ENGINEERED PLASTICS WORKSHOP

Learn About Thermoplastics | Connect with Experts

2017 KING OF PRUSSIA / PENNSYLVANIA
(PHILADELPHIA AREA)

YOUR GLOBAL COMPOUNDER OF
CUSTOM ENGINEERED THERMOPLASTICS

RTP Co.
Imagineering Plastics®

Imagineering Plastics®

Introduction to RTP Company: Your Global Compounder of Custom Engineered Thermoplastics

Bob Williams | Regional Sales Manager
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(484) 459-1608

8:00 a.m.

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

RTP Company

Your Global Compounder of Custom Engineered Thermoplastics

Bob Williams
Regional Sales Manager

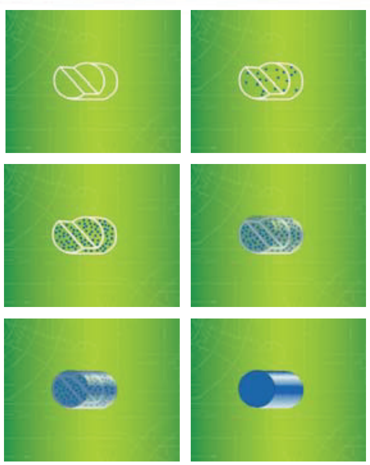
rtpcompany.com • rtp@rtpcompany.com

ABOUT RTP COMPANY

RTP Company is an **independent, privately owned** thermoplastics compounder with **global** manufacturing, engineering support, and sales representation.

- 1,500+ employees
- $600+ million annual sales

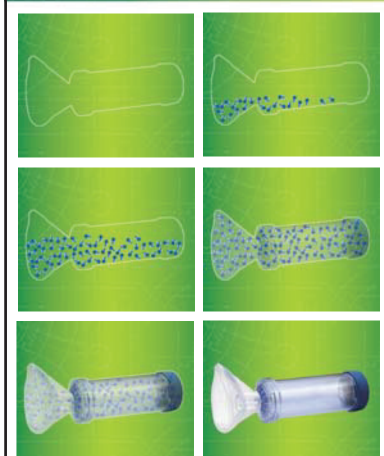
CUSTOM SOLUTIONS



High-Tech Compounds to Unfilled Resins

- 60+ resins
- 100s of modifiers
- Broadest range of competitive compounds (From talc polypropylene to nanotube PEEK)

CUSTOM SOLUTIONS



High-Tech Compounds to Unfilled Resins

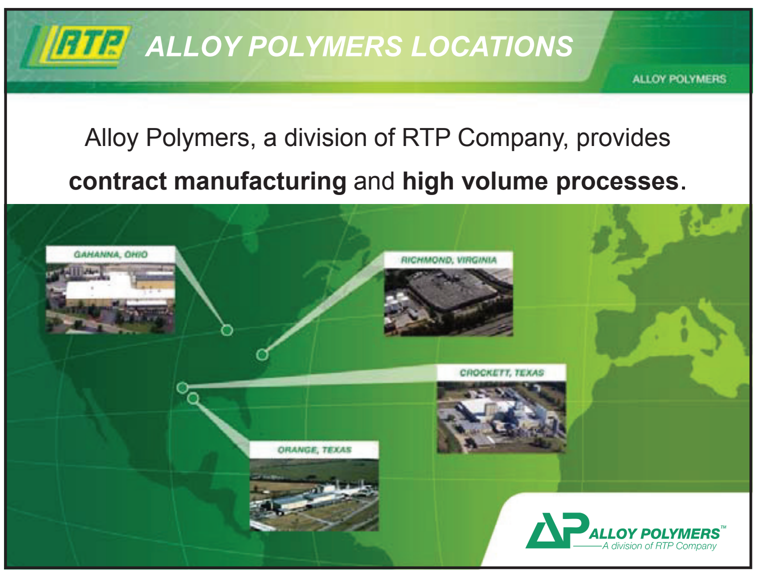
- 60+ resins
- 100s of modifiers
- Broadest range of competitive compounds (From talc polypropylene to nanotube PEEK)

Annual Production

- 6,000+ commercial products
- 1,750+ new products per year


GLOBAL MANUFACTURING
RTP Company operates **18 production plants** and has sales offices in major commerce centers around the world.


GLOBAL MANUFACTURING
RTP Company is a global compounder of **custom engineered thermoplastics**.
WINONA, MINNESOTA
HENDERSON, KENTUCKY
LADENBURG, GERMANY
SUZHOU, CHINA
SOUTH BOSTON, VIRGINIA
BEAUNE, FRANCE
SHENZHEN, CHINA
INDIANAPOLIS, INDIANA
SINGAPORE
MONTERREY, MEXICO
FORT WORTH, TEXAS


ALLOY POLYMERS LOCATIONS
ALLOY POLYMERS
Alloy Polymers, a division of RTP Company, provides **contract manufacturing** and **high volume processes**.
GAHANNA, OHIO
RICHMOND, VIRGINIA
CROCKETT, TEXAS
ORANGE, TEXAS
ALLOY POLYMERS
A division of RTP Company


WIMAN LOCATIONS
WIMAN
Wiman Corporation, a wholly-owned subsidiary of RTP Company, produces customized, high quality **plastic films** and **film laminates.**
SAUK RAPIDS, MINNESOTA
DUPO, ILLINOIS
Wiman

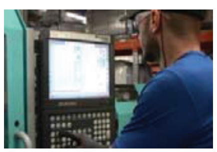
ESP™ LOCATIONS

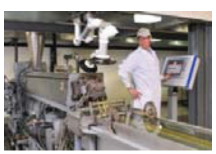
Engineered Sheet Products™ (ESP™), a division of RTP Company, manufactures **specialty engineered sheet**.

RESMART LOCATION

RTP Company partners with ResMart, a distributor of **off-the-shelf, unfilled resins**.

OUR GOAL





Our goal is to satisfy our customers with solutions, providing…

- Technology
- Flexibility
- Speed

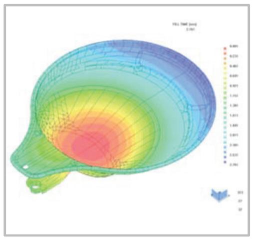
WE ARE INDEPENDENT

Our **independence** allows us to be **objective** in…

- Raw materials
- Formulations
- Solutions

PRODUCT DEVELOPMENT / R&D

Our **development services**
are available in each region of the world, and include:



- Application development
- Product development
- Process development
- CAE support
- Pilot Plant production

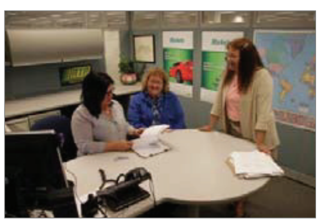
TECHNICAL SERVICE

RTP Company has **20+ Technical Service Engineers and Specialists** worldwide, that provide:

- Plastic processing trials
  Injection, extrusion, compression, film, and blow molding trials
- Process optimization
- Problem resolution
- Customer trials and samples

CUSTOMER SERVICE

RTP Company has **30+ Customer Service Representatives** worldwide, who are dedicated to serving you.



- Regionally located, experienced representatives for real-time service
- Deliver personalized attention to each order
- Dedicated to your account, serving as an extension of your team

Each year, RTP Company measures how satisfied customers are with the accessibility and helpfulness of their RTP Company Customer Service Representative. **In 2016, 86% of respondents indicated that they were satisfied with the service they received.**

GLOBAL COMPOUNDING

ISO 9001 REGISTERED FACILITIES

We develop it anywhere…

make it anywhere…

and support it everywhere!

- Scalability: Develop your solution on a small scale and produce your solution in large quantities
- Plant-to-plant consistency
- ISO: 9001:2008 registered facilities


RTP
PRODUCT FAMILIES
Compounds formulated to meet performance requirements, from one property to multiple technologies
Color
Conductive
Flame Retardant
Thermoplastic Elastomers
Structural
Wear Resistant
Film - Wiman
Sheet - ESP™


RTP
RESMART
RESMART
ResMart
Plastics Your Way
Looking for unfilled plastic resins?
We partner with ResMart to fulfill your needs!
www.resmart.com
ResMart Resins:
Ultra, Plus, and Utility grades:
• Polypropylene
• Nylon 6, 6/6
• Clear Nylon (Amorphous Nylon)
• Polycarbonate
• SAN
• ABS
• Polystyrene
• Clear ABS (MABS)
• ACETAL
• PBT
• Polypropylene
• ASA
• Black Masterbatch
• TPU
Specialty grades:
• Solvay Udel® PSU
• Solvay Radel® PPSU
• Solvay Ketaspire® PEEK


RTP
MARKETS
Appliances
Automotive
Business & Cash Machines
Construction & Agriculture
Consumer
Defense & Aerospace
Energy
Electrical/Electronics
Electronic Packaging & Data Storage
Industrial
Medical
Sports & Leisure


RTP
YOUR GLOBAL COMPOUNDER
RTP Company is your global compounder of custom engineered thermoplastics… and much more!


COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR
Thank You!
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ESP
Hueforia
Wiman

Introduction to Engineered Thermoplastics

Steve Maki | VP of Technology
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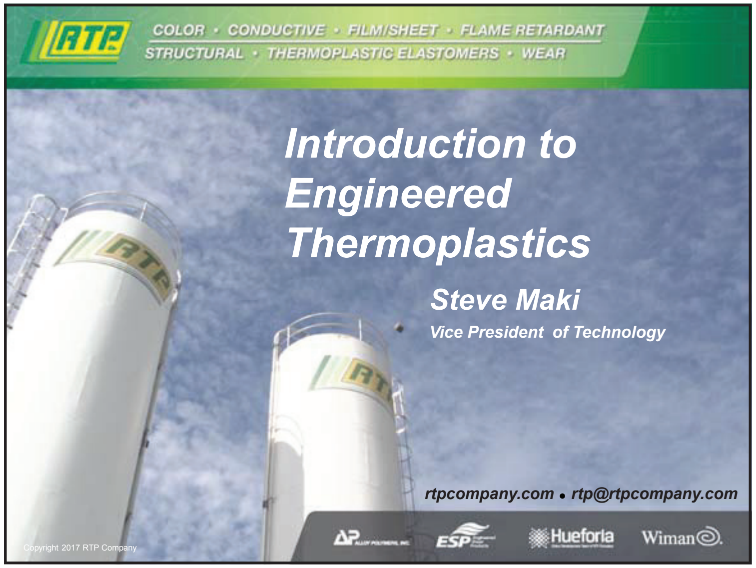
8:15 a.m.



AGENDA

1. Define Compounding
2. Plastic Resin Selection Process
3. Application Case Studies
4. Compounding To Enhance Performance
5. New RTP Company Technologies

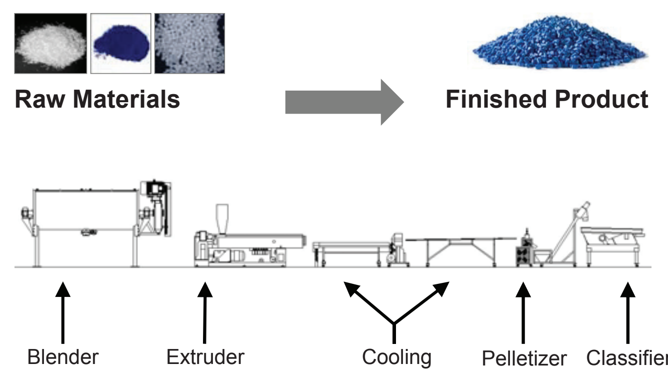
INDEPENDENT SPECIALTY COMPOUNDER

Compounder → We blend thermoplastic resins with fillers, additives, and modifiers

Specialty → We create engineered formulations

Independent → We are unbiased in our selection of raw materials

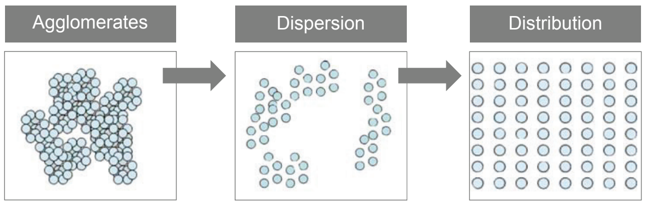
COMPOUNDING PROCESS



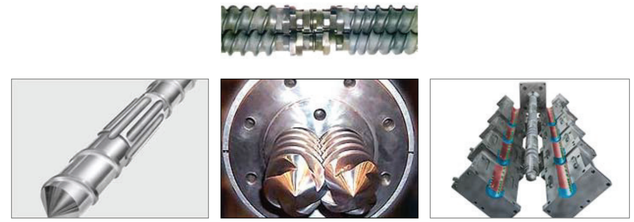
COMPOUNDING OBJECTIVES

Mixing

- Dispersive
- Distributive



COMPOUNDING EXTRUDERS

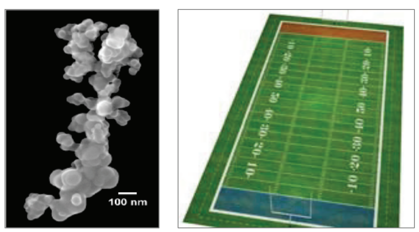


Single Screw

Twin Screw

Co-Kneader

PUTTING COMPOUNDING INTO PERSPECTIVE



- Conductive carbon black surface area = 130 m^2/gram
- 34 grams carbon black = surface area of football field (4460m^2)
- Dispersing a 20% carbon black compound is similar to evenly coating a football field with 136 grams of plastic!

Resin Selection

THE DILEMMA

60 thermoplastic resins + 100 additives = 1000's of potential compounds

Which ONE Do I Choose For My Application???

PLASTIC SELECTION PROCESS

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

PLASTIC SELECTION PROCESS

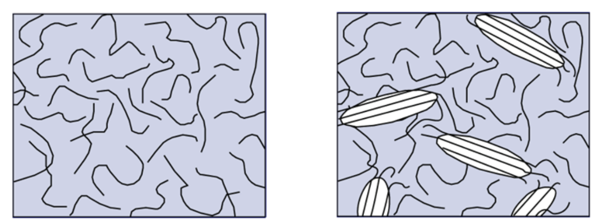
***Step 1:* Use Resin Morphology**

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

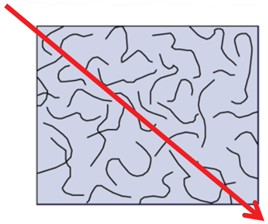
MORPHOLOGY

The form and structure the molecules of a polymer take upon solidification

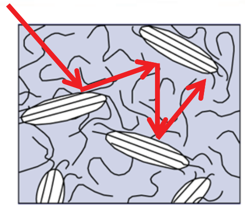


Amorphous Semi-Crystalline

MORPHOLOGY



Amorphous

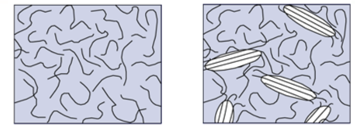


Semi-Crystalline

Compare

- Molecular packing (shrinkage)
- Resistance to molecular disentanglement (chemical/abrasion resistance)
- Melting characteristics (flow)
- Light refraction (opacity)

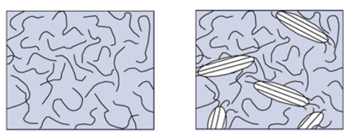
MORPHOLOGY CHARACTERISTICS



	Amorphous	Semi-Crystalline
Low Shrinkage	X	
Low Warpage	X	
Tight Tolerances	X	
Transparency	X	
Mold Flow Ease		X
Chemical Resistance		X
Wear Resistance		X

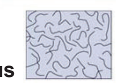
MORPHOLOGY CHARACTERISTICS

Lens?
Fuel Float?
Precision Printer Chassis?
Tool Housing?
Multiple Pin Connector?
Pulley?
Grease Fitting?
Laptop Cover?



	Amorphous	Semi-Crystalline
Low Shrinkage	X	
Low Warpage	X	
Tight Tolerances	X	
Transparency	X	
Mold Flow Ease		X
Chemical Resistance		X
Wear Resistance		X

MORPHOLOGY OF THERMOPLASTICS

Amorphous 

- Polyetherimide (PEI)
- Polyethersulfone (PES)
- Polysulfone (PSU)
- Amorphous Nylon
- Polycarbonate (PC)
- Acrylic (PMMA)
- Acrylonitrile Butadiene Styrene (ABS)
- Styrene Acrylonitrile (SAN)
- High Impact Polystyrene (HIPS)
- Polystyrene (PS)

Semi-Crystalline 

- Polyetheretherketone (PEEK)
- Polyphenylene Sulfide (PPS)
- Polyphthalamide (PPA)
- Polyamide (PA/Nylons)
- Polybutylene Terephthalate (PBT)
- Polyethylene Terephthalate (PET)
- Acetal (POM)
- Polylactic Acid (PLA)
- Polypropylene (PP)
- Polyethylene (HDPE, LDPE, LLDPE)

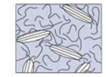
PLASTIC SELECTION PROCESS

Step 1: Use Resin Morphology

***Step 2:* Use Thermal & Cost Requirements**

Step 3: Fine Tune & Special Features

MORPHOLOGY VS. THERMAL/COST

Amorphous 	Semi-Crystalline 
Polyetherimide (PEI)	Polyetheretherketone (PEEK)
Polyethersulfone (PES)	Polyphenylene Sulfide (PPS)
Polysulfone (PSU)	Polyphthalamide (PPA)
Amorphous Nylon	Polyamide (PA/Nylons)
Polycarbonate (PC)	Polybutylene Terephthalate (PBT)
Acrylic (PMMA)	Polyethylene Terephthalate (PET)
Acrylonitrile Butadiene Styrene (ABS)	Acetal (POM)
Styrene Acrylonitrile (SAN)	Polylactic Acid (PLA)
High Impact Polystyrene (HIPS)	Polypropylene (PP)
Polystyrene (PS)	Polyethylene (HDPE, LDPE, LLDPE)

Thermal & Cost Increases ↑

Commodity (<$1.50) • Engineered ($1.50-$4.00) • High Performance (>$4.00)

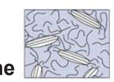
PLASTIC SELECTION PROCESS

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

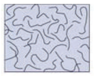
***Step 3:* Fine Tune & Special Features**

ENGINEERED & COMMODITY RESINS

Amorphous 	Semi-Crystalline 
Amorphous Nylon	Polyamide (PA/Nylons)
Polycarbonate (PC)	Polybutylene Terephthalate (PBT)
Acrylic (PMMA)	Polyethylene Terephthalate (PET)
Acrylonitrile Butadiene Styrene (ABS)	Acetal (POM)
Styrene Acrylonitrile (SAN)	Polylactic Acid (PLA)
High Impact Polystyrene (HIPS)	Polypropylene (PP)
Polystyrene (PS)	Polyethylene (HDPE, LDPE, LLDPE)

Commodity (<$1.50) • Engineering ($1.50-$4.00)

AMORPHOUS RESINS

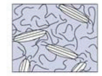


Morphology Features -- Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent (except HIPS & ABS), Poor Chemical & Abrasion, Poor Flow in Thin Mold Sections

Amorphous	Special Features
Amorphous Nylon	Transparent/good chem. resistance
Polycarbonate (PC)	Optical transparency/high impact
Acrylic (PMMA)	Optical transparency/UV stable
Acrylonitrile Butadiene Styrene (ABS)	High impact/high gloss/opaque
Styrene Acrylonitrile (SAN)	Transparent/mod. chem. resistance
High Impact Polystyrene (HIPS)	Moderate impact/opaque
Polystyrene (PS)	Transparent/brittle

Commodity (<$1.50) • Engineering ($1.50-$4.00)

SEMI-CRYSTALLINE RESIN



Morphology Features -- Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions, Opaque

Semi-Crystalline	Special Features
Nylon 6/12	Less Sensitive to humidity vs. 6&6/6
Nylon 6/6	Better thermal vs. 6/humidity Dep
Nylon 6	Hides GF/strong but humidity Dep
Polybutylene Terephthalate (PBT)	Good electricals/easier to mold
Polyethylene Terephthalate (PET)	Good electricals/difficult to mold
Acetal (POM)	Low wear & friction/high fatigue
Polylactic Acid (PLA)	Green/Low impact & thermal
Polypropylene (PP)	Poor low temp impact/mod thermal
Polyethylene (HDPE, LDPE, LLDPE)	Good low temp impact

Commodity (<$1.50) • Engineering ($1.50-$4.00)

PUTTING IT ALL TOGETHER

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

Test Your Knowledge With Application Examples

CASE STUDY

CD Jewel Case

- Transparent
- Flat & Dimensionally Stable
- Low Cost

CASE STUDY

Gas Tank

- Good chemical resistance
- Good low temperature impact
- Low cost

CASE STUDY

Auto Tail Lamp Cover

- Transparent Colors
- Dimensionally Stable
- Excellent UV
- Low Cost

CASE STUDY

Plastic Glass Tumblers

- Transparent
- Reasonable Thermal & Chemical
- Resistance (Dishwasher Cycles)
- Low Cost

CASE STUDY

Sump Pump Housing

- Chemical resistance
- Reasonable thermal resistance
- Low cost

CASE STUDY

Safety Glasses

- Optical transparency
- High impact
- Moderate cost OK

CASE STUDY

Hub Odometer Lens

- Transparent
- Good Chemical Resistance
- Moderate-High Cost OK

CASE STUDY

Chemical Beakers

- Excellent chemical resistance
- Low Cost
- Transparent

CASE STUDY

Nail Gun Housing

- Good chemical resistance
- Excellent strength, stiffness & impact
- Good surface finish when reinforced
- Moderate cost OK

CASE STUDY

Automotive Intake Manifold
- Chemical resistance
- Excellent strength, stiffness & impact
- Moderate heat resistance
- Moderate cost OK

CASE STUDY

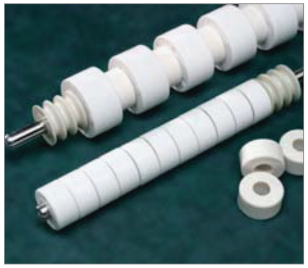
Oil Pan
- Chemical resistance
- Excellent strength, stiffness & impact
- Moderate heat resistance
- Moderate cost OK
- Extremely tight dimensions & flat

CASE STUDY

Electrical Connectors
- Good flow in thin walls
- Excellent electrical properties
- Dimensionally stable in humidity
- Moderate cost OK

CASE STUDY

Conveyor Rollers
- Good abrasion resistance
- Low wear & friction
- Moderate cost OK



CASE STUDY

Printer Gears

- Extremely tight dimensions
- Moderate cost OK
- Good abrasion resistance
- Low wear & friction

CASE STUDY

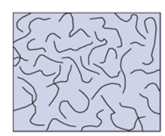
Lawn Tractor Hood

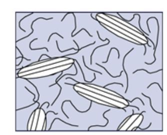
- Tight dimensions & low warp
- Moderate cost OK
- Chemical resistance
- Good mold flow

Overcoming Resin Deficiencies Via Compounding

MORPHOLOGY DEFICIENCIES

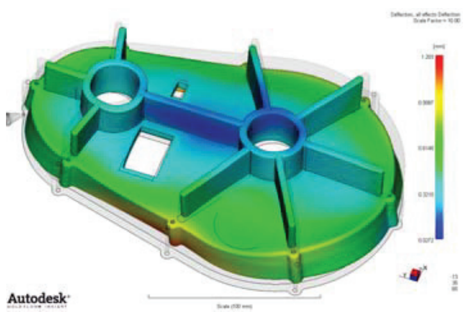
	Amorphous	Semi-Crystalline
Low Shrinkage	X	D
Low Warpage	X	D
Tight Tolerances	X	D
Transparency	X	D
Mold Flow Ease	D	X
Chemical Resistance	D	X
Wear Resistance	D	X



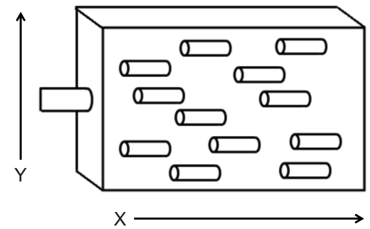


DIMENSIONAL STABILITY

Can We Reduce Shrink Rate & Improve Dimensional Stability of Semi-Crystalline Resins?

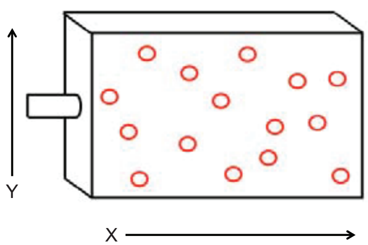


FIBER REDUCES SHRINK



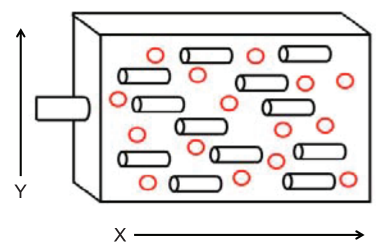
Shrink Rate X ≠ Shrink Rate Y ⟶ Warp

WARP CONTROL



Shrink Rate X = Shrink Rate Y ⟶ Flat Part
But Low Strength!

STRENGTH & WARP CONTROL



Common Loading = 15% Glass Fiber & 25% Mineral or Beads

CASE STUDY

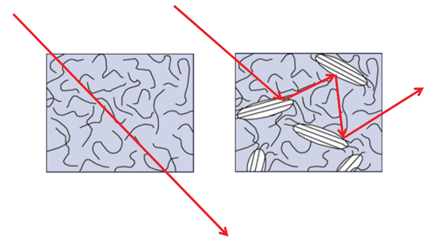
Oil Pan

- Chemical resistance
- Excellent strength, stiffness & impact
- Moderate heat resistance
- Moderate cost OK
- Extremely tight dimensions & flat

Nylon 66 + 15% GF + 25% Mineral

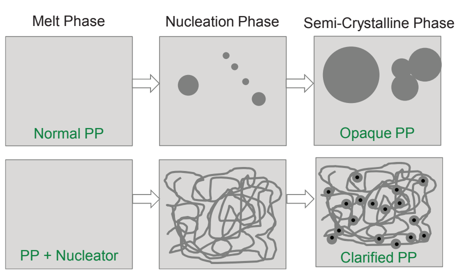
TRANSPARENCY

Can We Make A Semi-Crystalline Resin Transparent?



NUCLEATION/CLARIFICATION

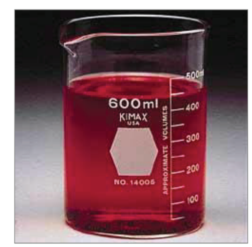
Compounding nucleator into PP or PE
controls crystal size to less than wavelength of light
= Transparency



CASE STUDY

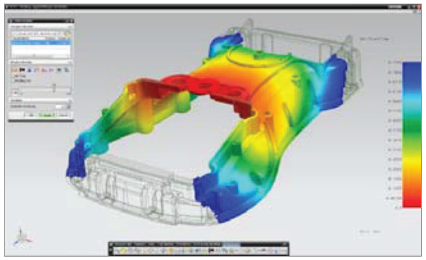
Chemical Beakers

- Excellent chemical resistance
- Low Cost
- Transparent



CHEMICAL RESISTANCE/MOLD FLOW

Can We Improve Chemical Resistance & Mold Flow of Amorphous Resins?



ALLOYING

Alloy PC with ABS
RTP 2500 A Series

	PC	PC/ABS
Tensile Strength, psi	9000	8900
Flexural Mod, E6 psi	0.34	0.40
Izod Impact, ft lb/in	15	13
HDT @ 264 psi, ºF	270	210
Fuel Resistance	Poor	Poor
Melt Flow, gm/10 min	10	15
Clarity	Transparent	Opaque

ALLOYING

Alloy PC With Polyester (PBT or PET)
RTP 2099 X 63578 B

	PC	PC/PBT
Tensile Strength, psi	9000	8700
Flexural Mod, E6 psi	0.34	0.35
Izod Impact, ft lb/in	15	15
HDT @ 264 psi, ºF	270	250
Fuel Resistance	Poor	Fair
Melt Flow, gm/10 min	10	20
Clarity	Transparent	Opaque

CASE STUDY

Lawn Tractor Hood

- Tight dimensions & low warp
- Moderate cost OK
- Chemical resistance
- Good mold flow

WEAR RESISTANCE

Can We Make An Amorphous Resin Wear Resistant?

PTFE LUBRICATED

Compound PTFE Into PC

RTP 300 TFE 15

	PC	PC/15 PTFE	Acetal
Wear Factor	560	130	90
Dynamic Coef. of Friction	0.60	0.33	0.40

CASE STUDY

Printer Gears

- Extremely tight dimensions
- Moderate cost OK
- Good abrasion resistance
- Low wear & friction

WHAT'S NEW?

New Technologies

NEW TECH (HEALTHCARE)

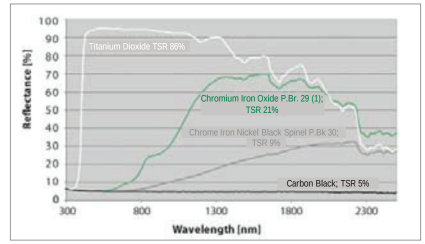
RTP 2000 HC Series

- Increased chemical resistance to healthcare cleaners vs PC, ABS, PC/ABS
- Good dimensional stability with shrinkage similar to above resins
- Flame retardant grade for electronic housings
  - RTP 2000 HC FR A

NEW TECHNOLOGIES (COLOR)

IR Reflecting Colors

Allows Dark Colored Plastics To Remain Cool When Exposed To Sunlight



- Patio Furniture
- Decking/Pavers
- Roofs/Siding
- Auto Interiors

NEW TECHNOLOGIES (FR)

FR Compounds for Plenum Applications (UL 2043)

Low Heat/Smoke Release Grades

- FR PP Grades (Glass Fiber, Mineral, Unfilled)
- FR Nylon (Glass Fiber)

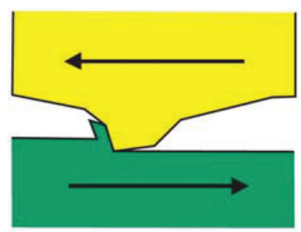
Opportunities

- Wireless Access Points
- Speaker Housings
- Vent Diffusers
- Cable Racks
- Light Housings

NEW TECHNOLOGIES (WEAR)

Abrasion Resistant Compounds

To Compete With UHMWPE (Not Moldable)

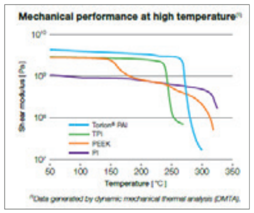


- Injection Moldable Polyolefin Alloy
- Similar Abrasion Resistance To UHMWPE
  - → Gears
  - → Cams
  - → Slides
  - → Wear Liners

NEW TECH (HIGH TEMPERATURE)

Specialty Torlon Compounds

RTP Company has a license agreement with Solvay Specialty Polymers to manufacture specialty compounds based on Torlon polyamide-imide



- Custom Fiber Reinforced
- Custom Wear Formulas
  - → Automotive
  - → Aerospace
  - → Industrial

REVIEW

Intro To Compounding

The Dilemma

Resin Selection Procedure

- Resin Morphology
- Resin Cost & Thermal Performance
- Unique Resin Features

Application Case Studies

Compounding in Performance

- Overcoming Resin Deficiencies

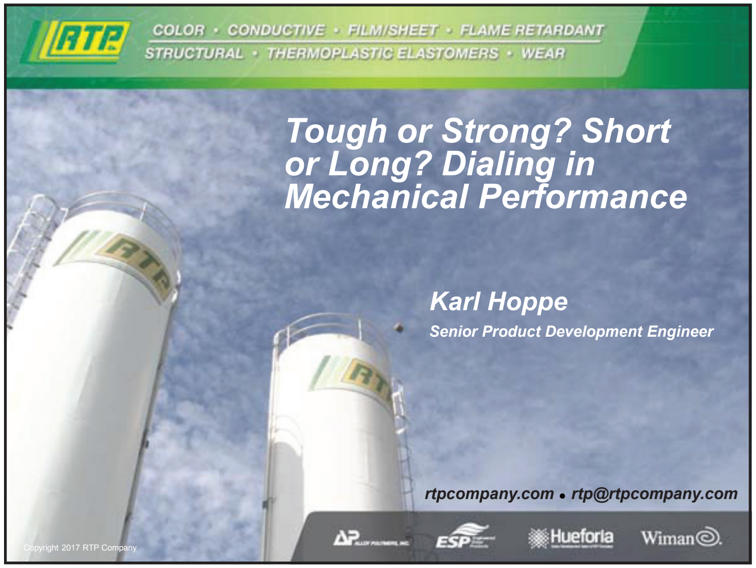
Introduction To New Technologies

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

Tough or Strong? Short or Long? Dialing in Mechanical Properties

Karl Hoppe | Senior Product Development Engineer
khoppe@rtpcompany.com
(507) 474-5367

9:15 a.m.


COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR
Tough or Strong? Short or Long? Dialing in Mechanical Performance
Karl Hoppe
Senior Product Development Engineer
rtpcompany.com • rtp@rtpcompany.com
Copyright 2017 RTP Company
Hueforia
Wiman


STRENGTH

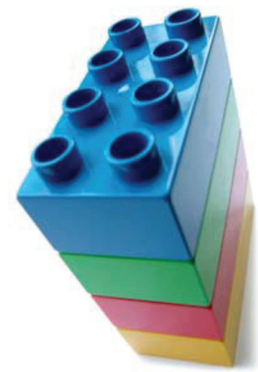

STIFFNESS


IMPACT

THE FORMULA

Resin + Additives = Change in Properties

THE FOUNDATION

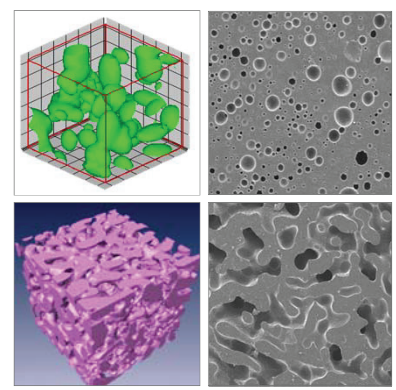


THE ADDITIVES TOOLBOX

MODIFIERS

Polymer blends

Impact modifiers



POLYMER BLENDS

PC/ABS → **ABS brings**
- Improved flow
- Chemical resistance
- Cost reduction

Nylon/PP → **PP brings**
- Improved flow
- Chemical resistance
- Cost reduction

PC/PBT → **PBT brings**
- Improved flow
- Chemical Resistance

POLYMER BLENDS

ABS/PC → **PC brings**
- Toughness
- Strength

PP/Nylon → **Nylon brings**
- Strength
- Stiffness
- Temperature

PBT/PC → **PC brings**
- Toughness
- Dimensional stability

POLYMER BLENDS

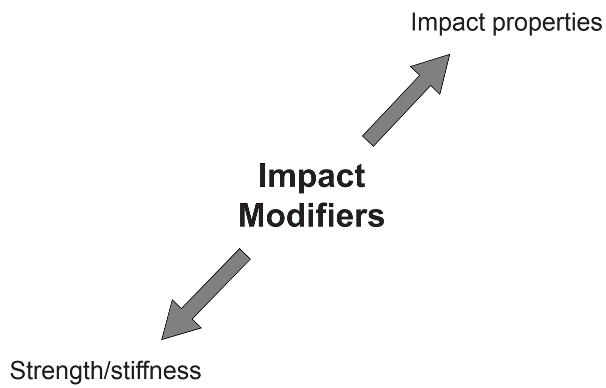
	PC	PC/ABS (RTP 2500 A)	ABS
Specific Gravity	1.19	1.15	1.06
Tensile Strength (MPa)	60	60	45
Notched Izod Impact (J/m)	800	700	270

POLYMER BLENDS

Housing for Hearing Tester

Problem:	Toughness and chemical resistance
Solution:	Polycarbonate/ABS Alloy
Benefits:	Strength and toughness of PC with the added chemical resistance of ABS

MODIFIERS



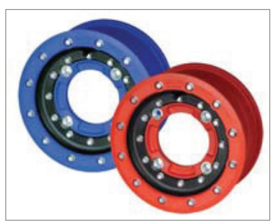
IMPACT MODIFIERS

	PA 6/6	Impact Modified PA 6/6
Specific Gravity	1.14	1.08
Notched Izod Impact (J/m)	55	900
Tensile Strength (MPa)	80	52
Flexural Modulus (GPa) (Stiffness)	2.8	2.1

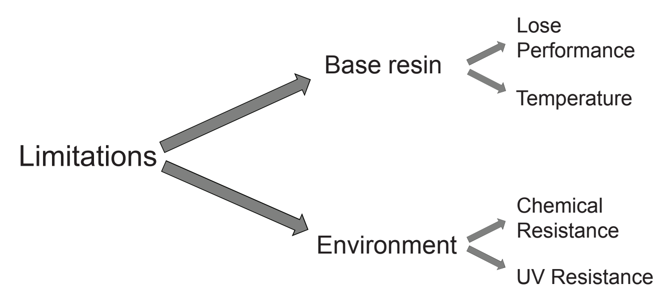
IMPACT MODIFIERS

ATV Wheel Bead Lock Ring

Problem:	Low ductility
Solution:	Impact Modified Nylon 6/6 with fiber reinforcement
Benefits:	• Retain some stiffness of reinforced Nylon • Improved ductility for high strain rate loads



IMPACT MODIFIERS

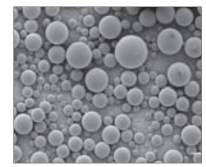


THE ADDITIVES TOOLBOX

Modifiers

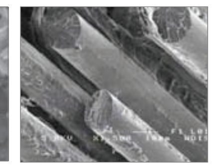
Fillers

FILLERS



Beads
(Glass)
Photo: Potters, Inc.

Minerals
(Talc)

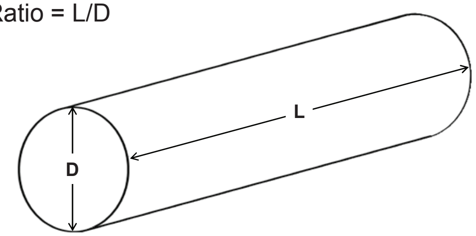


Fibers
(Glass)

ASPECT RATIO

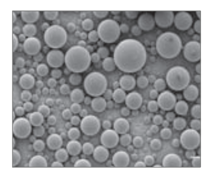
Property change determined by:

Aspect Ratio = L/D



↑ Aspect Ratio ↑ Reinforcing

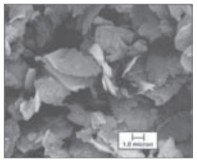
LOW ASPECT RATIO



Beads
(Glass)
Photo: Potters, Inc.
Aspect Ratio = 1

	PC	PC + 10% Glass Beads	PC + 30% Glass Beads
Specific Gravity	1.19	1.27	1.42
Tensile Strength (MPa)	60	55	48
Notched Izod Impact (J/m)	800	100	80
Flexural Modulus (GPa)	2.3	2.6	3.4

LOW ASPECT RATIO

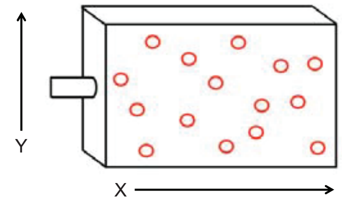


Minerals
(Talc)

Aspect Ratio = 2 - 50

	PP	PP + 20% Talc	PP + 40% Talc
Specific Gravity	0.91	1.05	1.25
Tensile Strength (MPa)	32	32	30
Notched Izod Impact (J/m)	53	53	43
Flexural Modulus (GPa)	1.4	2.6	3.9

LOW ASPECT RATIO

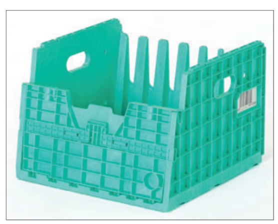


Shrink Rate X = Shrink Rate Y ⟹ Flat Part

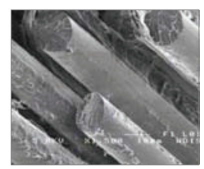
LOW ASPECT RATIO

Reusable Handling Container

Problem:	Warpage prevented smooth operation
Solution:	Mineral filled Polypropylene
Benefits:	• Reduced warpage • Improved functionality



HIGH ASPECT RATIO

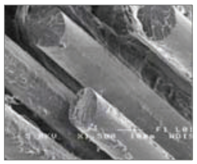


Fibers
(Glass)

Aspect Ratio = 50 - 250

	PC	PC + 30% Glass Beads	PC + 30% Glass Fiber
Specific Gravity	1.19	1.42	1.42
Tensile Strength (MPa)	60	48	124
Notched Izod Impact (J/m)	800	80	160
Flexural Modulus (GPa)	2.4	3.4	7.6

HIGH ASPECT RATIO



Fibers
(Glass)

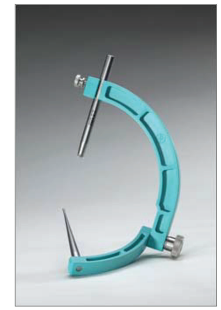
Aspect Ratio = 50 - 250

	PP	PP + 40% Talc	PP + 40% Fiber
Specific Gravity	0.91	1.25	1.21
Tensile Strength (MPa)	32	30	82
Notched Izod Impact (J/m)	53	43	120
Flexural Modulus (GPa)	1.4	3.9	6.5

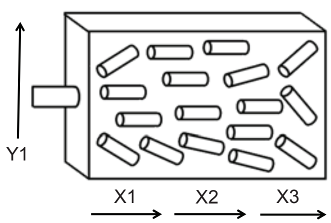
HIGH ASPECT RATIO

Surgery Drill Guide

Problem:	Stiffness and dimensional stability
Solution:	Glass fiber reinforced Polycarbonate
Benefits:	• Rigidity • Tight tolerances

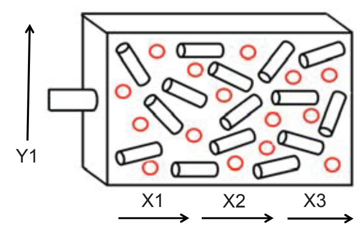


HIGH ASPECT RATIO - WARP



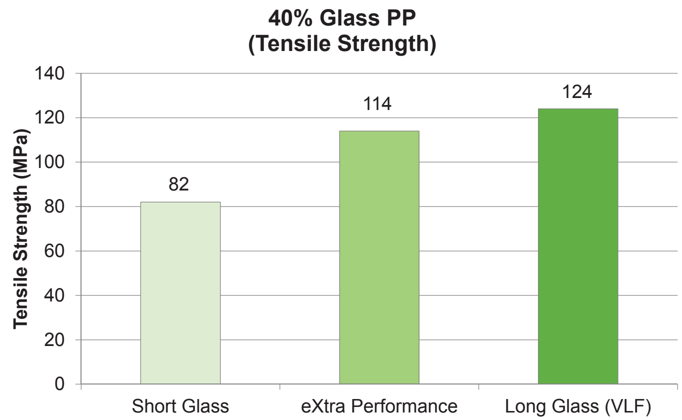
Shrinkage X1 & X2 ≠ X3 ⟹ Warp

HIGH ASPECT RATIO - FLAT

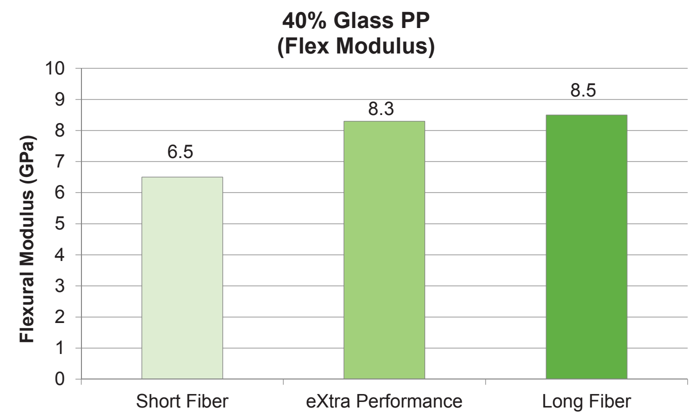


Shrinkage X1 = X2 = X3 ⟹ Flat Part

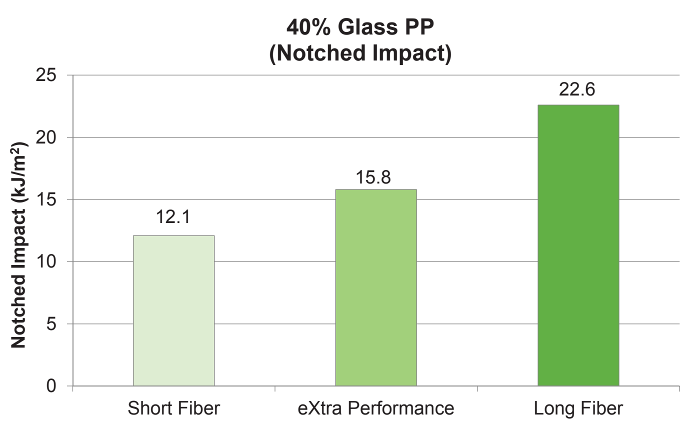
IMPROVEMENTS IN SGF PP



IMPROVEMENTS IN SGF PP



IMPROVEMENTS IN SGF PP



HIGH ASPECT RATIO

Carbon Fibers

Aspect Ratio = 50 - 250

	PEEK	PEEK + 40% Glass Fiber	PEEK + 40% Carbon Fiber
Specific Gravity	1.30	1.61	1.45
Tensile Strength (MPa)	93	186	265
Notched Izod Impact (J/m)	53	133	91
Flexural Modulus (GPa)	3.8	13.8	30.3

FIBER COMPARISON- PP

	PP 40% GF	PP 40% VLF	PP 20% CF
Flexural Modulus (GPa)	6.5	8.5	8.9
Tensile Strength (MPa)	82	124	93
Notched Izod Impact (kJ/m^2)	12.1	22.6	5
Specific Gravity	1.21	1.21	1.00

FIBER COMPARISON – PA 6/6

	PA 6/6 60% VLF (Long Fiber)	PA 6/6 30% Carbon Fiber
Flexural Modulus (GPa)	20.0	19.0
Tensile Strength (MPa)	262	248
Tensile Elongation (%)	2.0	2.5
Specific Gravity	1.71	1.27

FIBER COMPARISON – PPS

	PPS 40% Glass	PPS 15% Carbon
Flexural Modulus (GPa)	15.2	15.9
Tensile Strength (MPa)	169	172
Tensile Elongation (%)	1.5	1.1
Specific Gravity	1.68	1.40

CARBON FIBER APPLICATION

Brake Rotor Measuring Probe

Problem:	Casting replacement
Solution:	Carbon fiber reinforced PPA
Benefits:	• High strength • High stiffness

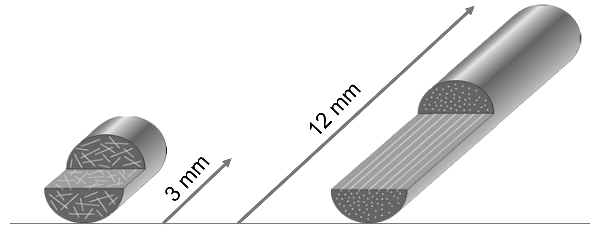
EXTREME ASPECT RATIO -VLF

Long Glass Fiber

Aspect Ratio = 300+

	PP + 40% Short Glass	PP + 40% Long Glass
Specific Gravity	1.21	1.21
Tensile Strength (MPa)	82	124
Notched Izod Impact (J/m)	120	228
Flexural Modulus (GPa)	6.5	8.5

EXTREME ASPECT RATIO - VLF



Short Fiber
Fiber length: ~ 1-2 mm

Long Fiber
Fiber length: 12 mm

EXTREME ASPECT RATIO - VLF

Secret to success: *the fiber skeleton*

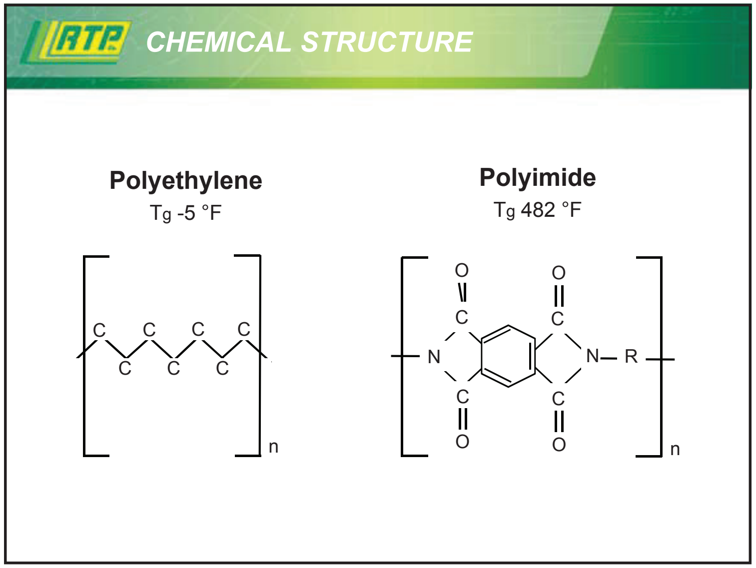
PA 66 + 60% VLF
Seat Belt Tension Housing

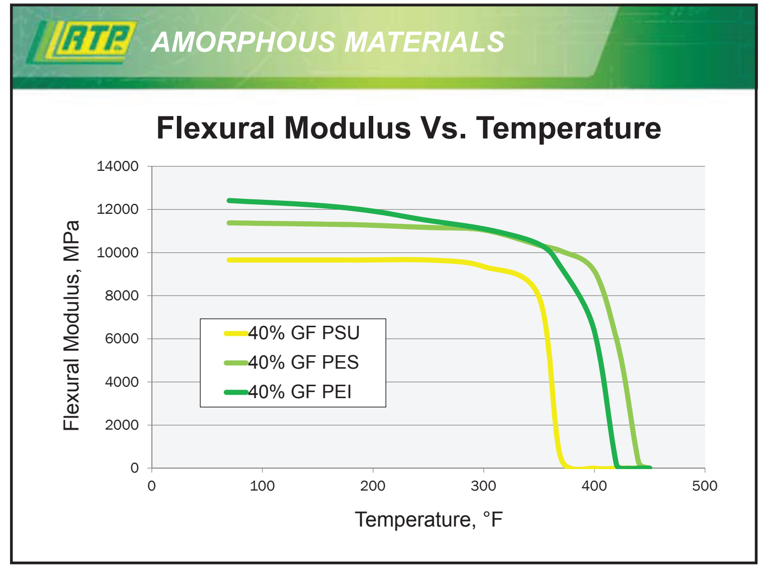
HIGH TEMPERATURE POLYMERS

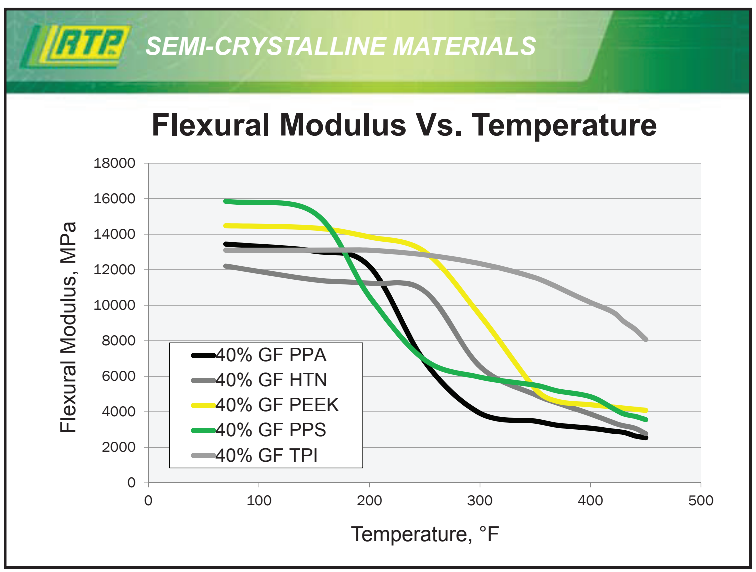
Amorphous	Semi-Crystalline
Polyetherimide (PEI)	Polyetheretherketone (PEEK)
Polyethersulfone (PES)	Polyphenylene Sulfide (PPS)
Polysulfone (PSU)	Polyphthalamide (PPA)
Amorphous Nylon	Polyamide (PA/Nylons)
Polycarbonate (PC)	Polybutylene Terephthalate (PBT)
Acrylic (PMMA)	Polyethylene Terephthalate (PET)
Acrylonitrile Butadiene Styrene (ABS)	Acetal (POM)
Styrene Acrylonitrile (SAN)	Polylactic Acid (PLA)
High Impact Polystyrene (HIPS)	Polypropylene (PP)
Polystyrene (PS)	Polyethylene (HDPE, LDPE, LLDPE)

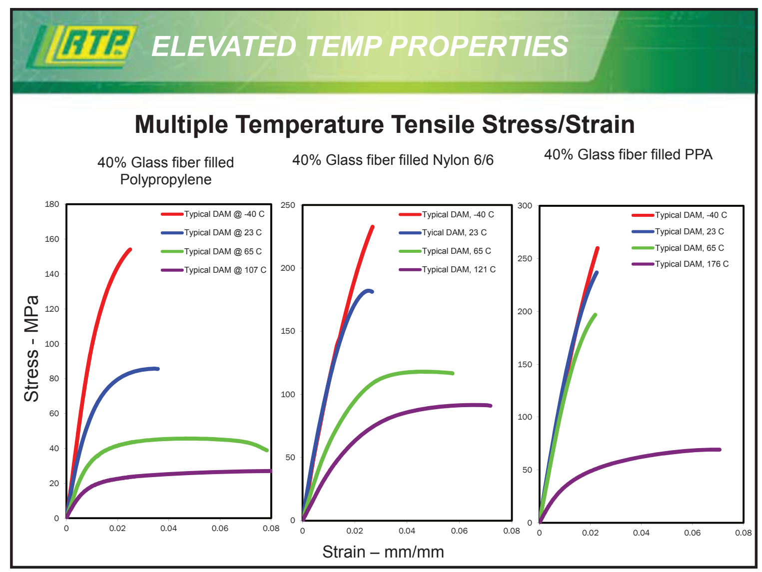
Thermal & Cost Increases

Commodity • Engineered • High Performance

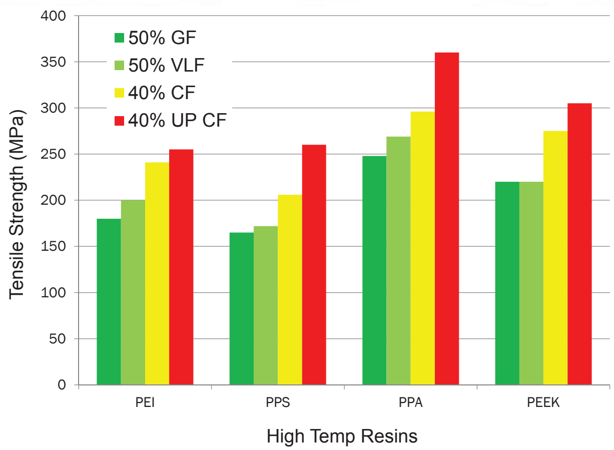

CHEMICAL STRUCTURE
Polyethylene
Tg -5 °F
Polyimide
Tg 482 °F
n
N
R
n


AMORPHOUS MATERIALS
Flexural Modulus Vs. Temperature
Flexural Modulus, MPa
Temperature, °F
40% GF PSU
40% GF PES
40% GF PEI


SEMI-CRYSTALLINE MATERIALS
Flexural Modulus Vs. Temperature
Flexural Modulus, MPa
Temperature, °F
40% GF PPA
40% GF HTN
40% GF PEEK
40% GF PPS
40% GF TPI


ELEVATED TEMP PROPERTIES
Multiple Temperature Tensile Stress/Strain
40% Glass fiber filled Polypropylene
40% Glass fiber filled Nylon 6/6
40% Glass fiber filled PPA
Typical DAM @ -40 C
Typical DAM @ 23 C
Typical DAM @ 65 C
Typical DAM @ 107 C
Typical DAM, -40 C
Typical DAM, 23 C
Typical DAM, 65 C
Typical DAM, 121 C
Typical DAM, -40 C
Typical DAM, 23 C
Typical DAM, 65 C
Typical DAM, 176 C
Stress - MPa
Strain – mm/mm

ULTRA PERFORMANCE PRODUCTS



HIGH TEMPERATURE APPLICATION

Surgical Head Restraint

Problem:	Stable under MRI/CT energy
Solution:	Carbon fiber reinforced PEEK
Benefits:	• High stiffness • Creep resistance • Resistance to autoclave

SUMMARY

Modifiers

- Polymer Blends - overcome morphology deficiencies
- Impact Modifiers - increase impact but reduction in strength/stiffness

Fillers

- Performance driven by aspect ratio

High Temperature

- Range of polymers offer array of performance

Overall: Combinations of technologies result in balancing of properties and requirements

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

Light and Color:
Create. Control. Communicate.

Hannah Fiore | Color Development Engineer
hfiore@rtpcompany.com
(507) 474-5505

10:15 a.m.

TOPICS

- Brief introduction to RTP Company Color Division
- Color Fundamentals
  - Three Sciences of Color
  - Evaluation & Control
  - Effective Color Communication
- Beyond the Visible Light
  - Laser Welding
  - Laser Marking
- Questions

TOPICS

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RTP COMPANY COLOR DIVISION

Color virtually all resins
- Engineering resins
- Styrenic resins
- Polyolefin resins

Color in multiple formats
- Masterbatches
- Precolored resins
- Cube blends

Advanced Color Development
- Custom colors
- Multiple light sources
- Regulatory knowledge
  - UL, FDA, USP, RoHS, etc.

GLOBAL COLOR CONSISTENCY

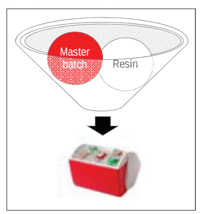
Color Lab Locations
- USA - Winona, MN; Indianapolis, IN; Fort Worth, TX
- Monterrey, Mexico
- Beaune, France
- Shenzhen and Suzhou, China
- Singapore

Color Control
- Consistent raw materials
- Identical hardware and software
- Global database

Speed
- Fast color matching service
- Transfers across regions

COLORING OPTIONS

Masterbatches
- Concentrated formulation of colorants and/or additives dispersed in a polymer carrier
- Usage defined by let-down ratio or percentage
- Most widely used form to color commodity resins

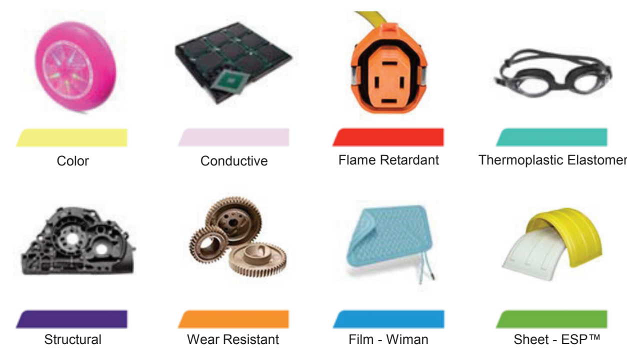


Precolor
- Colorants are added to the polymer and extruded
- Ready to use as-is

Cube blend
- Masterbatch is blended with resin
  - Two or more pellet solution

PRODUCT FAMILIES

Compounds formulated to meet performance requirements, from one property to multiple technologies



TOPICS

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COLOR SCIENCE

Biology

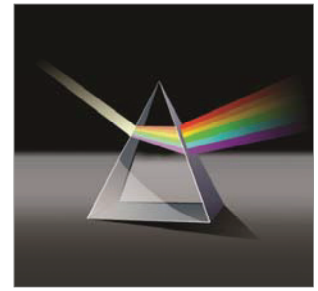
- Color perception

Physics

- Light interactions

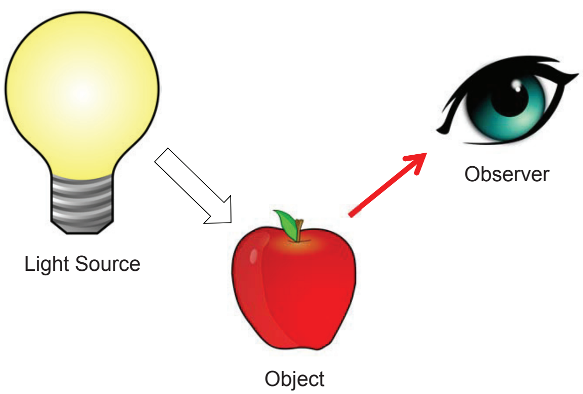
Chemistry

- Colorants



BIOLOGY

How do we see color?



BIOLOGY

Optical nerve sends signal to brain for decoding

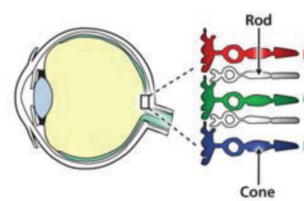
Photoreceptors

Rods

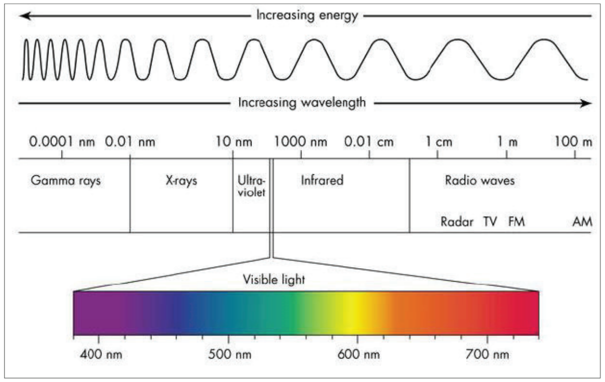
- Vision at low light levels

Cones

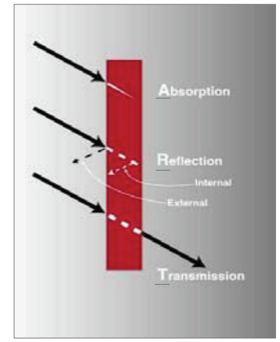
- Sensitive to three colors



PHYSICS



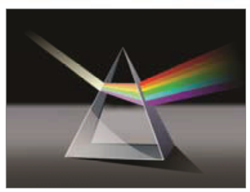
PHYSICS

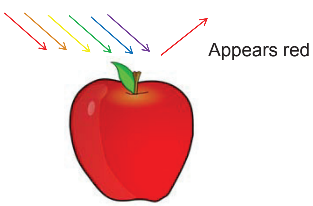


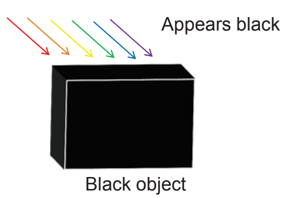
PHYSICS

White light is made up of all wavelengths of visible light.

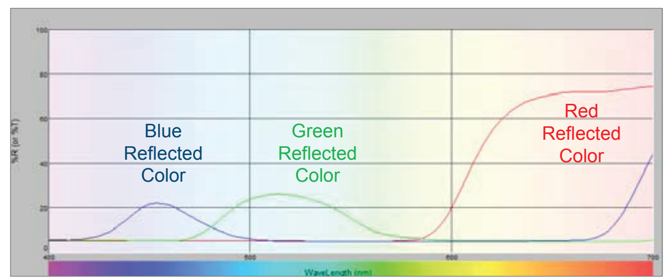
It is separated into individual colors when light passes through a glass prism.







PHYSICS



- Spectral reflectance curves produced by spectrophotometer
- Graph shows light reflected from an object at each wavelength
- Each color has a unique spectral curve

CHEMISTRY

Colorant Types

Pigments

- Particles suspended in matrix
- Inorganic - made from various metals or other materials from nature
- Organic - made synthetically

Dyes

- Soluble in polymer
- Organic

CHEMISTRY

Pigment Types & Limitations

Organic Pigments

- Small particle size
- Difficult to disperse
- Limited heat stability
- High color strength
- Light fastness

Inorganic Pigments

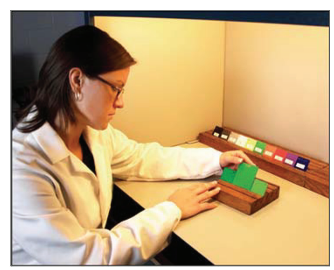
- Large particle size
- Easy to disperse
- Heat stable
- Weak color strength
- Improved light fastness

CHEMISTRY

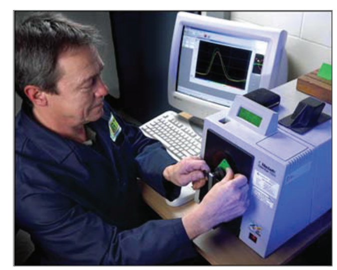
Dyes

- Soluble
  - Migration concerns
- High color strength
- Transparent
- Commonly used in:
  - Styrenic Resins
  - Engineering Resins

COLOR EVALUATION & CONTROL



Visual Color Evaluation



Instrumental Color Evaluation

VISUAL COLOR EVALUATION

Observer

- Each person sees color uniquely

Light Source

- Different spectral distributions (D65, CWF, Incandescent)

Daylight | Incandescent | Horizon | Cool White | Ultra Violet

VISUAL COLOR EVALUATION

Observer

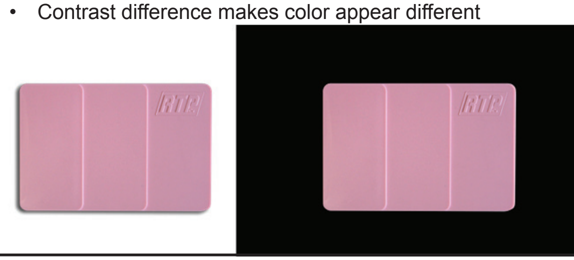
- Each person sees color uniquely

Light Source

- Different spectral distributions (D65, CWF, Incandescent)

Background

- Contrast difference makes color appear different



VISUAL COLOR EVALUATION

Observer

- Each person sees color uniquely

Light Source

- Different spectral distributions (D65, CWF, Incandescent)

Background

- Contrast difference makes color appear different

Viewing Angle

- Most common 45°

Keep viewing conditions **CONSTANT**

INSTRUMENTAL COLOR EVALUATION

Numeric Color Modeling

Numeric model provides

- 3 dimensional color space
- Quantify colors numerically
- Can be used for specification, identification, comparison, tolerancing

Several Color Spaces

- CIE 1931 Yxy
- CIE L*a*b* 1976
- CIE LCh
  - CMC l:c 1984

COMMON COLOR TERMS

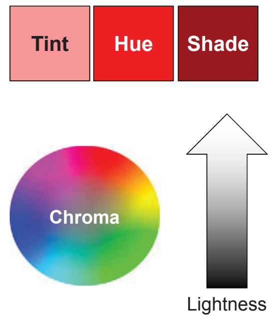
Hue
- Color perceived

Chroma
- Saturation
- Vividness of a color

Lightness
- Measure of brightness
- Luminance

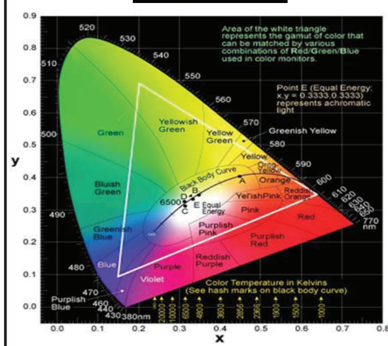
Tint
- Hue has been lightened

Shade
- Hue has been darkened



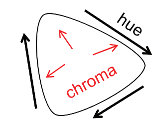
COLOR SPACE

CIE 1931 Yxy



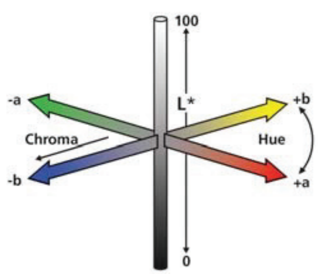
Non-Uniform Color Space

- Numeric values
  - Y = luminance
  - x, y = chromaticity values
- Only chromaticity values shown
- Measures the transmissivity and chromaticity of a color
- Hue changes around color gamut
- Chroma increases from center outward



COLOR SPACE

CIE L*a*b* 1976 Model



(L_1^*, a_1^*, b_1^*) and (L_2^*, a_2^*, b_2^*)

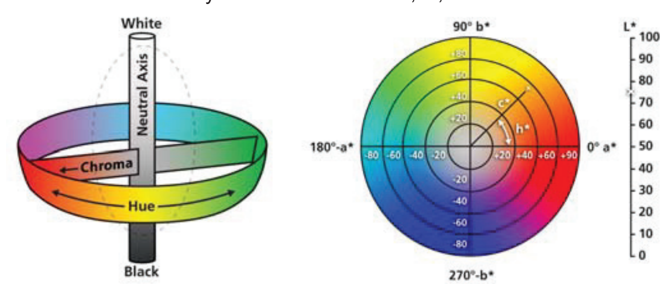
$$\Delta E^* = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

- Numeric values
  - L* = lightness to darkness (100-0)
  - a* = redness to greenness
  - b* = yellowness to blueness
  - ΔE* = total color shift
- Traditional X-Y-Z coordinate system
- Most popular color space
- Uniform color space

COLOR SPACE

CIE LCh Model

cylindrical coordinates r, Φ, z

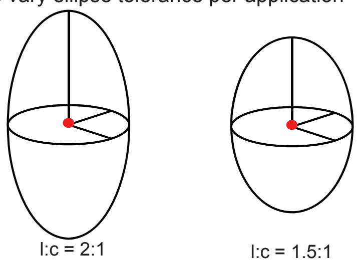


Lightness	Chromaticity	Hue
$L = L$	$C = \sqrt{a^2 + b^2}$	$h° = tan^{-1}(\frac{b}{a})$

COLOR SPACE

CMC l:c (1984)

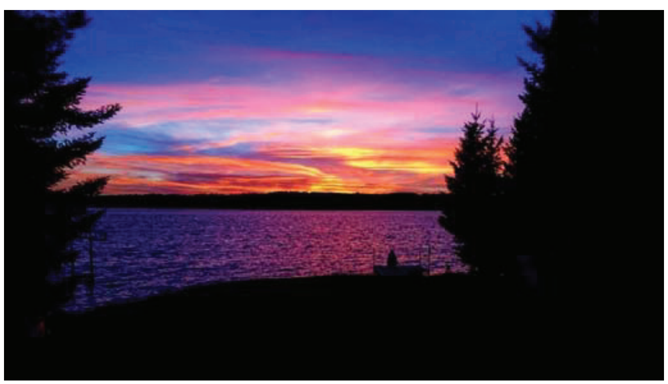
- Used for tolerancing
- l:c (lightness:chromaticity) values are typically 2:1
- Provides better agreement between visual and instrumental assessment
- Allows user to vary ellipse tolerance per application



TOLERANCES

- Tolerances are developed around variation in raw materials, processing, customer goals for visual appearance
- Asymmetrical color tolerances are perfectly acceptable to use

COLOR COMMUNICATION



It's important to specify all targets through color communication

APPLICATION REQUIREMENTS/TARGET

Application Requirements:

- Resin/compound
- Regulatory restrictions
- Processing method
- Secondary operations

Color Target

Physical Color

Grass Green
Pantone: 347

Color Reference

L* = 43
a* = -22.9
b* = 26.21

Color Space Values

SATISFYING EXPECTATIONS

Color Nomenclature

- Identifies both regulatory and formulation commitment

Lot Control

- Ingredient traceability

Process Control

- Defined manufacturing specifications
- Engineering review during development
- Contributes to consistency

Color Quality Control

- Color meets defined requirements
- Physical properties

TOPICS

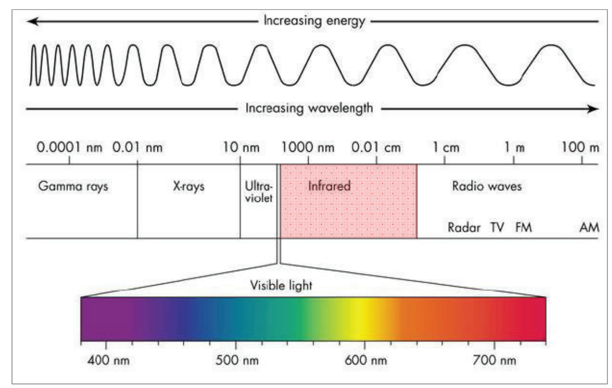
- Brief introduction to RTP Company Color Division
- Color Fundamentals
  - Three Sciences of Color
  - Evaluation & Control
  - Effective Color Communication
- Beyond the Visible Light
  - Laser Welding
  - Laser Marking
- Questions

LASER WELDING

Beyond Visible Light – IR/NIR

- Utilizes the infrared (IR) and near infrared (NIR) spectrums
  - Active 700 – 2500 nm range
- Combination of light controlling attributes
- Transparent or opaque at specific wavelengths
- Commonly used in:
  - Fiber optics
  - Transmitters/receivers

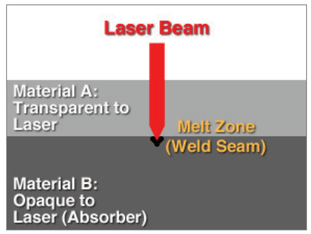
LASER WELDING



LASER WELDING

Requires materials with different NIR behavior

Method for joining thermoplastic parts by using the power of the laser to bond materials



LASER WELDING

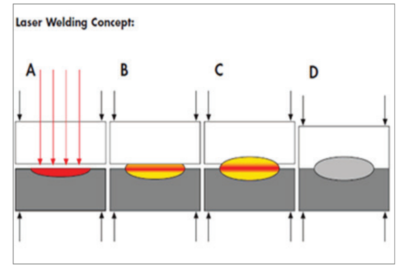
Mechanism

A. Light transmits through upper material and is absorbed by lower material

B. Melting pool is created

C. Heats upper layer

D. Melting pool solidifies under external pressure



LASER WELDING

Resin Types

IR Transparent:

Amorphous Resins

- Require the least amount of energy

Semi-Crystalline

- Require more energy due to scattering

Welding challenges

- PEEK, LCP, PPS, etc.

Highly crystalline materials have significant scatter, therefore require a higher amount of energy

IR Absorbing:

All resins…

- Amorphous
- Semi-Crystalline

Need IR Absorbing colorants

LASER WELDING

Additive Types

IR Reducing:

Glass fibers
Glass beads
Colorants
Various additives

- UV stabilizers, heat stabilizers, etc.

IR Blocking:

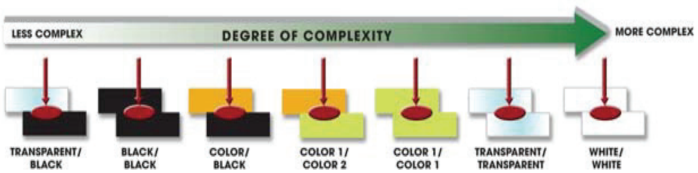
Carbon fiber
Minerals
Metals

Part thickness and laser frequency also determine material transmissivity

LASER WELDING

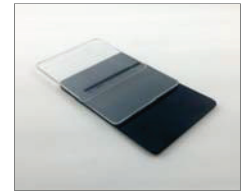
Degree of Complexity

- RTP Company has experience with pigment/filler combinations, and loading levels, to support successful welding using both Diode and Nd:YAG lasers
- Color combinations influence complexity of formulation



LASER WELDING

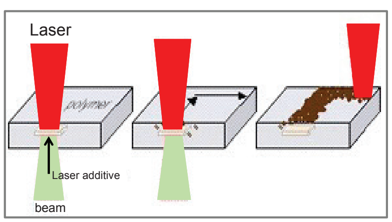
- Weld complex parts
- No flash is produced
- High-precision joints can be produced (Hermetic seals)
- Resins of different compositions can be joined
- No consumables
- No adhesives



LASER MARKING

Basic mechanism

Laser energy absorbed causing a reaction
- Charring (dark mark)
- Foaming (light mark)
- Ablation (removal of layer, ex. Paint)



LASER MARKING

One Light Source

Charring produces dark marks

Foaming produces light marks

No Universal Additives
- Can be combined with other additive technologies
- Unique colors achievable

Marks vary with resin, additive, and color package

LASER MARKING

What gives the highest contrasting mark?

Black resin color with light marks:

- PP (Olefins)
- Nylon
- ABS (Specific Grades)
- POM
- PMMA
- And more

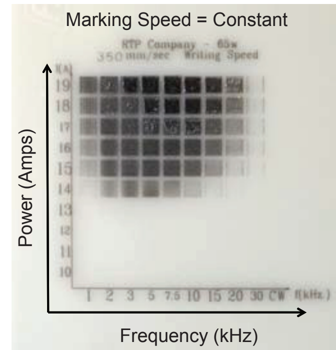
LASER MARKING

Type of laser and marking parameters will influence quality of mark.

Nd:YAG *(Neodymium doped Yttrium Aluminum Garnet)*

is the best compromise of…

- Speed
- Flexibility
- Marking quality



LASER MARKING

- Eliminates the need for pad printing or labeling
- Laser marker has no contact with part
- Most durable

SUMMARY

Create

- RTP Company supplies innovative colors and functional additives to assist you in the creation of your application
- Logos and designs can be created on your part using laser marking

Control

- Our color formulas are controlled by raw materials choices and internal and customer tolerances
- Laser welding of two materials can be done by controlling their IR transmissivity

Communicate

- Effective color communication is crucial for color matching and tolerancing


COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR
Thank You!
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Wiman
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Wear in the World of Plastics

Ben Gerjets | Product Development Engineer
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11:00 a.m.

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

Wear in the World of Plastics

Ben Gerjets
Product Development Engineer
Wear and Friction Products

rtpcompany.com • rtp@rtpcompany.com

WEAR AND FRICTION

"My application is wearing out!"

Fatigue?

?

Chemical Attack?

?

Abrasion?

?

Weather/UV Resistance?

?

WEAR AND FRICTION

Be Specific!

Wear – Sliding wear of thermoplastic compounds against a contact surface (steel, aluminum, other thermoplastics, etc.)

Friction – Reducing/controlling the friction in a sliding or moving system.

Internally Lubricated Thermoplastics

WEAR AND FRICTION SOLUTIONS

Wear and Friction Resistant compounds provide solutions for a number of common issues, including:

External Lubrication
Eliminate messy secondary operations and costs with internally lubricated plastics

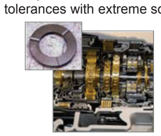
Stiction
Reduce stick-slip phenomenon by selecting materials based on Glide Factor℠ data

Buzz-Squeak Rattle (BSR)
Reduce noise caused by part movement and vibration with economical compound technologies

Scratch and Mar
Enhance product quality and increase customer satisfaction using Surface Protection (SPR) compounds

Abrasion
Manage catastrophic third party abraders with abrasion resistant technology for injection molding

Extreme Conditions
Withstand high temperatures, pressure, velocity, chemicals, and demanding tolerances with extreme solutions



AGENDA

I. Wear Definitions & Test Methods
II. Friction Definitions & Test Methods
III. Additive Technologies
IV. Application Examples
V. Extreme Conditions – Ultra Wear

WEAR DEFINITIONS

Tribology

The Science of the mechanisms of friction, lubrication, and wear of interacting surfaces that are in relative motion




WEAR DEFINITIONS

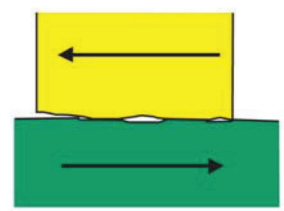
Recall: Sliding surfaces

Wear = Loss of material over time

WEAR DEFINITIONS

Adhesive Wear Mechanism

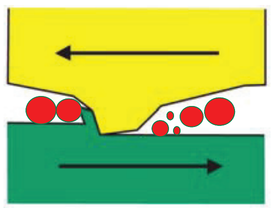
- The primary mechanism for thermoplastic wear
- Characterized by transfer of material from one part to the other caused by frictional heat



WEAR DEFINITIONS

Abrasive Wear Mechanism

- Caused by a hard material scraping or abrading away at a softer material
- Characterized by grooves cut or gouged into the surface
  - Three body



WEAR TESTING

Question: How do you simulate an application and test a material for long-term wear resistance?

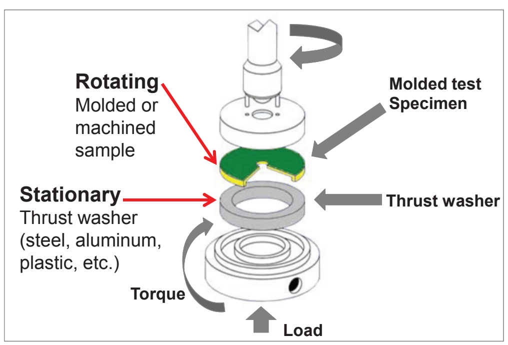
Answer: RTP Company uses **ASTM D-3702** wear test to quantify the amount of material a sample loses over time under specific conditions (pressure, speed, temperature)

WEAR TESTING

ASTM D-3702 "Thrust Washer" Wear Test

Adjustable:

- Counter-surface (thrust washer)
- Pressure
- Velocity
- Temperature



The best use of this test is to perform comparative screening of multiple candidate materials

WEAR TESTING

- RTP Company has six thrust washer wear testing machines in our wear lab located in Winona, MN
- Equipment is available to perform customer requested testing
- A test isn't always just a test
  - Conditions matter!

WEAR TESTING

Wear factor (K): Used to quantify wear resistance.

Lower Value = Better Wear Resistance!

$$K = W/(F \times V \times T)$$

K = Wear Factor: *(in^3-min/ft-lb-hr) · 10^{-10} or (mm^3/N-m) · 10^{-8}*

W = Volume wear: *in^3 or mm^3*

F = Force: *lb or N*

V = Velocity: *ft/min or m/sec*

T = Elapsed time: *hr or sec* **100 Hour Test!**

WEAR TESTING

Standard Conditions:

- Steel thrust washer
- 40 psi · 50 ft/min
- Ambient temp
- 100 hour test

PV = (Pressure · Velocity)

Conditions often used together to characterize severity of a wear environment

2,000 PV = (40 psi · 50 ft/min)

Typical testing done at 2,000 to 10,000 PV

WEAR TESTING

RTP Wear Brochure

PV (psi*ft./min) Wear Factor (K)

Nylon 6/6 (RTP 200 Series)						Load (lb)	Speed (ft/min)	PV	PV (SI)	Wear Factor (K)	K (SI)	μk
RTP 0200	-	-	-	-	-	8	50	2000	(70)	400	(1811)	0.66
RTP 0200	-	-	-	-	-	10	100	5000	(175)	95	(191)	0.91
RTP 0200	-	-	-	-	-	40	50	10000	(350)	191	(384)	0.60
RTP 0200 SI 2	-	-	-	-	2	8	50	2000	(70)	639	(1284)	0.54
RTP 0200 SI 2	-	-	-	-	2	10	100	5000	(175)	181	(364)	0.78
RTP 0200 SI 2	-	-	-	-	2	40	50	10000	(350)	85	(171)	0.77
RTP 0200 TFE 5	-	-	-	5	-	8	50	2000	(70)	957	(1924)	0.61
RTP 0200 TFE 5	-	-	-	5	-	10	100	5000	(175)	427	(858)	0.77
RTP 0200 TFE 5	-	-	-	5	-	20	100	10000	(350)	76	(153)	0.59
RTP 0200 TFE 10	-	-	-	10	-	8	50	2000	(70)	341	(685)	0.31
RTP 0200 TFE 10	-	-	-	10	-	10	100	5000	(175)	171	(344)	0.28
RTP 0200 TFE 10	-	-	-	10	-	40	50	10000	(350)	156	(314)	0.29
RTP 0200 TFE 18 SI 2	-	-	-	18	2	8	50	2000	(70)	11	(22)	0.20
RTP 0200 TFE 18 SI 2	-	-	-	18	2	10	100	5000	(175)	59	(119)	0.36
RTP 0200 TFE 18 SI 2	-	-	-	18	2	40	50	10000	(350)	18	(36)	0.19

- Excellent Wear Resistance (K= < 75) - Good Wear Resistance (K = 75 – 200) - Fair Wear Resistance (K = 200 – 400)

WEAR TESTING

Question: Does an equivalent PV always result in the same data?

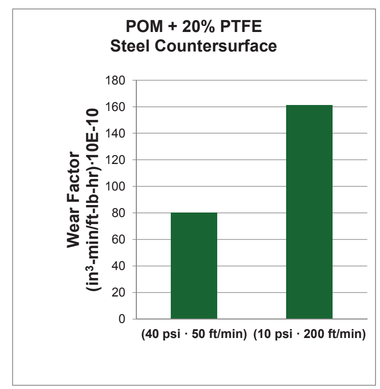
Standard Conditions: PV = 2,000

- P = 40psi
- V = 50 ft./min

Non-Standard Conditions: PV = 2,000

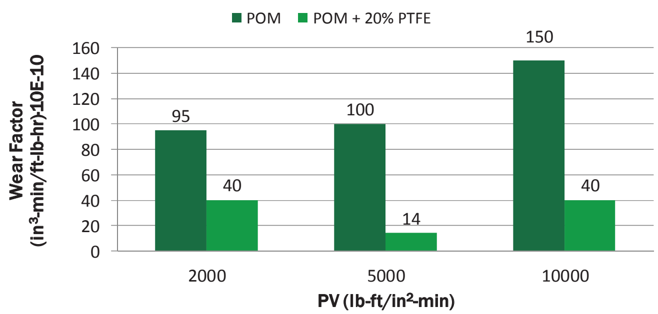
- P = 10psi
- V = 200 ft./min

Answer: No…Wear factor will change based on individual conditions



WEAR TESTING

Question: What happens when PV is increased? Does Wear Factor (K) also increase?

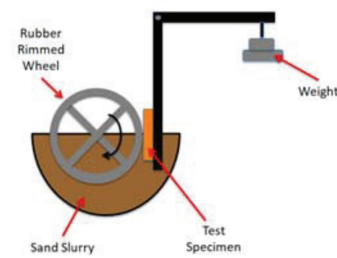


Wear per ASTM D 3702 against C1018 Steel

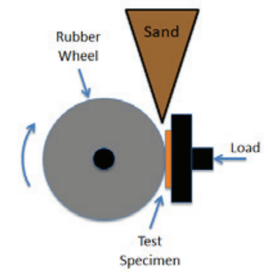
WEAR TESTING

Dry sand or sand-slurry abrasion testing

ASTM G105



ASTM G65

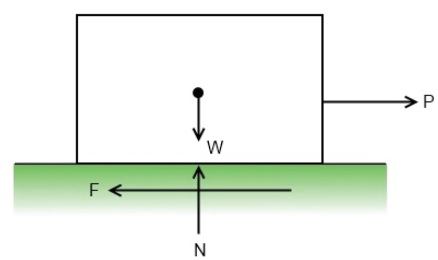


AGENDA

I. Wear Definitions & Test Methods
II. Friction Definitions & Test Methods
III. Additive Technologies
IV. Application Examples
V. Extreme Conditions – Ultra Wear

FRICTION DEFINITIONS

Coefficient of Friction (μ)
Ratio of the force of friction between two bodies and the force pressing them together



$\mu = F/N$

FRICTION DEFINITIONS

Coefficient of Friction (μ)

Static coefficient of friction (μ_s) = Fx/Fy

Fx = Force to *initiate* motion

Fy = Normal force holding surfaces together

Dynamic coefficient of friction (μ_k) = Fx/Fy

Fx = Force to *sustain* motion

Fy = Normal force holding surfaces together

FRICTION DEFINITIONS

- In most non-plastic materials
  - $\mu_s > \mu_k$
- Thermoplastics are somewhat unique
  - $\mu_k > \mu_s$
- May cause "slip/stick" – ***Glide Factor***^{SM}
- If $\mu_k >> \mu_s$ you may have squeaking

FRICTION TESTING

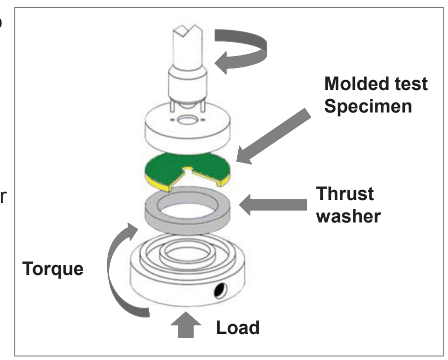
ASTM D 1894 "sled test"

- Coefficient of friction testing
- Does not determine wear resistance
- Can show slip/stick

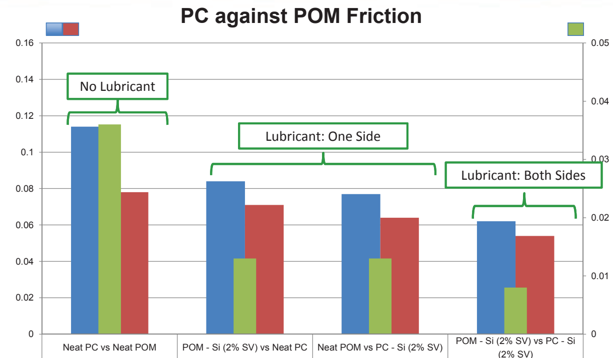
FRICTION TESTING

RTP Modified ASTM D3702 Friction Test

- Oscillating motion used to measure Friction coefficients and *Glide Factor*^{SM}
- *Glide Factor*^{SM} is used to quantify the difference between μ_s and μ_k in order to reduce/eliminate stick/slip
- Used to generate friction data for optimal material selection in medical devices



PLASTIC VS PLASTIC FRICTION EXAMPLE



	Neat PC vs Neat POM	POM - Si (2% SV) vs Neat PC	Neat POM vs PC - Si (2% SV)	POM - Si (2% SV) vs PC - Si (2% SV)
Initial Static μ	0.114	0.084	0.077	0.062
Initial Dynamic μ	0.078	0.071	0.064	0.054
Δ	0.036	0.013	0.013	0.008

Settings:
50 psi

TESTING REVIEW

Question: What is the primary method RTP Company uses measure wear resistance?

Answer: ASTM D3702 Thrust Washer wear test; Wear Factor (K)

Question: What methods does RTP Company use to measure Friction?

Answer 1: ASTM D1894 "Sled Test"
(Static and Dynamic Coefficient of Friction)

Answer 2: Modified ASTM D3702 Thrust washer friction test
(Glide Factor^{SM})

AGENDA

I. Wear Definitions & Test Methods
II. Friction Definitions & Test Methods
III. Additive Technologies
IV. Application Examples
V. Extreme Conditions – Ultra Wear

ADDITIVE TECHNOLOGIES

PTFE

Silicone

PFPE

Graphite

MoS_2

Fibers

ADDITIVE TECHNOLOGIES

PTFE – Polytetrafluoroethylene (5-20%)

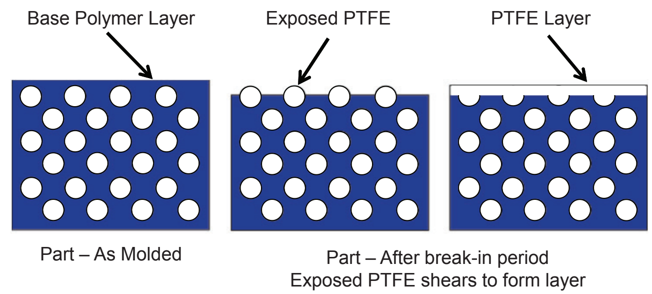
- Workhorse additive – solid white powder
- Compatible with nearly all thermoplastic resins

Limitations

- Fluorine content
- Die plate-out
- Relatively high loadings
- Cost fluctuation

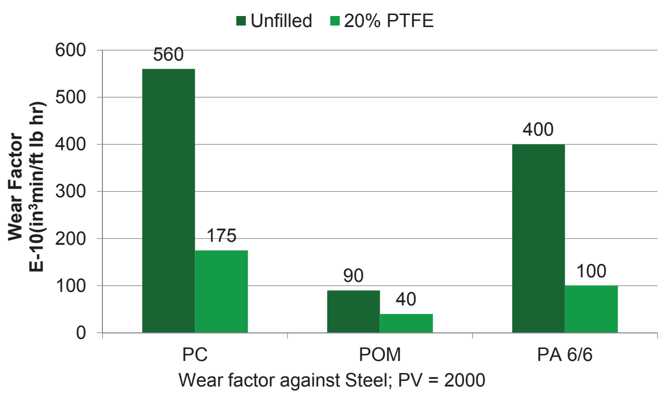
ADDITIVE TECHNOLOGIES

PTFE Wear Mechanism



ADDITIVE TECHNOLOGIES

Unfilled vs. PTFE Wear Factor



APPLICATION EXAMPLE

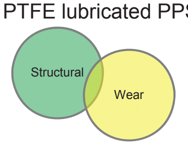
Laser Printer Fuser Gears

Requirements

- High operating temperatures
- Good wear resistance

Solution

- Glass fiber reinforced and PTFE lubricated PPS



ADDITIVE TECHNOLOGIES

PTFE

Silicone

ADDITIVE TECHNOLOGIES

Silicone – Polydimethylsiloxane (1-3%)

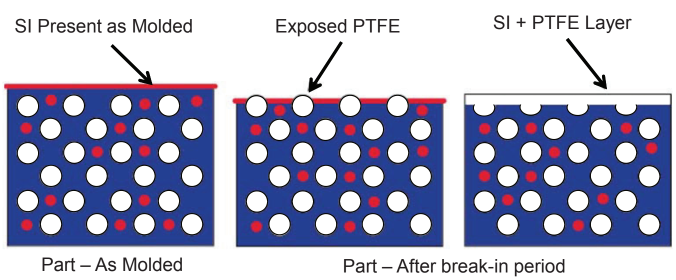
- Boundary lubricant which migrates to the surface over time
  - Migration rate is viscosity dependent
- Excellent friction reducer
- Best in high speed/low load applications

Limitations

- Limited use in decorated parts
  - Poor adhesion of paint or print inks
- Bad for electrical applications
  - Can foul contacts

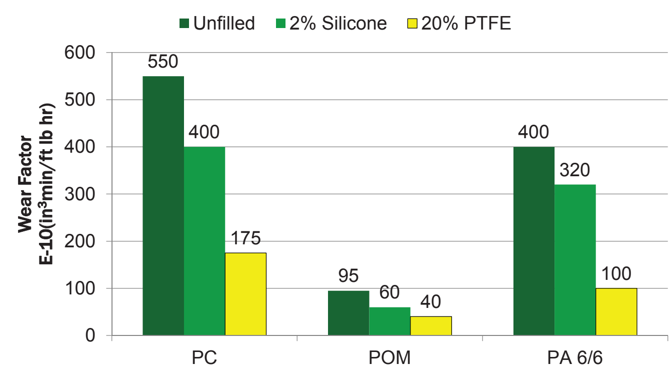
ADDITIVE TECHNOLOGIES

PTFE + Silicone Wear Mechanism



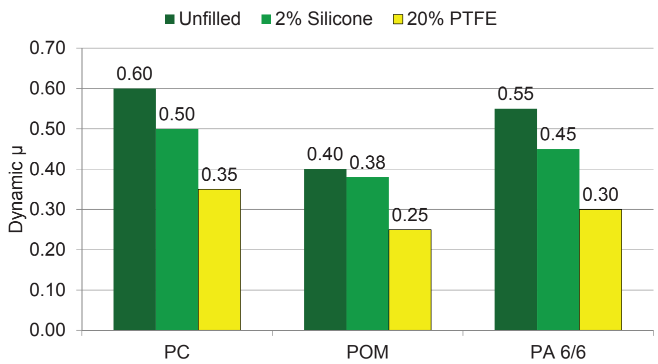
ADDITIVE TECHNOLOGIES

Wear Resistance with PTFE and Silicone



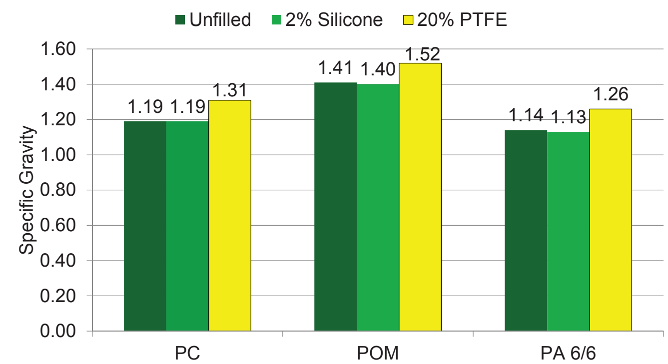
ADDITIVE TECHNOLOGIES

Friction Reduction with PTFE and Silicone



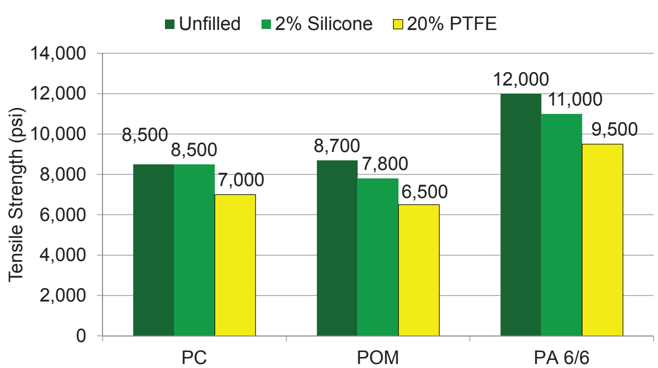
ADDITIVE TECHNOLOGIES

Specific Gravity Differences with PTFE and Silicone



ADDITIVE TECHNOLOGIES

Tensile Strength with PTFE and Silicone



ADDITIVE TECHNOLOGIES

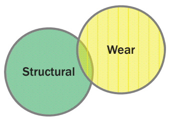
	PC			PA 6/6			POM		
	Unfilled	PTFE (20%)	Silicone (2%)	Unfilled	PTFE (20%)	Silicone (2%)	Unfilled	PTFE (20%)	Silicone (2%)
Specific Gravity	1.19	1.31	1.19	1.14	1.26	1.13	1.41	1.52	1.40
Tensile Strength (psi)	8,500	7,000	8,500	12,000	9,500	11,000	8,700	6,500	7,800
Flexural Modulus (psi)	340,000	320,000	350,000	400,000	400,000	400,000	350,000	300,000	350,000
Notched Impact (ft-lb/in)	7.5	3.5	10.5	1.0	1.0	1.0	1.5	1.0	1.5

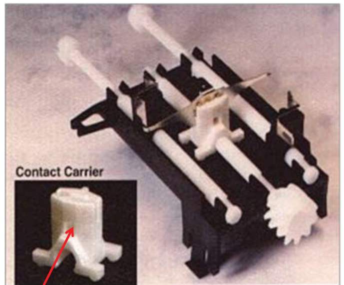
APPLICATION EXAMPLE

Garage Door Opener Limit Switch

Requirements
- Dimensional stability
- Good strength and stiffness

Solution
- Silicone lubricated PC

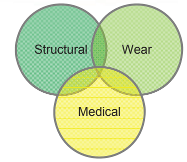




Not Transparent! More on this later…

APPLICATION EXAMPLE

Drug Delivery Pen Components



Requirements
- Good strength, dimensional stability, eliminate secondary lubricant application and no slip/stick.

Solution(s)
- Optimal Plastic "Friction Pairs" with low *Glide Factor*[SM]

Fiber reinforced and internally lubricated PC or PBT

Internally lubricated POM or PBT

ADDITIVE TECHNOLOGIES

PTFE

Silicone

PFPE

ADDITIVE TECHNOLOGIES

PFPE – Perfluoropolyether Oil (< 1%)

- Thermally stable up to PEEK processing temps
- Differentiates RTP Company from others
- Synergy with PTFE
- Specific gravity benefits

Limitations
- Limited effectiveness in amorphous resins
- Needs PTFE "kick" to deliver optimum friction reduction

APPLICATION EXAMPLE

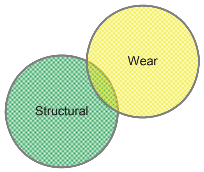
Agricultural Pump

Requirements

- Chemical and wear resistance

Solution

- PFPE lubricated PP



APPLICATION EXAMPLE

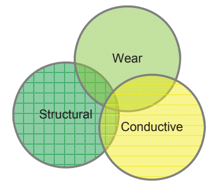
Universal Conveyor Roller

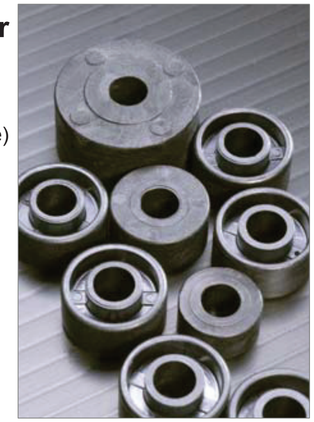
Requirements

- Strength, conductivity and wear resistance (must be silicone-free)

Solution

- Carbon fiber reinforced and PTFE/PFPE lubricated PPS





ADDITIVE TECHNOLOGIES

Additives Reduce Clarity!

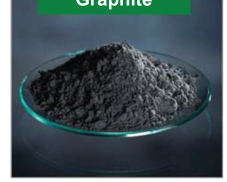
ADDITIVE TECHNOLOGIES

PTFE

Silicone

PFPE

Graphite



MoS_2

ADDITIVE TECHNOLOGIES

Graphite Powder (5-30%)

- Aqueous environments
- Excellent temperature resistance
- Black color

Molybdenum Disulfide - MoS_2 (1-5%)

- Nucleating agent in nylons: creates harder surface
- High affinity to metal:
  - Smoother mating metal surface = lower wear

Limitations

- Limited use
- Dark color limits colorability
- Sloughing type additives

APPLICATION EXAMPLE

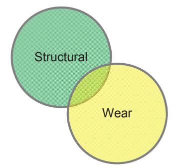
Water Meter Valve

Requirements

- Dimensional stability, potable water contact - NSF listed

Solution

- Graphite lubricated PS and SAN



ADDITIVE TECHNOLOGIES

PTFE

Silicone

PFPE

Graphite

MoS_2

Fibers

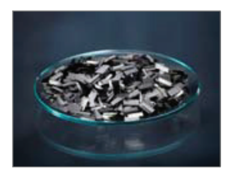
ADDITIVE TECHNOLOGIES

Reinforcing Fibers and Wear Resistance

Glass Fiber

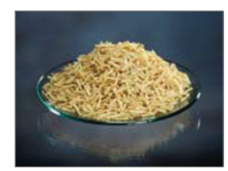
- Improved bearing capabilities/wear resistance
- Very abrasive

Carbon Fiber



- Higher bearing capabilities
- Excellent thermal resistance
- Conductive
- Less abrasive

Aramid Fiber



- Little strength improvement
- Very gentle to mating surface

ADDITIVE TECHNOLOGIES

Fibers protect the polymer, but may be abrasive against the mating material

Glass

Carbon

Aramid

Aluminum Contact Surface

APPLICATION EXAMPLE

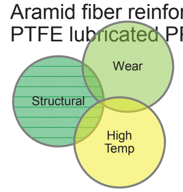
Copier Bushings

Requirements

- High heat deflection temperature and good wear resistance

Solution

- Aramid fiber reinforced and PTFE lubricated PPA



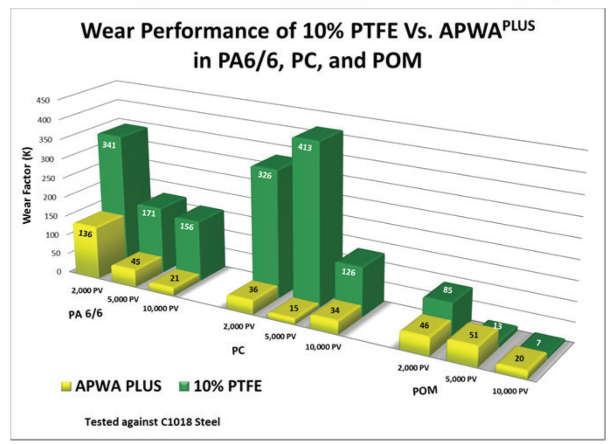
ADDITIVE TECHNOLOGIES

APWA^{PLUS}: All Polymeric Wear Alloy

A unique polymer alloy technology offering:

- Improved wear and friction performance
  - Especially effective in plastic vs. plastic wear
- Good retention of base resin physical properties
- Lower specific gravity than PTFE
- Reduction/elimination of plate-out associated with PTFE

ADDITIVE TECHNOLOGIES



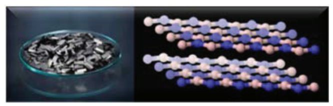
ADDITIVE TECHNOLOGIES

Additive Synergies

10/10/10 – Carbon Fiber/Graphite Powder/PTFE
Typical additive package for high load bearing/high temp. applications

Aramid Fiber/PTFE
Excellent wear package that is gentle on the mating surface

Carbon Fiber/Ceramic Additive
Non-PTFE solution, good for very demanding conditions



AGENDA

I. Wear Definitions & Test Methods
II. Friction Definitions & Test Methods
III. Additive Technologies
IV. Application Examples
V. Extreme Conditions – Ultra Wear

EXTREME CONDITIONS

What happens when your application has a PV higher than 10,000?

High Temperature
High Loads (500+ psi)
High Speeds
Chemical Resistance

Excellent Mechanical Properties
Injection Molded Parts

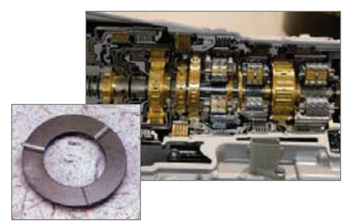
100 ft/min tests	*200 ft/min tests*
10,000 PV: 100 psi	*10,000 PV: 50 psi*
25,000 PV: 250 psi	*25,000 PV: 125 psi*
50,000 PV: 500 psi	*50,000 PV: 250 psi*

EXTREME CONDITIONS

Ultra Wear Products Developed for Demanding applications

Transmission Seal
High Load Thrust Washers
Pipe Gaskets

Off-Shore Drilling
Construction Vehicles
Oil and Gas Industry



EXTREME CONDITIONS

1. **Develop a series of high performance RTP products ideal for "Ultra" testing**

Resins

- PEEK
- PPS
- PPA

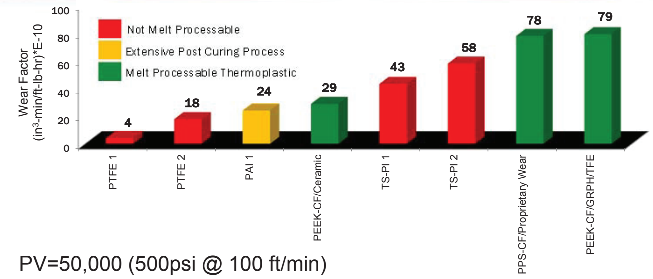
Additives

- Carbon Fiber
- Graphite
- Aramid Fiber
- PTFE
- Ceramic
- MoS_2

2. **Compare RTP Ultra Products with industry leading wear resistant materials**

- Rulon® J
- Rulon® LR
- Torlon® 4301
- Torlon® 4630
- Vespel® SP-21
- Vespel® SP-211
- Stanyl® TW371

EXTREME CONDITIONS

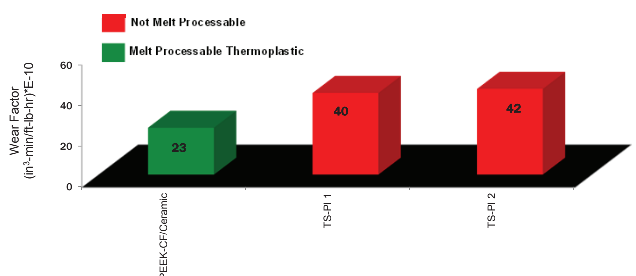


PV=50,000 (500psi @ 100 ft/min)

Compound	Wear Factor (in³-min/ft-lb-hr)*E-10	Dynamic μ	Compound	Wear Factor (in³-min/ft-lb-hr)*E-10	Dynamic μ
PTFE 1	4	0.15	PPS-CF/TFE	134	0.26
PTFE 2	18	0.16	PPS-AF/TFE	Wear Limit	NA
PAI 1	24	0.12	PPS-GF/TFE	Wear Limit	NA
PEEK-CF/Ceramic	29	0.06	PEEK-CF/TFE	Wear Limit	NA
TS-PI 1	43	0.14	PEEK-CF/AF/TFE	Wear Limit	NA
TS-PI 2	58	0.15	PEEK-CF/GRPH/TFE/PFPE	Wear Limit	NA
PPS-CF/Proprietary Wear	78	0.24	PEEK-CF/PFPE	Wear Limit	NA
PEEK-CF/GRPH/TFE	79	0.16	PPA-CF/TFE	Wear Limit	NA
PAI 2	105	0.18	PPA-CF/Proprietary Wear	Wear Limit	NA
PEEK-AF/TFE	119	0.18	PPA-CF/AF/TFE/SI	Wear Limit	NA
PEEK-CF/GRPH/TFE (CGP)	133	0.23	PA 46 - TFE	Wear Limit	NA

Wear per ASTM D-3702 against Steel

EXTREME CONDITIONS



Disc Material	Wear Factor (in³-min/ft-lb-hr)*E-10	Dynamic μ
PEEK-CF/Ceramic	23	0.05
TS-PI 1	40	0.10
TS-PI 2	42	0.07
PTFE 1	Wear Limit	NA
PAI 1	Wear Limit	NA
PPS-CF/Proprietary Wear	Wear Limit	NA

Wear per ASTM D-3702 against Steel at **400°F; PV = 100,000**

EXTREME CONDITIONS

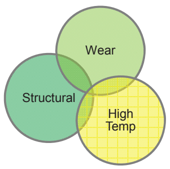
	Torlon 4301 (PAI)	Vespel SP-21 (TS PI)	Rulon J (PTFE)	Stanyl TW371 (PA46)	RTP 1300 AR 15 TFE 15 (PPS)	RTP 4085 TFE 15 (PPA)	RTP 2285 HF TFE 15 (PEEK)	RTP 2299 X 125404 A (PEEK)
Manufacturer	Solvay	DuPont	St. Gobain	DSM	RTP	RTP	RTP	RTP
Polymer	PAI	TS PI	PTFE	PA 4/6	PPS	PPA	PEEK	PEEK
Generic Description	PTFE/Grph	Grph	PI Pwdr	PTFE	AF/PTFE	CF/PTFE	CF/PTFE	CF/Ceramic
Strength	G	G	P	F	F	E	E	G
Stiffness	G	G	P	P	F	E	E	G
~ Cont. Use Temperature	>500 °F (260 °C)	>600 °F (316 °C)	~550 °F (290 °C)	~350 °F (177 °C)	~400 °F (205 °C)	~375 °F (190 °C)	~475 °F (246 °C)	~475 °F (246 °C)
Chem. Resistance	E	E	E	P	E	G	E	E
Processing	17 Day Cure	Parts Only	Parts Only	G	G	G	G	G
Friction	G	G	E	G	E	F	G	G
Wear resistance	E	E	E	G	G	G	G	E
Moisture sensitivity	P	G	E	P	E	G	G	G

APPLICATION EXAMPLE

AC Compressor Scroll Seal

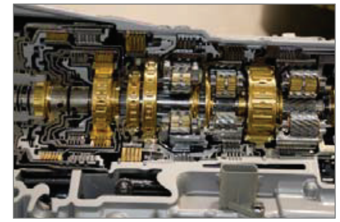
Requirements
- High temperature, chemical and wear resistance

Solution
- Carbon fiber reinforced and PTFE/Graphite lubricated PEEK



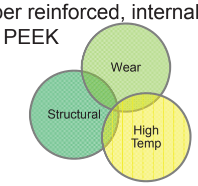
APPLICATION EXAMPLE

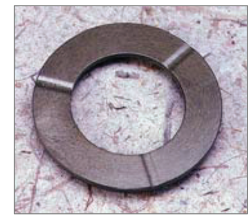
Transmission Seal Rings/ Thrust Washers



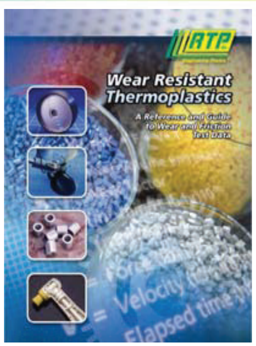
Requirements
- Ability to survive extremely high PV conditions with external lubrication

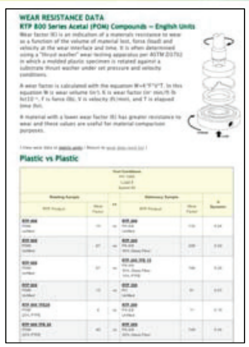
Solution
- Carbon fiber reinforced, internally lubricated PEEK





ADDITIONAL INFORMATION





Wear Factor (K) and friction coefficient (μ_K) for common tribological compounds:
www.rtpcompany.com/info/wear

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

RTP Co.
Imagineering Plastics®

Get Amped Up about Conductive Plastics

Ned Bryant | Senior Product Development Engineer
nbryant@rtpcompany.com
(507) 474-5361

1:30 p.m.

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Get Amped Up about Conductive Plastics

Ned Bryant
Sr. Product Development Engineer

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OVERVIEW

Conductive Classification and Testing

Overview of Conductive Modifiers

- Migratory Anti-stats
- Inherently Dissipative Polymers
- Carbon (Powder, Fiber, Nanotubes)

More Specialized Technology

- EMI Shielding
- Thermal Conductivity

Wrap Up and Questions

WHAT IS CONDUCTIVITY?

Conductivity

- Electrical – A material's ability to carry electric current
- Thermal – A material's ability to conduct thermal energy

Resistivity

- How strongly a material opposes the flow of an electric current

CONDUCTIVE CLASSIFICATION

Anti-static

- Cleanliness
- Prevent dirt & dust build up

Static Dissipative

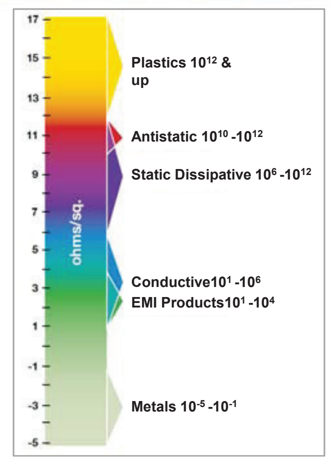
- Protect delicate electronics
- Prevent explosions

Conductive

- Exceptionally sensitive devices
- Grounding electrical circuits

Shielding

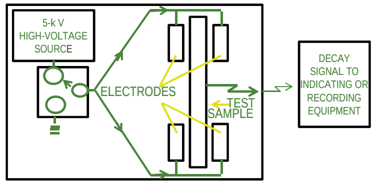
- Provide protection against RFs



STATIC DECAY TESTING

Static Decay Rate

- Measures seconds to decay
- 5000V to 50V
- 12% relative humidity



Standards/Specifications

- MIL PRF 81705 D
- NFPA 56A
- Numerous others

SURFACE TESTING

Surface Resistivity (ohms/square)

Surface Resistance (ohm)

Standards/Specifications

- ASTM D257
- ESD STM11.11
- IEC 60079-0
- Numerous others

SURFACE RESISTIVITY TEST

Guarded Ring Electrode

Flat Specimen

Precise Measurement

Units = ohms/square

SURFACE RESISTANCE TEST

Surface <u>Resistance</u> Meter

- Point to point
- Measuring small & critical areas on part
- Units = ohm

SURFACE RESISTANCE TEST

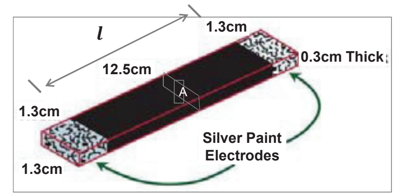
Another Surface Resistance Meter

- Point to point, 5lb weighted probes
- Typically used for flooring applications and large parts
- Units = ohm

VOLUME RESISTIVITY TEST

$$\rho = R\frac{A}{l}$$

ρ = Volume Resistivity
R = Resistance
A = Cross-sectional Area
l = Length



Units = ohm-cm
ASTM D-257

OVERVIEW

Conductive Classification and Testing

Overview of Conductive Modifiers

- Migratory Anti-stats
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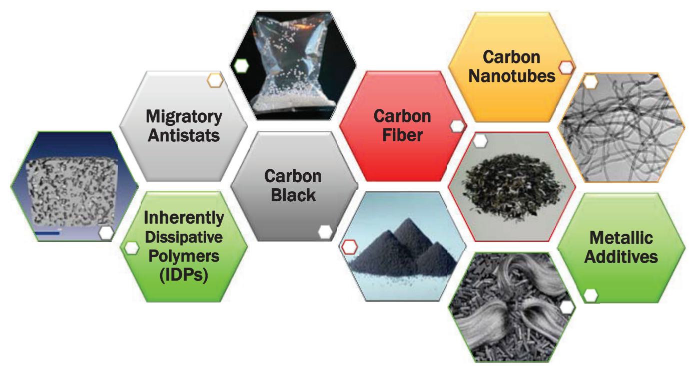
- Carbon (Powder, Fiber, Nanotubes)

More Specialized Technologies

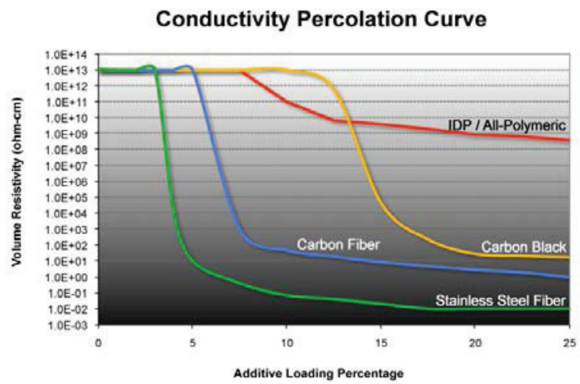
- EMI Shielding
- Thermal Conductivity

Wrap Up and Questions

CONDUCTIVE MODIFIERS



PERCOLATION CURVE



MIGRATORY ANTI-STATIC AGENTS

- Migrating surfactant based – not bonded to resin
- Temperature & humidity dependent
  - Best at room temperature & high humidity
- Colorable
- Liquids & semi-solids with low boiling points
- Compatible only with low temp. resins
  - Olefins, Styrenics, PVC
- Economical/commodity materials

INHERENTLY DISSIPATIVE POLYMERS (IDP)

All-polymeric, based on IDP

- Typically consist of PE oxide
- Other block dictates compatibility
- Forms a co-continuous morphology with the base resin

Over 20 different resin systems

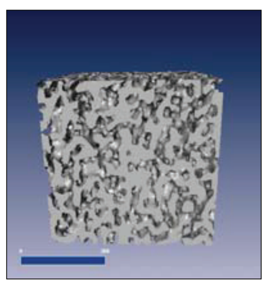
- Limited process temps (< 520 °F)

Surface resistivity

- Standard: 10^{10} to 10^{11} ohm/sq
- PLUS: 10^{8} to 10^{9} ohm/sq

Static decay rate

- Standard < 2.0 s
- PLUS < 0.5 s



PermaStat®

PERMASTAT® TECHNOLOGY BENEFITS

- Permanent Protection: Not dependent on migration, RH or temperature
- Clean Technology: Non-sloughing, FDA, biocompatible grades available
- Transparent grades available and fully colorable
- Base resin properties retained
- PermaStat PLUS® can meet ATEX requirements

TYPICAL APPLICATIONS

Reticle Boxes
ABS, PMMA

Inhalers
ABS, PP, PMMA

ATEX IBC
PE

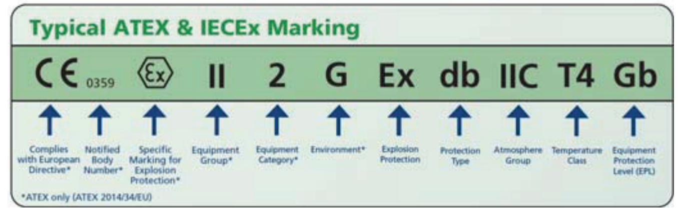
WHAT IS ATEX?

<u>AT</u>MOSPHERE <u>EX</u>PLOSIVE

- Potentially explosive environments

Began as a European Directive

- Standardize compliance procedure
- Now seen in U.S. and other countries (IECEx)



ATEX TESTING

Actual requirements defined by customer

All tests are on actual parts (Article Testing)

Tests typically include:

- <u>Surface Resistance</u> (almost always included)
- Relative Thermal Index (RTI)
- Chemical Resistance
- Impact (Low temperature)
- Ultra Violet (UV)
- High Humidity Aging Testing
- Flame Retardant (FR)

Need to fully identify all requirements for proper material selection

ATEX SURFACE RESISTANCE

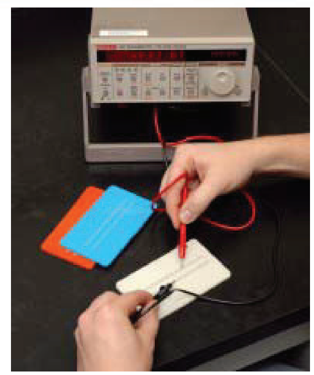
Specific test

- Isolation resistance <1 Gohm at 50% RH
- Tested at 500 V

Different from the standard surface resistance or resistivity widely used in the industry

- IEC 60093
- ASTM D 257
- ESD STM11.11

No real correlation



ATEX MARKETS

- Mining
- Personal protective equipment
- Food, chemicals, and paint industries
- Hand-held equipment
- Industrial equipment
  (pneumatic, hydraulic, venting systems, pumps)

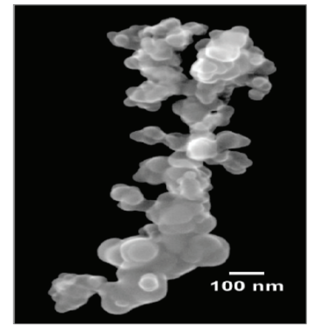




CONDUCTIVE CARBON BLACK

Characterized by:

- Structure
- Size of particles
- Porosity
- Surface Chemistry



CONDUCTIVE CARBON BLACK

- Permanent
- Black color only
- Sloughing / Marking / Crayoning
- Economical
- Dissipative or conductive

- SR 10^3 to 10^9 ohm/sq.
- VR 10^0 to 10^6 ohm-cm

CARBON BLACK APPLICATIONS

Electronic device trays
PP, PS, PC

Pipette tips
PP

Storage bins & totes
PP

Fuel filler tubes
PE

CARBON FIBER

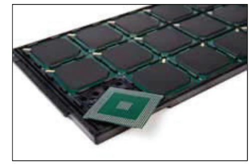
- Non-sloughing
- Colorable
- Anisotropic shrinkage
- Reinforcing
- Dissipative or Conductive
  - SR 10^2 to 10^6 ohm/sq
  - VR 10^{-1} to 10^4 ohm-cm

Chopped Fiber
(6 mm long "bundles")

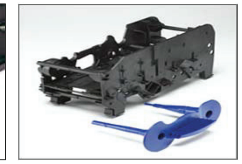
Milled Fiber

CARBON FIBER APPLICATIONS

Full Line components
PPA, Nylon, Acetal



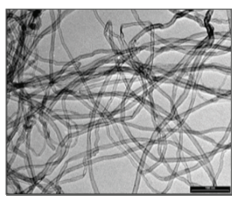
Chip transport/Storage trays
PC, PEI, PES

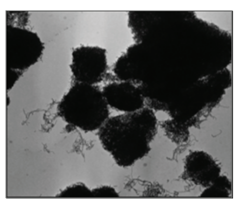


Card printer chassis
PC

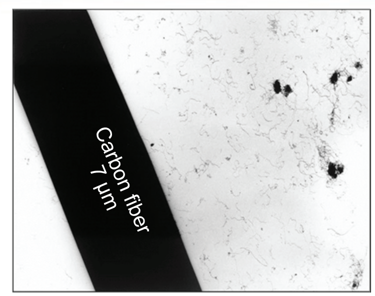
CARBON NANOTUBES (CNT)

- > 90% graphite
- Hollow
- 10 nanometer diameter
- High L/D ratio





CNT IS NANOTECHNOLOGY



A carbon fiber surrounded by CNTs

PRIMARY BENEFITS OF CNTS

Uniform Conductivity – Prevent hot spots

Effective at low loadings – Cleaner product

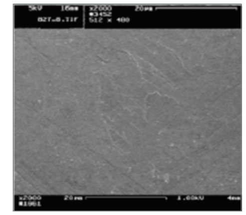
Isotropic Properties – Behaves like neat resin

Ability to use regrind – Maintains conductivity

ELECTRICAL CONDUCTIVITY

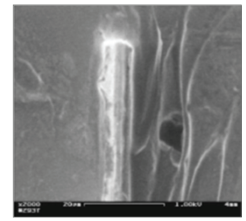
SEM (2000x) of typical CNT compound

- Smooth surface finish
- Uniform shading is a direct result of uniform electrical conductivity



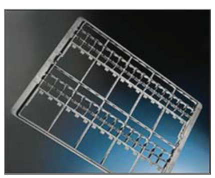
SEM (2000x) of typical CF compound

- Rough surface finish
- White shading indicates a point of high conductivity - “Hot Spot”
- Possible conductive particle generation



ELECTRONICS INDUSTRY APPLICATIONS

- Hard disc drive (HDD) handling components
- Silicon wafer handling components
- Semiconductor chip trays
- ESD shipping trays



Trays

Wafer Caddy

HDD

OVERVIEW

Conductive Classification and Testing

Overview of Conductive Modifiers

- Migratory Anti-stats
- Inherently Dissipative Polymers
- Carbon (Powder, Fiber, Nanotubes)

More Specialized Technology

- **EMI Shielding**
- Thermal Conductivity

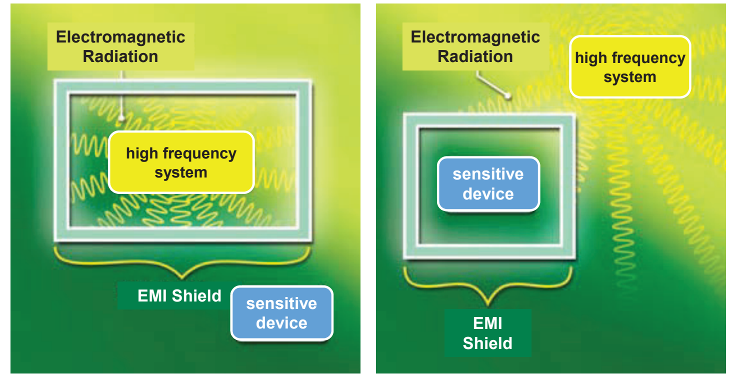
Wrap Up and Questions

INTRODUCTION TO EMI SHIELDING

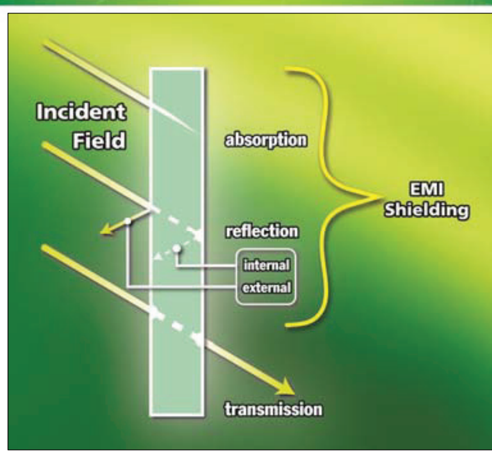
- **E**lectro**M**agnetic **I**nterference = EMI
- Emitted from a source *or* Received by a device
- Typical frequency range of 1 kHz to 10 GHz
- Faraday Cage Principle, provide “Immunity”
- Microwave Oven: 2.45 GHz (122 mm)

EMI IN ACTION

EMI shields protect devices from high frequency sources



EMI IN ACTION



EMI SHIELDING FILLERS

Electrically Conductive modifiers:

- Carbon Black (CB)
- Carbon Fiber (CF)
- Graphite
- **Stainless Steel Fiber (SSF)**
- **Nickel Coated CF (NCCF)**
- Other metallic additives

KEY ADDITIVE COMPARISON

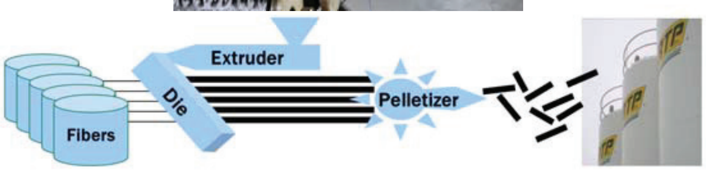
SSF
- Minimal affect on neat resin properties
- **Neat resin shrinkage**
- Good shielding
- Cost effective
- Colorable

NCCF
- Properties similar to carbon fiber compounds
- High shielding performance
- Higher cost
- Less colorable

WHAT TYPE OF SSF?

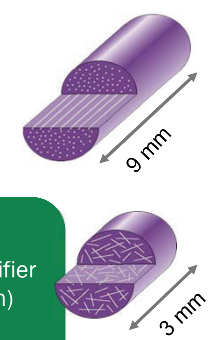
Stainless Steel Fiber
- 8 µm Diameter
- 304 Tool Steel
- Very Flexible

THE LONG FIBER PROCESS



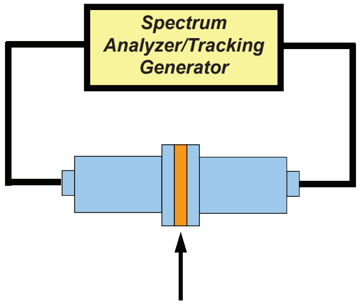
CUBE BLENDS

Cube blend
- Physical blend of resin with conductive modifier
- Necessary to retain aspect ratio (fiber length)
- Evenly dispersed during injection molding
- SSF loading up to 20%

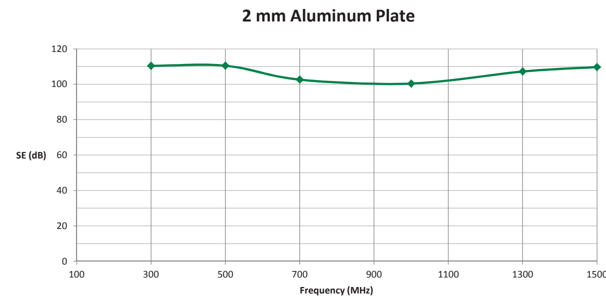


COAXIAL TRANSMISSION LINE TEST

- ASTM D4935
- Direct measurement method
- Relative ranking of materials
- Frequency range of 300MHz to 1.5 GHz
- Fast & Repeatable
- Flat test specimen – min. 6" diameter
- Units = Decibels of SE

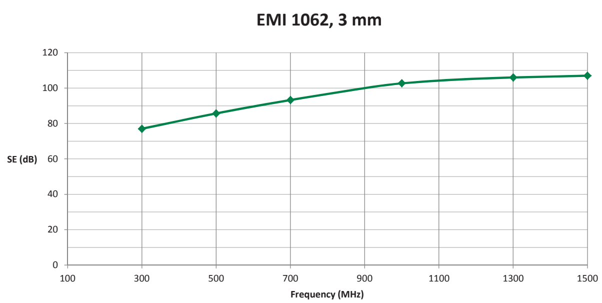


TEST RESULTS



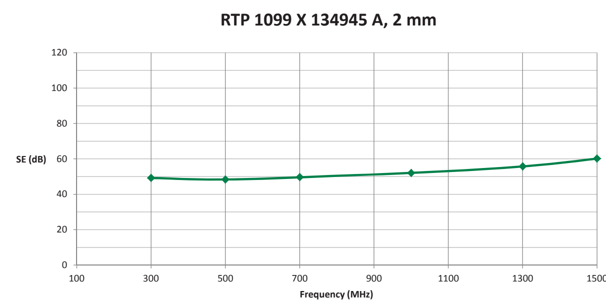
This represents the Maximum Capability of the test equipment.

TEST RESULTS



15% SSF

TEST RESULTS



This is a combined technology with conductive fillers and SSF to increase the low frequency SE.

EMI SHIELDING METHODS

- Actual metal housing
- Metallic paint/metal coatings
  - Traditional TV Cabinets
- Metal foil/screen
  - Microwave Oven
- Polymer compound
  - Increases design freedom, part consolidation
  - Eliminates secondary operations & reduces part cost

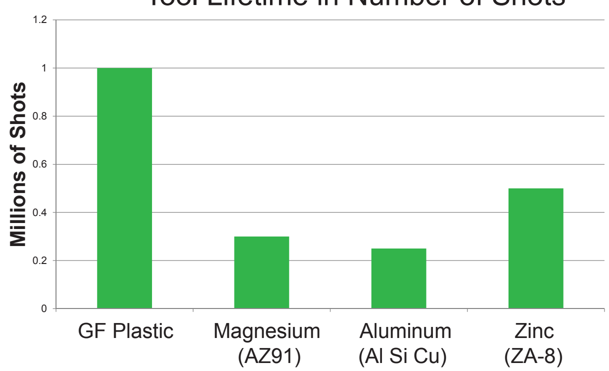
METAL OR PLASTIC

Metal
- High Thermal Conductivity
- High Electrical Conductivity (EMI Shielding)
- Very High Stiffness
- Very Low Creep
- Low CLTE
- High Strengths at High Temperatures
- Narrow Tolerances are Realistic

Plastic
- No Corrosion
- Lower Density
- Design Freedom (Integration of Functions)
- **High Tool Life Time**
- Good Chemical Resistance
- Acoustic Dampening
- Consolidation of Parts

TOOL LIFETIME IN SHOTS

Tool Lifetime in Number of Shots



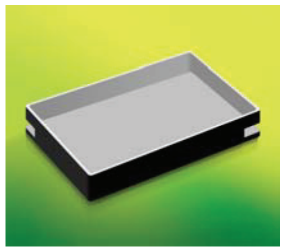
CONTROLLING EMI

EMI Shielding is a function of 4 variables:

- **Conductivity of the material**
- Thickness of the material
- Frequency of the interference
- Distance between the source of the interference and the shield

ELIMINATE CONDUCTIVE PAINT

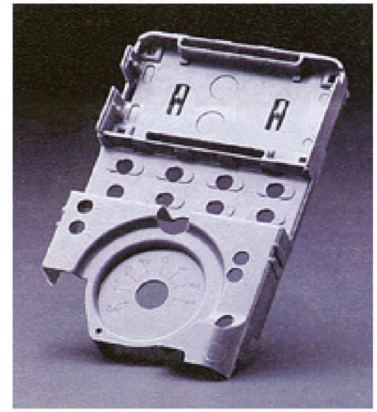
- Review of Conductive Paint:
  - Durability (flaking and scratching)
  - Potential thin spots in coating
  - Yield fallout from masking operation
  - Environmental considerations
  - Additional process
  - Additional supplier
  - Additional $$$



METAL REPLACEMENT

EMI 300 Series (PC):

- UL Listed (V-0 @ 1.5 mm)
- SE 30-70 dB
- GF from 0% - 20%
- Economical alternative to metal or coated plastics



COMBINING EMI & THERMAL CONDUCTIVITY (TC)

- SSF is a poor thermal conductor
- Thermal fillers can provide some EMI shielding
- Custom formulations can balance design requirements

RTP Formulation	SE @ 2 mm (300 MHz – 1.5 GHz)	TC (Through-plane)	TC (In-plane)
EMI 2562	60 – 85 dB	0.3 W/mK	---
299X124222C	30 – 55 dB	3.4 W/mK	25 W/mK
299X124222D	32 – 38 dB	3.1 W/mK	19 W/mK
299X124222E	40 – 60 dB	5.3 W/mK	32 W/mK
299X124223B	45 – 55 dB	1.4 W/mK	4.1 W/mK

OVERVIEW

Conductive Classification and Testing

Overview of Conductive Modifiers
- Migratory Anti-stats
- Inherently Dissipative Polymers
- Carbon (Powder, Fiber, Nanotubes)

More Specialized Technology
- EMI Shielding
- **Thermal Conductivity (TC)**

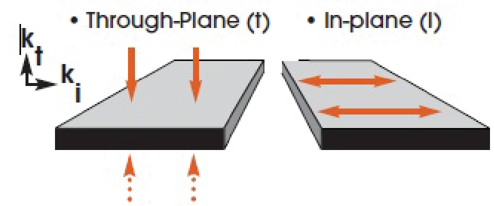
Wrap Up and Questions

TC ADVANTAGES

Property	Unfilled Plastics	TC Compounds	Aluminum
TC	0.1 – 0.2 W/m-K	1 – 35 W/m-K	150 – 250 W/m-K
Isotropic TC	No	No	Yes
Manufacturing processes	Injection molding, extrusion	Injection molding, extrusion	Casting, machining, extrusion
Design freedom	Unlimited	Unlimited	Limited by mfg processes
Weight (g/cc)	0.9 – 1.1	1.5 – 1.8	2.7
Shipping cost	reduced	reduced	standard
Electrical isolation	Yes	Possible	Not possible
Color	Unlimited	White, Gray & Colors	Gray only

TC DESIGN - ANISOTROPY IN PLASTICS

- **Through Plane**
  - Measured perpendicular to the flow of material
  - “Worst case scenario” for TC
- **In Plane**
  - Measured parallel to the flow of material
  - Influenced by fillers with high aspect ratios
  - Important for spreading and directing thermal energy



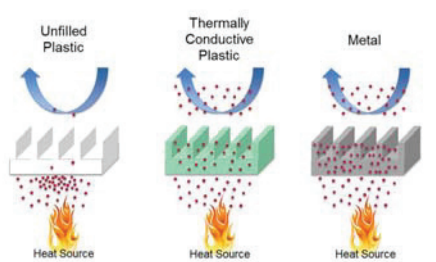
TC DESIGN – CONVECTION CONSTRAINT

Convection Limited

- The high TC of metal is typically not necessary
- Limited by convection to the environment

More Surface Area

- Ribs, fins and pins maximize convection
- Reduce the bottleneck in thermal transfer



Energy is not conducted through the plastic part	Energy is conducted through the plastic part	Energy is conducted through the metal part
Energy not available for convective heat transfer	Energy is available for convective heat transfer	Energy is available for convective heat transfer
Conduction Limited	Balanced System	Convection Limited

TC DESIGN – RADIANT HEAT TRANSFER

- Heat Transfer is a combination of:
  - Conduction, Convection, & Radiation
- Metals possess poor radiant transfer properties
- TC plastics possess excellent radiant properties
- This has real advantages, especially in doors or behind dashboards (places with low airflow rates)
- Al can be anodized to increase radiant heat transfer, but this is an additional process and cost to the system

TC FILLER OPTIONS

Electrically Conductive	Electrically Isolating
• Utilizes graphite and metallic fillers • Allows for higher thermal conductivity at a lower cost • Provides no dielectric strength to assembly • Typically produces black colored compounds • Thermal conductivity: – *Through-plane k = 1.0 to 8.0 W/mK* – *In-plane k = 2.0 to 35.0 W/mK*	• Utilizes ceramic fillers • Compromises some thermal conductivity to maintain electrical isolation • Dielectric strength allows for lower cost, more creative LED designs • Good choice when white color is desired • Thermal conductivity: – *Through-plane k = 0.5 to 2.5 W/mK* – *In-plane k = 1.0 to 10.0 W/mK*

TC VALUE

Why convert from metal?

- Highly complex geometries
- Increase surface area
- Weight reduction
- Simplified manufacturing
- Corrosion resistance
- Increased design freedom
- **Cost Reduction**

CONDUCTIVE MODIFIERS: PROS AND CONS

Technology	Pros	Cons
Migratory Antistats	• Economical	• Non-permanent • Process temperature limited • Humidity dependent
Inherently Dissipative Polymer PermaStat®	• Permanent • Transparent availability • Colorable • No loss of mechanical properties	• Limited to dissipative range • Process temperature limited
Carbon Black	• Economical • Dissipative or conductive • Resists Tribocharging	• Sloughing • Black only • Lower impact strength
Carbon Fiber	• Dissipative or conductive • Reinforcing • Non-sloughing	• Anisotropy • Poor tribocharging
Carbon Nanotubes	• Dissipative or conductive • Superior tribocharging performance • Minimal effect on mechanical and viscosity • Low Liquid Particle Count (LPC)	• Cost • Black only
Metallic Additives	• EMI/RFI shielding • Highly conductive	• Limited colorability • Higher specific gravity
Ceramic Additives	• Provide Thermal Conductivity • Electrically insulative	• High loadings required • Reduction in physical properties

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

Thank You!

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AP ESP Hueforia Wiman

Everything You Need to Know about TPEs

Paul Killian | Business Manager - TPE
pkillian@rtpcompany.com
(507) 474-5490

2:30 p.m.

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

Everything you need to know about TPEs

Paul Killian
Business Manager - TPE

rtpcompany.com • rtp@rtpcompany.com

TPE DIVISION

AGENDA

- Establish a Definition
- Understanding how TPEs work
- TPE Types
- RTP Company Product offering
  - Additive Capability
  - Styrenic Based TPEs
  - TPV Alloys
  - Bondable Technology

GOALS

- A basic understanding of various TPEs
- Relate this knowledge to the RTP Company TPE product line

DEFINITION

THERMOPLASTIC ELASTOMER

"…Having the property of softening or fusing when heated and of hardening again when cooled…"

"…Any of various elastic substances resembling rubber…"

Int'l Inst. of Synthetic Rubber Producers (IISRP) definition:

"Polymers, polymer blends or compounds which, above their melt temperatures, exhibit thermoplastic character that enables them to be shaped into fabricated articles and which, within their design temperature range, possess elastomeric behavior without cross-linking during fabrication. This process is reversible and the product can be reprocessed and remolded."

WHAT IS TPE

A diverse family of rubber like materials that, unlike conventional vulcanized rubber, can be processed and recycled like thermoplastic materials.

Thermoset	Thermoplastic
	

HOW TPEs WORK

TPEs are composed of **hard** and **soft** domains; they are **multiphase** materials in their solid state.

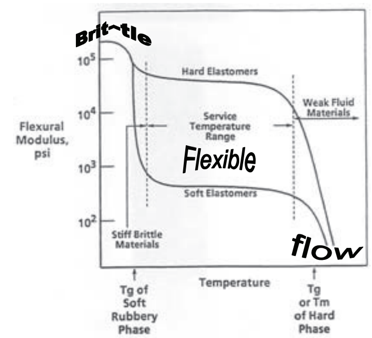
Hard phase contributes "plastic" properties such as:

- High-temperature performance
- Thermoplastic processability
- Tensile strength
- Tear strength

Soft phase contributes "elastomeric" properties:

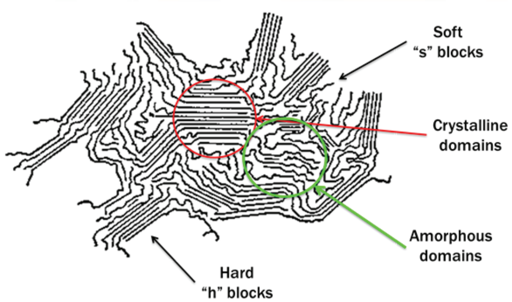
- Low-temperature performance
- Hardness
- Flexibility
- Compression & tension set

BUT WHY ARE TPEs RUBBERY?

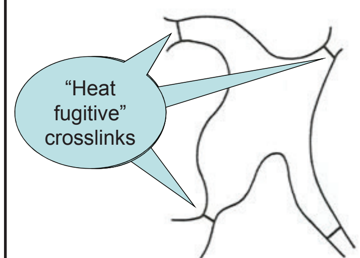


The design temperature range of a TPE is bounded by the glass transition temperature of the rubbery phase and the glass transition or melt temperature of the hard phase.

HOW TPE'S WORK

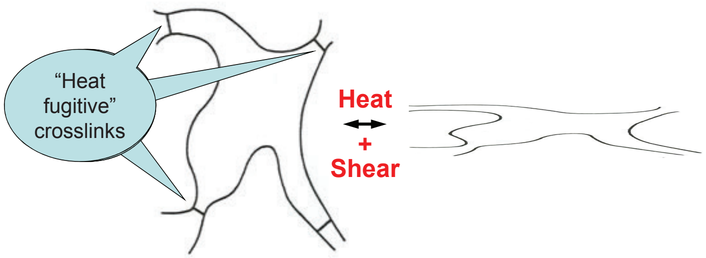


SO, HOW CAN TPEs BE MELT PROCESSABLE?



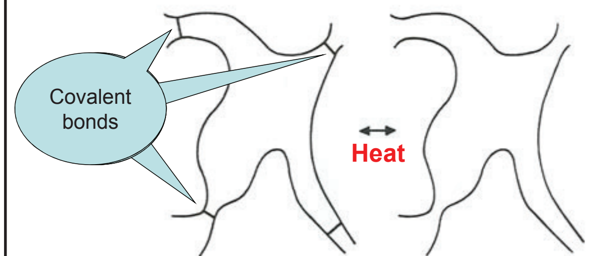
By raising the temperature of the TPE above the glass transition or melting temperature of the **plastic phase**.

SO, HOW CAN TPEs BE MELT PROCESSABLE



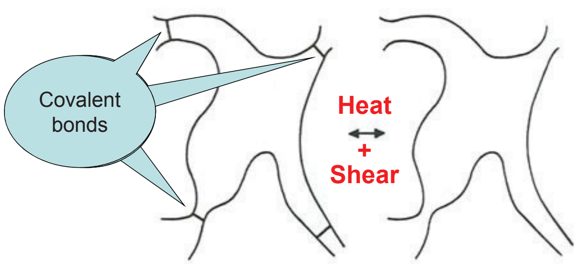
And applying shear forces typical of thermoplastic processes.

UNLIKE THERMOSET RUBBER...



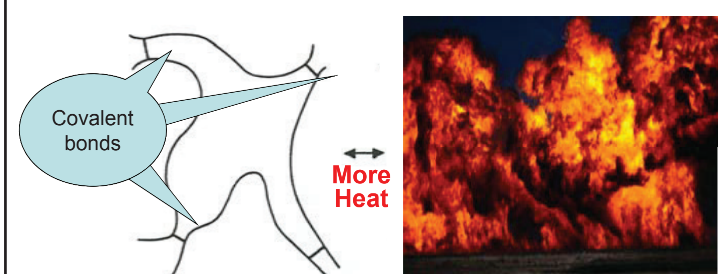
By comparison, thermoset rubbers (TSRs) are **single phase** materials with **non-reversible** chemical (covalent) bond cross-links.

UNLIKE THERMOSET RUBBER...



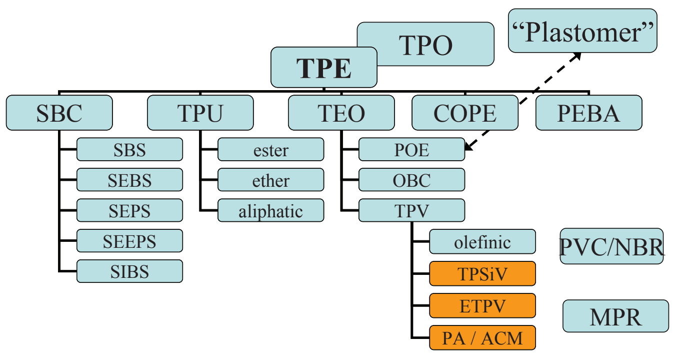
And are unaffected by shear forces.

UNLIKE THERMOSET RUBBER...



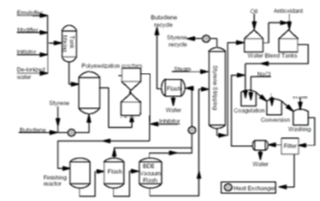
Or increasing heat...

LINEAGE (ALPHABET SOUP)

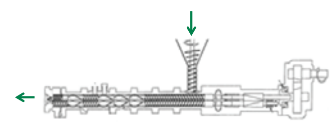


NEAT POLYMER VS COMPOUND

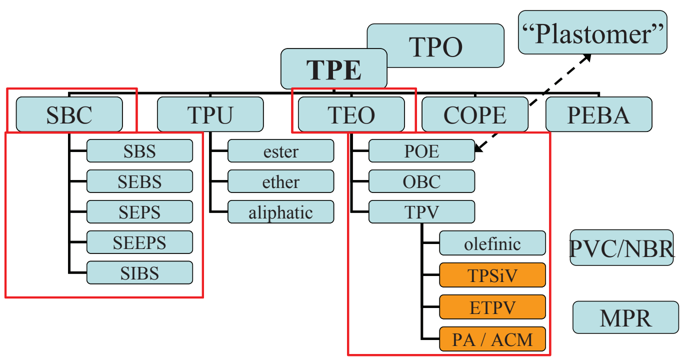
NEAT POLYMER
Created in a reactor, polymerizing thermoplastics chemically from feedstock



COMPOUND
Using a mechanical mixing process to improve one or more neat polymers



LINEAGE (ALPHABET SOUP)



Most Commonly seen as compounds

CLASSIFICATION & NOMENCLATURE

- Performance (heat & oil resistance following ASTM, SAE, etc.)
- Chemistry (styrenic, olefinic, urethane, etc.)
- Structure
  - Block copolymers
  - Blends & alloys
  - Dynamic vulcanizates

BLOCK COPOLYMERS - MECHANISM

Block copolymer based TPEs are made of polymers that have both hard (semi-crystalline or glassy) blocks and soft (amorphous) blocks along the backbone.

s-s-s-s-s-h-h-h-h-h-s-s-s-s-s-h-h-h-h

In the bulk, as they cool from the melt, the hard blocks will coalesce into crystalline or glassy domains creating physical crosslinks.

The soft blocks are left to form amorphous rubbery domains that provide the elastomeric bridges between the crystalline domains.

BLOCK COPOLYMERS - EXAMPLES

Styrenic block copolymers "SBC"

- SBS, SEBS, SIS, SIBS, SEEPS (neat rubber)
- **Rarely used in their neat form**

Polyolefin elastomer "POE"

Thermoplastic urethane "TPU"

Copolyether-ester "COPE"

Polyether-block-amide "COPA" or "PEBA"

BLENDS & ALLOYS - EXAMPLES

Styrenic block copolymers "SBC"

- SBS, SEBS, SIS, SIBS, SEEPS → RTP 2700 S Series
- Most frequently compounded with PP, PE, or POE

Bondable TPES

- Polabond™
- Nylabond™

FOCUS – SBC BASED TPEs

COMPOSITION

OIL *(white mineral, other)*
SBC POLYMER(S) *(type, MW, and structure)*
FILLER *(CaCO3, talc, none)*
POLYPROPYLENE (lots of choices)
Stabs, pigments, etc

DESIGN FLEXIBILITY

Hardness – Gels (Shore OOO) to 50D
Viscosity – Extrusion to ultra-high flow
Clarity – Opaque to water clear
Properties – Tailored elasticity, strength
Feel – Super grippy to dry
Fillers – Throw in the kitchen sink

STRENGTHS

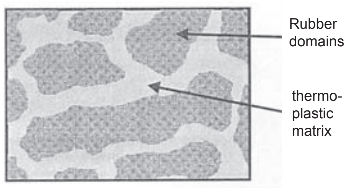
Elasticity– Highly elastic to "dead"
Versatility– Broad range of customizations
Low temp and RT – Great CS and flexibility
Cost– General purpose to boutique compounds
Aesthetics– Excellent moldability, consistency
Colorability– Very bright colors possible
Bond to PP

LIMITATIONS

Oil resistance– High affinity for absorption
High Temp– Max CUT ~100C
High Temp #2– Properties drop off as temp ↑
Reputation– A few bad apples . . .
Balance – Formulations flexibility is capped by inverse requirements – no free lunch

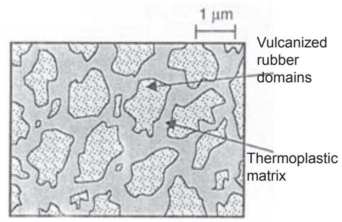
DYNAMIC VULCANIZATES - MORPHOLOGY

Simple melt-mixing



Coarse *morphology - TPO*

Dynamic vulcanization



Fine *morphology - TPV*

FOCUS – TPVs

COMPOSITION

- **EPDM RUBBER** *(non-vulcanized bale)*
- **POLYPROPYLENE** *(usually GP grades)*
- **FILLER** *(CaCO3 or talc, low %)*
- **CURE PACKAGE** (phenolic, peroxide, etc)
- **Oil** (generally low % add)
- **Stabs, pigments,etc**

DESIGN FLEXIBILITY

ALLOYS

- **Hardness**– 35A to 50D
- **Viscosity**– Shear dependent flow
- **Clarity –** Opaque, nat color vs cure pkg
- **Properties –** Driven by hardness
- **Feel**– Most "rubber-like" feel
- **Fillers**– Crosslinked EPDM limits filler

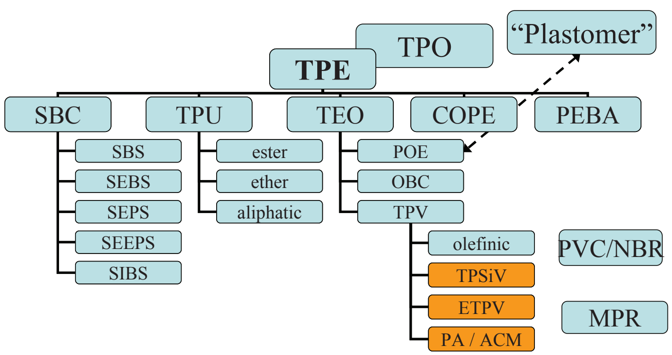
STRENGTHS

- **"Industrial"–** Higher temp property retention
  - Long term sealability (think auto)
  - Great inherent UV stability
  - Chemical and oil *resistance*
- **Rubber-like–** Most similar TPE to rubber
- **Commoditized**– Standard products and stocks
- **Bond to PP**

LIMITATIONS

- **Customization–** Technology and mfg limited
- **Aesthetics–** Shear sensitivity and gate defects
- **RM flexibility–** TPV does not drive inputs
- **Color–** Opaque natural, cure technology driven
- **Regulatory vs Cost–** Control capable, but "true" TPV has major cost implications

LINEAGE (ALPHABET SOUP)



TPE DESIGN FLEXIBILITY

Design Flexibility is a key component in leveraging the value of TPE's

Mass Reduction

Complex Geometries

Multi-Material Design

TPE ≠ RUBBER

Keep in mind:

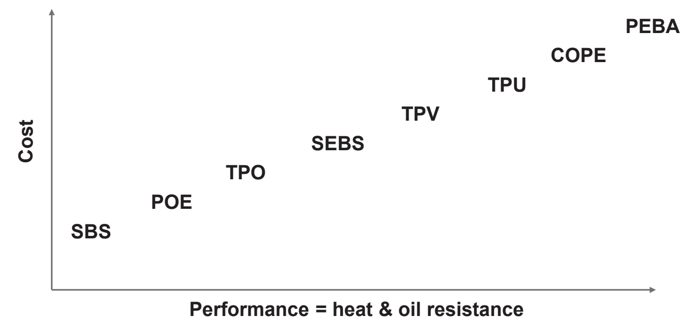
This is a broadbrush of many (very) different technologies that make up generic "TPE", relative to many (very) different technologies making up thermoset elastomers.

PROS	CONS
• Recyclable	• High Temp performance
• Mass reduction	• Material cost
• Manufacturing cost	• Elastomeric properties
• Design flexibility	• No in-house compounding

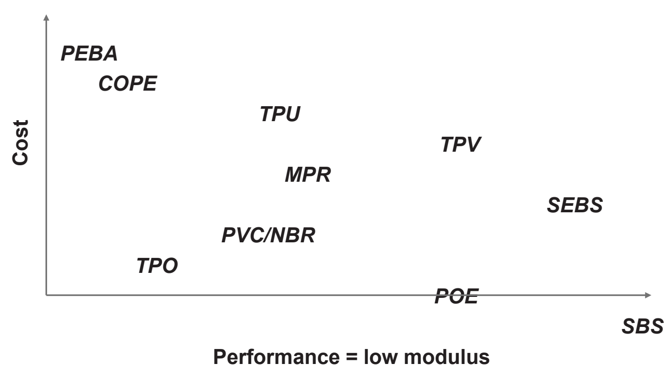
TPEs are not a one-to-one replacement for Thermoset Elastomers

Proper material selection is highly dependent on the application requirements, design, and ability to take advantage of the strengths inherent to TPE or Thermoset Elastomers

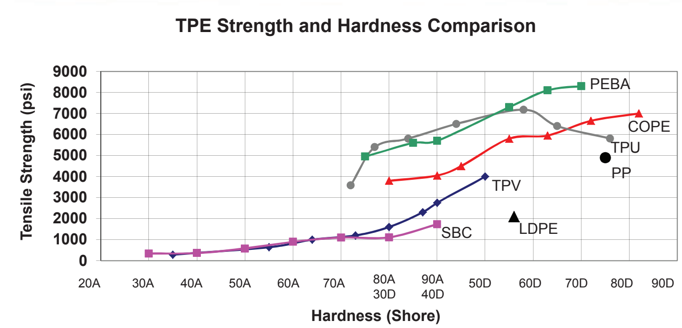
RELATIVE VALUE OF TPEs



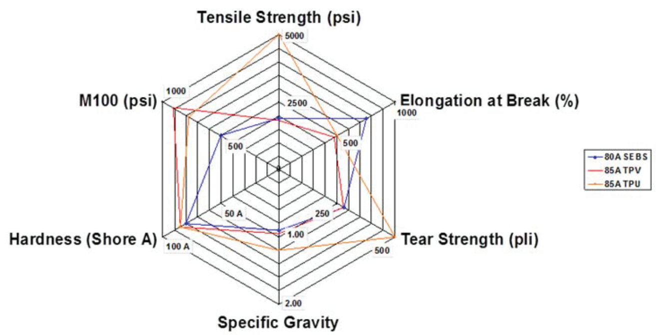
RELATIVE VALUE OF TPE'S



THE PROBLEM WITH HARDNESS



THE PROBLEM WITH HARDNESS



WHY RTP COMPANY?

RTP Company has been built on several basic principles:

- Independent, Value Added Custom Compounding
- Incorporating Specialty Additives into a Wide Variety of Base Resins
- Very Highly Focused on (and invested in) R&D, Technology, and Engineering

SBS • POE • TES • SBC • TPV • TPU • COPE • PEBA

TPE compounding requires the exact same approach – Only different?

- Mix R&D / Engineering capability with ability to supply "volume" compounds

- **Standard – Compounds common to the market**
- **TPE Alloys – Combining neat technologies to optimize performance**
- **Specialties – Incorporating RTP Company additive expertise**

STYRENIC BASED TPEs

RTP 2700 S & 2740S Standard Products

- **RTP 2700 S Series - 30A to 80A unfilled**
  - Translucent to clear, low gravity, excellent elasticity
  - Medical and FDA compliant grades available (MD and Z)
- **RTP 2740 S- HF Series – 30A to 90A filled SBC**
  - Opaque, higher gravity, FDA compliant grades available

Attributes

- *Highly elastic*
- *Highly customizable*
- *Design flexibility*
- *Broad cost spectrum*
- *Great RT compression set*

2799 SX Design Flexibility

- Water clear
- Increased elasticity
- Low hardness + strength
- EU food contact compliant
- Processing tweaks
- Haptics (touchy-feely)

VULCANIZATE BASED TPEs

Permaprene™ 2800 B & 2840 B Standard Products

- **Permaprene™ 2800 B Series - 45A to 50D TPV Products**
  - HF Grades preferred for cost & appearance improvement
  - FDA compliant grades available in non-HF only
- **Permaprene™ 2840 B Series – 55A to 90A TPV VA/VE Option**
  - Higher Gravity, Lower temp, good extrusion, smoother feel

Attributes

- *Broad temp range*
- *Improved chem resistance*
- *Easily colorable*
- *Broad cost spectrum*
- *Great RT compression set*

2899 X Design Flexibility

- Targeted viscosity
- Targeted properties
- Improved UV (good to great)
- Application tailoring
- Splitting the difference
- Haptics (touchy-feely)

NYLABOND™

Nylabond™ 6091 Series: Nylon Bondable TPVs

- Formulated specifically for melt bonding to Nylon 6 and 6/6
- Available in durometer levels of 55A to 85A
- TPV based product based on Santoprene® technology
- Market leading technology, unequalled property set
- Significant value in automotive – temp & chem resistance

Attributes

- Superior heat resistance
- *Superior chemical resistance*
- Superior compression set
- *Automotive approvals*

Automotive Specifications

- GMW 15817 Type 1
- GMW 15817 Type 2
- MSAR 100 AAN
- MSAR 100 BAN
- MSAR 100 CAN
- VW 50123 Conformance
- Daimler DBL5562-30
- SAE J200 callouts
- ASTM D4000 callouts



POLABOND™

Polabond 6042 Series: ABS, PC, and PC/ABS Bondable SEBS Alloys

- Excellent Bonding due to unique technology
- Great grip and feel, very durable
- Good aging properties relative to competitors
- Excellent processability and aesthetics
- Specialty versions available for unique applications

Attributes

- *RTP Company offers multiple technology platforms*
- *Variety of feel and performance*
- *Colorability*
- *Excellent bond strength in both insert and multishot processes*

Polabond 6041 Series - 55A and 70A TPV based

- Excellent Bonding to PC, ABS, PMMA, RTPU
- Premium polar bonding product
- Excellent chemical resistance at high temps
- Superior weatherability

ADDITIVE INCORPORATION

	Color	Conductive	Structural	Wear	FR

- PEBA (RTP 2900)
- COPE (RTP 1500)
- TPU (RTP 1200) (RTP 2300)
- TPV (RTP 2800)
- SBC (RTP-2700)
- 2-Shot (RTP 6000)
- TEO (RTP 2600)

RTP Company's Bread & Butter, Applied to TPE

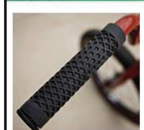
- Strong market leadership
- Leverage expertise and resources
- Deliver unique solutions & functionality

Precolor anything	CoF modified TPEs
Conductive anything	FR TPEs
Glass RTPU	ATEX Bondables
Wear TPU / COPE	Density modified


Side Benefit - Uniquely Experienced with all TPE chemistries

- Technical acumen to create custom formulations and alloys
- Culture of customer co-development – create what you NEED

WHAT TO TAKE AWAY FROM TODAY



RTP 2700 S - SBCs

- Common stand-alone TPE; 20A to 90A hardness
- **2700 S** – higher cost, lower gravity, translucent
- **2740 S-xx HF** – lower cost, higher gravity, opaque
- Bonds to PP; Custom tailoring possible
- Temp limited ~100C

Permaprene™ –TPV Alloys

- **2800 B-xx HF** - TPV offset in most non-auto applications
- 45A to 50D hardness, can be FDA
- **2840 B** –xx – VA/VE where TPV over-engineered
- Good chemical resistance, smooth feel, extrusion

Nylabond™ Polabond™

- **6091** – TPV based PA bonding, lots of auto approvals
  - 125 °C CUT, 55A to 85A,campaign products
- **6092** – in development, targeting Powertool market
- **6041** – TPV based polar bondable, high performance
- **6042-xx HF** – Cost effective, excellent bonding

Specialty

- Elastomeric + Any RTP Company core competency
- Conducive to "typical" RTP Company sales process

APPLICATION GUIDELINES

- What is the operating temperature range for my application?
- What chemical and/or environmental exposures might there be?
- What are the key performance requirements for the application (beyond just shore hardness)?
- What kind of process will be used to produce final parts?

Answers to Your Burning Questions: Flame Retardants and Regulations

Jesse Dulek | Product Development Engineer
jdulek@rtpcompany.com
(507) 474-5502

3:15 p.m.

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

Answers to Your Burning Questions: Flame Retardants and Regulations

Jesse Dulek
Product Development Engineer

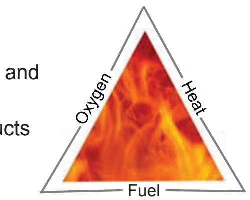
rtpcompany.com • rtp@rtpcompany.com

FLAME RETARDANT (FR) MATERIALS

Definition

Materials that do not ignite readily or propagate flames under small to moderate fire exposures

- Materials are combustible
- Fire retardants reduce the intensity and spread of fire
- Reduces smoke and toxic by-products of combustion



Fire Triangle

GOALS OF FLAME RETARDANT COMPOUNDS

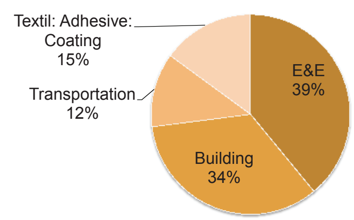
- Increase resistance to ignition
- Reduce rate of flame spread
- Reduce rate of heat release
- Reduce smoke emission

End Goal:

- Meet FR specifications
- Make the world a safer place!

MARKETS FOR FR THERMOPLASTICS

Segmentation of FR Consumption by Value



- Electrical Parts
- Electronic Enclosures
- Wire and Cable
- Appliances
- Transportation
- Building and Construction

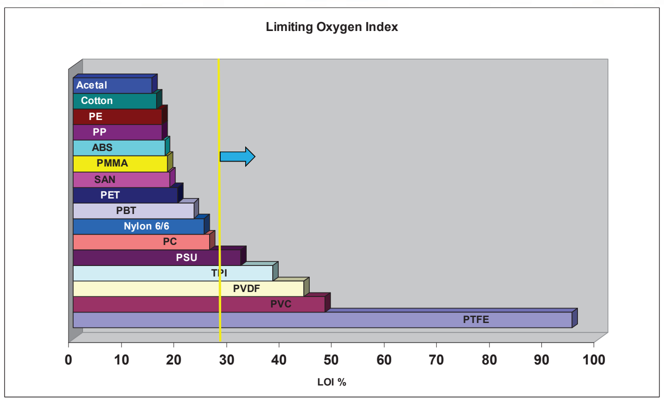
OVERVIEW

- **Thermoplastic Flammability**
  - **Flame Retardant Additive Chemistries and Mechanisms**
- Testing Standards
- Aerospace Requirements
- Case studies

THERMOPLASTIC RESIN FLAMMABILITY

Flammable	Inherently Flame Resistant
• Polyolefins • Nylons • Polycarbonate • Polyesters • Styrenics • TPEs	• Polysulfones • Polyphenylene Sulfide • Polyetheretherketone • Polyetherimide • Flouropolymers

CHALLENGES OF FLAME RETARDING PLASTICS

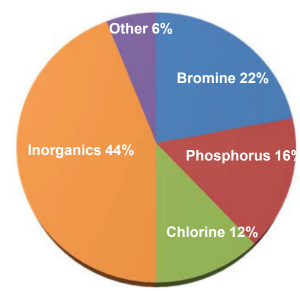


COMMON TYPES OF FR ADDITIVES

Halogenated FRs
- Brominated
- Chlorinated

Halogen Free FRs
- Metal hydroxides
- Phosphorous based
- Melamine based

Flame Retardant Additive Usage, 2011



HALOGENATED FR MECHANISM

- Halogenated technology inhibits the chemical reaction in the gas/vapor phase
- Various molecules that efficiently get large amounts of free radicals to the gas phase

Additive Type	Polymeric Type
• Higher halogen content • Lower loadings • High thermal stability	• Melt blendable • Less effect on physical properties • Enhanced flow

Halogenated flame retardants are compatible in most resin systems with the exception of Acetal

NON-HALOGEN MECHANISMS

Phosphorous	Hydrated Minerals	Melamine Cyanurate
• Various forms • Contributes to the condensed phase char formation	• Produce water during combustion process, dilute flammable vapors • Insulative char formation	• Endothermic decomposition • Physical removal of flame from surface
Resin Systems		
Polyolefins, Polyamides, Polyesters, Polycarbonate and alloys	Polyolefins, Polyamides	Polyamides, used as a synergist for other Phosphorous technologies

HALOGEN VS. HALOGEN-FREE

Halogenated	Halogen Free
• Lower cost • Better processing • Better efficiency • Better physical properties	• Evolving economics • Improved processing • Wide variety of products • Low smoke • Lower toxicity • Less corrosive • Lower specific gravity

CHOOSING A FR SYSTEM

How do we decide which FR mechanism to use?

- Resins system
- FR specification
- Part function
- Fillers/additives
- Regulatory concerns
  - Halogen, RoHS, etc.

OVERVIEW

- Thermoplastic Flammability
  - Flame Retardant Additive Chemistries and Mechanisms
- **Testing Standards**
- Aerospace Requirements
- Case studies

INDUSTRY AND MARKET DRIVEN

Electrical and Electronics (E&E)

- UL 94
  - V, 5V, HB
- UL 746
  - HAI, HWI, CTI

UL94 RATINGS

UL94 Ratings

- HB
- V-2
- V-1
- V-0
- 5VB
- 5VA

Ratings in order of difficulty to meet!

UL94 RATINGS

HB

- Handheld electronics
- Cell phone

V-2

- Low-voltage, attended
- Electric shaver

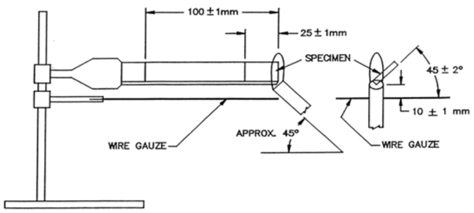
V-1/V-0

- High-voltage, un-attended
- Electronic connectors

- **5VB/5VA**
  - Electronic enclosures

UL94 - HB

Horizontal burning test for HB classification



Classification Criterion

3.0 mm to 13.0 mm thickness

- *slower than 40 mm/minute or…*
- *combustion ceases prematurely*

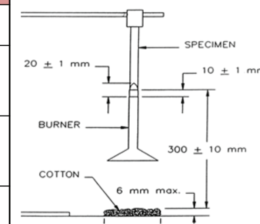
< 3.0 mm thickness

- *slower than 75 mm/minute or…*
- *combustion ceases prematurely*

***** In general most thermoplastics meet this criteria*****

UL94 - VB

Classification Criteria	V-0	V-1	V-2
Number of bar specimens	5	5	5
Maximum flame time per specimen per flame application, sec	10	30	30
Maximum total flame time 5 specimens, 2 ignitions, sec	50	250	250
Specimen drips, ignites cotton	No	No	Yes
Maximum afterglow time per specimen, sec	30	60	60
Burn to holding clamp	NO	NO	NO



*****Thickness dependent ratings*****

UL94 VERTICAL BURN DEMO

Flame Retardant – V-0

Non- Flame Retardant – No Rating

RTP COMPANY UL CERTIFICATION

RTP Company has 600+ UL Yellowcards

- Continuous expansion of UL listed products

UL Certified Laboratory under Client Test Data Program (CTDP)

- Short term properties to UL94
- Long term thermal aging (RTI)

RTP Company offers custom UL certifications to achieve full commercialization

- Quick turnaround
- Compress your Time to Market!

BUILDING / INDUSTRIAL

Requirements focus on:
- Low smoke, heat release, burn rate, flame spread

Various standard that apply:
- UL2043, UL723/ASTM E84, ASTM E1354, NFPA 701, FM 4996, CAL TB133

Applications
- Wall coverings, furniture, plenum, pallets, storage systems, roofing, floor coverings, ventilation

OVERVIEW

- Thermoplastic Flammability
  - Flame Retardant Additive Chemistries and Mechanisms
- Testing Standards
- **Aerospace Requirements**
- Case studies

AIRCRAFT INTERIORS FR REQUIREMENTS

All Commercial Aircraft (FAR 25.853 (a))

- Appendix F, Part 1, (a)(1) = Interior compartments occupied by crew & passengers
  - **(i) = 60 second Vertical Burn Test**
    - Ceiling & Wall Panels, Partitions, Galley Structure, Large Cabinet Walls, Structural Flooring, Stowage Compartments
  - **(ii) = 12 second Vertical Burn Test**
    - Floor Covering, Textiles, Seat Cushions, Paddings, Fabric, Leather, Trays, Galley Furnishings, Electrical Conduit, Air Ducts, Joint & Edge Covering, Trim Strips, & Others

AIRCRAFT INTERIORS FR REQUIREMENTS (CONT.)

All Commercial Aircraft (FAR 25.853 (a))

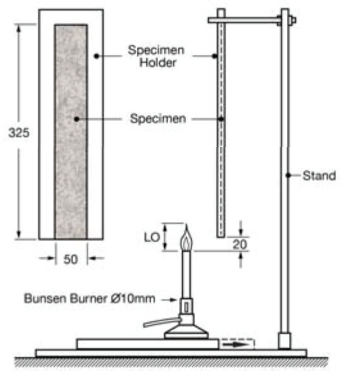
- Appendix F, Part 1, (a)(1) = Interior compartments occupied by crew & passengers
  - **(iv) = 15 second Horizontal Burn Test <2.5 in/min**
    - Clear Plastic Windows & Signs, Parts Made From Elastomers, Edge Lighted Instruments, Seat Belts, Containers/Bins/Pallets, and Others
  - **(v) = 15 second Horizontal Burn Test <4.0 in/min**
    - Small parts that would not contribute significantly to propagation of a fire (Knobs, Handles, Rollers, Clips, Grommets, Rub Strips, Pulleys and Others)

FAR 25.853(A) BURN TESTS

Vertical Burn

- 60 Second Ignition (i)
  - <15 sec flame time
  - <3 sec drip flame time
  - <6 in. avg. burn length
- 12 Second Ignition (ii)
  - <15 sec flame time
  - <5 sec drip flame time
  - <8 in. avg. burn length

FAR Part 25 testing in a vertical position

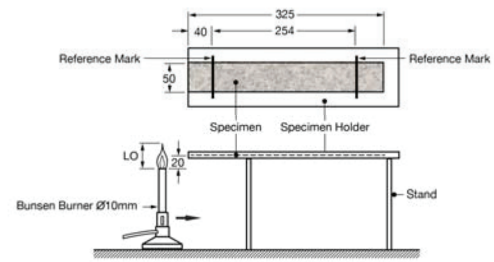


FAR 25.853(A) BURN TESTS

Horizontal Burn

- 15 Second Ignition
  - <2.5 in/min average burn length (iv)
  - <4.0 in/min average burn length (v)

FAR Part 25 testing in a horizontal position



AIRCRAFT INTERIORS FR REQUIREMENTS (CONT.)

Commercial Aircraft With Passenger Capacities > 20 (FAR 25.853 (d))

- FR Reqs same as Appendix F, Part 1, (a)(1) PLUS below for interior ceiling & wall panels, partitions, galley structure, and large cabinets & stowage compartments
- Appendix F, Part 4
  - Ohio State University (OSU) Heat Release Test
    - <65 kWminutes/m^2 total average heat release in first 2 minutes
    - <75 kW/m^2 peak heat release (Many specs require <65 kW/m^2)
- Appendix F, Part 5
  - NBS Smoke Density Test
    - <200 average Ds (3 specimens measured at 4 minutes)

STRATEGY

Product Priorities:

- *Weight Reduction*
  - *Stow Bins, Seating, Lavatory, Galley, Cockpit Controls, etc.*
  - *Part Consolidation & Metal-to-Plastic Conversion*
- *Economical Low-Smoke/Low-Toxicity Materials*
  - *Polyamide, Polypropylene, etc.*
  - *Custom Formulations & Alloys/Blends*
- *High Strength/Modulus Materials*
  - *Fasteners, Clamps, Brackets, etc.*
- *Custom Colored, OSU Materials*
  - *PEI, PES, PEEK, PPS, PPSU*
- *Lightning Strike Compounds*
- *ECO/Green Initiatives (Carbon Fiber Recycling)*

STRATEGY

Application Priorities:

- *Aircraft Interiors*
  - *Seating – Armrests, Tray Table Arms, Actuation Components*
  - *Door Frame Seals/Bumpers*
  - *Stow Bin Brackets*
  - *Trim/Rub Strips*
  - *Lavatory Components*
  - *Galley Components*
- *Flight Controls*
- *Engine Nacelles & Fuel Systems*
  - *Brackets, Fittings, etc.*
- *Fasteners, Cable Ties, and Other Fluid Systems*
- *Electronics Housings*

TRADITIONAL AIRCRAFT INTERIOR MATERIALS

- PEEK (Victrex PEEK®, Solvay KetaSpire®)
- PEI (Sabic Ultem®)
- Challenges
  - Cost
  - Availability
  - Color
  - Surface Aesthetics
  - Processability

AIRCRAFT INTERIOR MATERIALS

RTP Company Expanded Portfolio

- PEEK
- PEI
- PPS
- PPSU
- PES
- PPS
- Polyamides/Nylons (6/6, 6/12, 12, etc.)
- PC
- PC/ABS
- PP

RTP COMPANY MATERIAL OPTIONS

ENGINEERED COMPOUNDS	15 Second Horizontal Burn	12 Second Vertical Burn	60 Second Vertical Burn	Smoke Density	Toxic Gas Emission	OSU Heat Release (Reinforced)	OSU Heat Release (Unreinforced)
RTP100-Series Compounds (Polypropylene)	Pass	Pass	-	Pass	Pass	-	-
RTP 200-Series Compounds (Polyamide 6/6)	Pass	Pass	Pass	Pass	Pass	-	-
RTP 200 D-Series Compounds (Polyamide 6/12)	Pass	Pass	Pass	Pass	Pass	-	-
RTP 200 F-Series Compounds (Polyamide 12)	Pass	Pass	Pass	Pass	Pass	-	-
RTP 300-Series Compounds (Polycarbonate)	Pass	Pass	Pass	Pass	Pass	-	-
RTP 1300-Series Compounds (Polphenylene Sulfide)	Pass	Pass	Pass	Pass	Pass	Pass	-
RTP 1400-Series Compounds (Polyethersulfone / Polyphenylsulfone)	Pass	Pass	Pass	Pass	Pass	Pass	-
RTP 2100-Series Compounds (Polyetherimide)	Pass	Pass	Pass	Pass	Pass	Pass	-
RTP 2200-Series Compounds (Polyetheretherketone)	Pass	Pass	Pass	Pass	Pass	Pass	-
RTP 2200 A-Series Compounds (Polyetherketoneketone)	Pass	Pass	Pass	Pass	Pass	Pass	-
RTP 4000-Series Compounds (Polyphthalamide)	Pass	Pass	Pass	Pass	Pass	-	-
RTP Radel® R-7000 Series Compounds (Polyphenylsulfone)	Pass	Pass	Pass	Pass	Pass	N/A	Pass

WHAT IS RADEL R-7000?

Proprietary PPSU blends designed for aerospace interior applications (unfilled for cosmetic parts)

- Meet all FAR requirements for flame, smoke, toxicity, heat release
  - FAR 25.853 (a) & (d), BSS7238, BSS 7239, OSU Heat Release
- Good Impact
- Excellent Surface finish
- Chemically Resistant
- Versatile processing

Radel R-7300/R-7400/R-7625

- Fully Colorable
- Extreme Chemical Resistance
- Boeing Approved

Radel R-7700

- Fully Colorable
- Extrusion Grade

Radel R-7159

- Fully Colorable
- Boeing Approved
- More Cost Competitive Option

TYPICAL APPLICATIONS

Unfilled grades specifically targeting aesthetic aircraft interior parts

- Seating
- Passenger service units
- Stow bins
- Air grilles

ACTIVE INTERIOR PROGRAMS

Commercial Aircraft

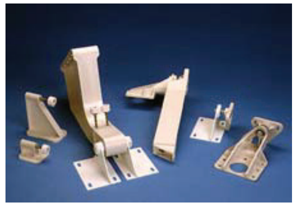
- *Stow Bin Brackets*
- *Seat Track Covers*
- *Trash Can*
- *Rub & Trim Strips*
  - *Seat Armrest*
  - *Galley*
- *Lavatory Components*
  - *Toilet Seats*
  - *Lighting*
  - *Floor Pan*
- *Flight Controls*
- *Oxygen Box Components*
- *PSU Rails*
- *HVAC/Air Handling Components*
- *Tray Table Arms*
- *Seat Actuation Components*

OVERVIEW

- Thermoplastic Flammability
  - Flame Retardant Additive Chemistries and Mechanisms
- Testing Standards
- Aerospace Requirements
- **Case studies**

APPLICATION EXAMPLE

Commercial Aircraft Stow-Bin Brackets



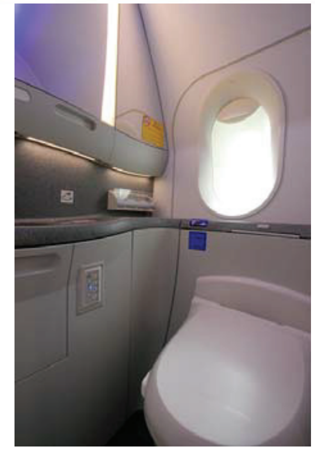
Features:
- High Stiffness
- Chemical Resistance
- FST & OSU 65/65 Compliance

Benefits:
- Metal-to-Plastic Conversion
- Lightweight
- Reduced Manufacturing Cost

- PEEK
- Glass Fiber
- Colored

APPLICATION EXAMPLE

Lavatory Components



RTP 299 D X 130507 A White & Gray
- Nylon 6/12
- Non-Halogen FR
- Color Matched

Specifications
- 12 second vertical burn
- Smoke Density
- Smoke Toxicity

APPLICATION EXAMPLE

Light & Lens Covers

RTP 399 X 138339
- Polycarbonate
- Non-Halogen FR
- Light Diffusing

Specifications
- 12 Second Vertical Burn

FR MEETS TRANSPARENCY

Market
Consumer

Application
LED Lens Cover

Problem
UL 94 V-0, High Light Transmission, UV, Light Diffusion, RoHS Compliance

Solution
PC – Transparent, Flame retardant, Specialty pigment package

Benefit
Provided ample diffusion of high powered LED lights with a proprietary pigment technology while achieving the required flame performance

FR MEETS OUTDOORS / UV

Market
Consumer

Application
Marine Connector

Problem
Strength/Impact, UV Resistance,
Specialty color, UL94 V-0, F1

Solution
PC/PBT – Glass reinforced,
UV stabilized, Flame retardant

Benefit
Product was able to pass the required drop impact testing and stringent UL outdoor and flammability ratings

FR BREAKS THROUGH THE CEILING

Market
Industrial

Application
Speaker Unit

Problem
Plenum location, UL 2043, UL94 5VA, Rigidity

Solution
Polypropylene -- Glass fiber reinforced, Halogen free flame retardant

Benefit
Provided structural requirements needed for function and stringent UL flame resistance

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR