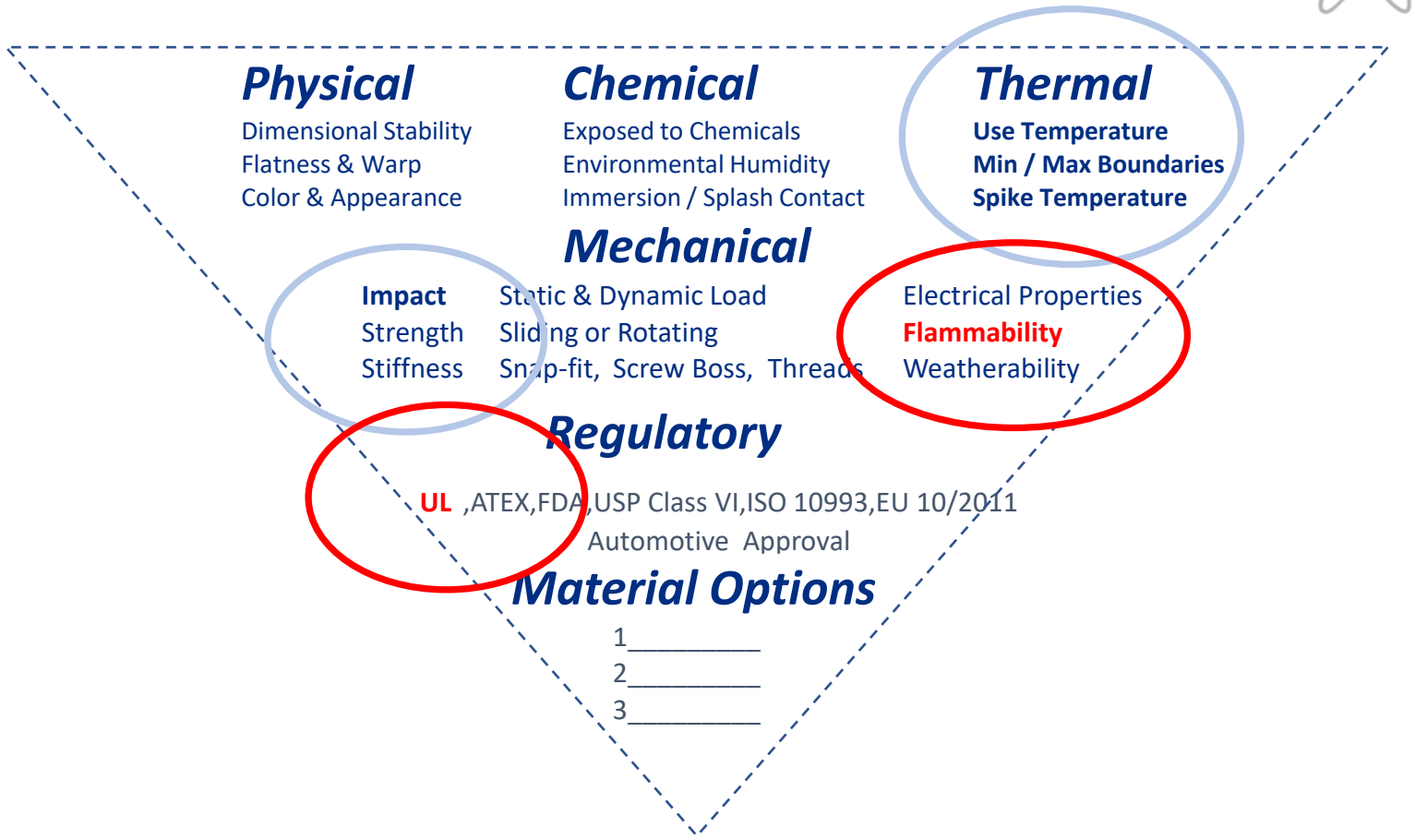
UL94-V0, Yellow card
Dimensional stability
Halogen free
CTI 600V

Safety limit switch
LATER 4 G/30-V0

UL94-V0, Yellow card
Dimensional stability
Colourability

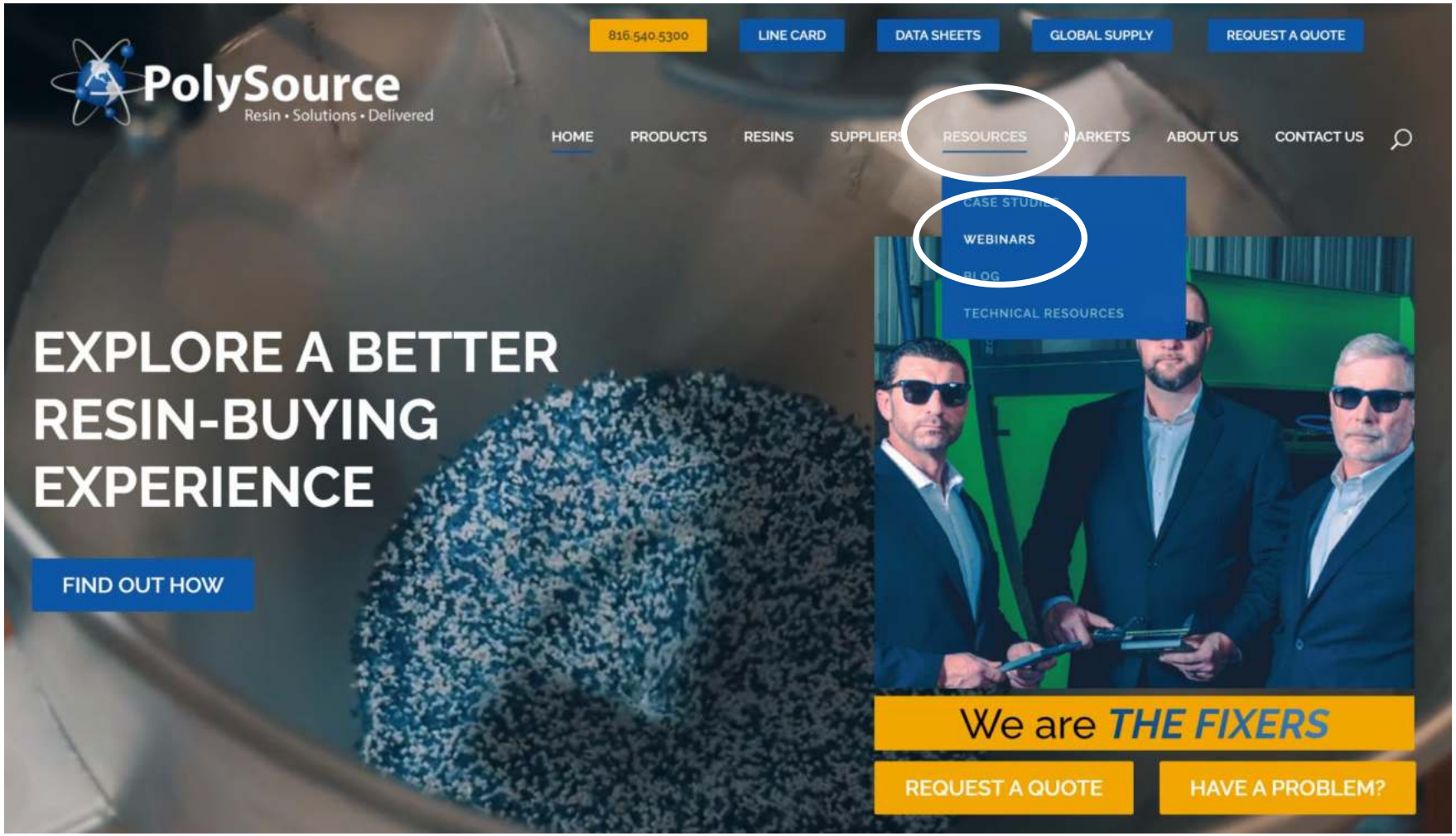
Non-Hal FR’s are Preferred for Consumer Appliances in the EU

The PolySource Design Funnel



Continuation of the use of ……”The PolySource Design Funnel”

Today's Webinar



Please Find the Presentation @www.polysource.net/resources/webinars

The PolySource Webinar Series

HOW TO SURVIVE THE STRUCTURAL PA66 SHORTAGE

HOW TO IMPROVE YOUR MATERIAL SELECTION PROCESS

COMPARING NYLON-POLYAMIDES, INCLUDING SPECIALTIES

SELECTING THE RIGHT RESIN TO MEET YOUR APPLICATIONS REQUIREMENTS

RESOLVING PROCESSING AND PART PERFORMANCE ISSUES BY CHANGING MATERIALS

POLYKETONE (POK) – A MATERIAL OPTION VS EXPENSIVE AND SCARCE ENGINEERING THERMOPLASTICS

COMPARING RESIN MATERIAL TOUGHNESS AND HEAT RESISTANCE

MATERIAL OPTIONS VS SCARCE ENGINEERING THERMOPLASTICS

FLAME RETARDANT THERMOPLASTICS '101'

https://polysource.net/resources/?type=webinar.

Special Thanks to:

Peter Schmieg

Philippe Ciniello

Samir Mutwalli

Special Thanks for the Application Photos & Very Helpful Discussions?!

Thank You for Joining the Discussion Today!!

- 39-Year Plastics Industry Veteran
- Past Owner of TP Composites- bought by Techmer PM in 2013
- Ph.D. Chemistry
- 14 Years with PPG Glass

Cliff Watkins PhD
Direction, Application Development
(302) 528-2036 / cliff@polysource.net

- 22-Year Plastics Industry Veteran
- Pittsburg State University-Plastics
- Process Engineering Expertise
- Six Sigma Black Belt

Jeremy Bland
Materials Technology Manager
(515) 782-2056 / jeremy@polysource.net

QUESTIONS????