

LUNCH & LEARN

2014 Thursday, November 13

Brought to you by:

**YOUR GLOBAL COMPOUNDER OF
CUSTOM ENGINEERED THERMOPLASTICS**



RTP Company

Lunch & Learn: Greene Tweed



*PDF copies of the presentations from today's Lunch & Learn can be downloaded from our website at **www.rtpcompany.com/GreeneTweed***

Schedule

11:00 a.m.	Welcome!	Duncan Hogg <i>Energy Market Manager</i>	Pg. 7
11:10 a.m.	An Engineer's Guide to Specifying the Right Thermoplastic	Jason Becker <i>Development Engineer</i>	Pg. 9
12:00 p.m.	Lunch		
12:50 p.m.	Introduction	Duncan Hogg <i>Energy Market Manager</i>	Pg. 27
1:00 p.m.	High Temperature Structural Products, Improved Performance at Elevated Temperatures and Harsh Environments	Matt Torosian <i>Product Manager, High Temperature Materials</i>	Pg. 33
1:45 p.m.	Wear and Friction, Beyond the Fundamentals	Gregg Newby <i>Product Manager, Wear Products</i>	Pg. 43
2:30 p.m.	Closing Remarks and Questions	Duncan Hogg <i>Energy Market Manager</i>	Pg. 59



Welcome!

Duncan Hogg
Energy Market Manager
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11:00 a.m.



An Engineer's Guide to Specifying the Right Thermoplastic

Jason Becker
Development Engineer
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11:10 a.m.

An Engineer's Guide to Specifying the Right Thermoplastic

Jason Becker
Application Development Engineer

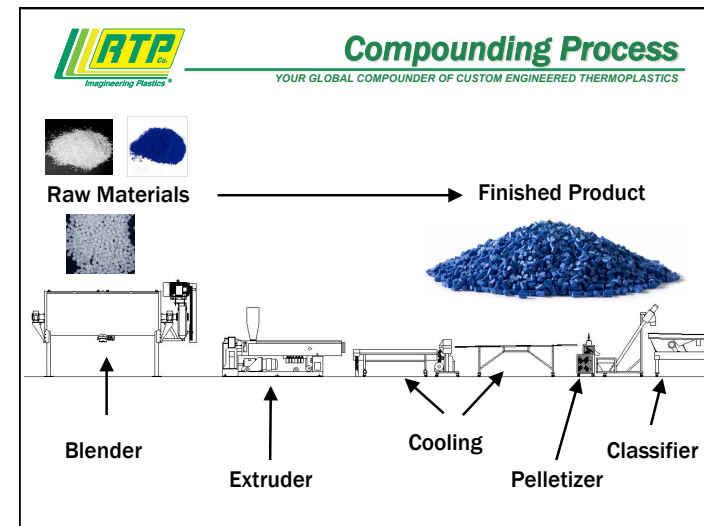
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- **Compounder** → We blend thermoplastic resins with fillers, additives, and modifiers
- **Specialty** → We create engineered formulations
- **Independent** → We are unbiased in our selection of raw materials

- Define Compounding
- Plastic Resin Selection Process
- Application Case Studies
- Compounding Performance
- Engineered Thermoplastic Compounds



Compounding Objectives
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Mixing**
 - Distributive
 - Dispersive

Compounding Extruders
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Single Screw Twin Screw Co-Kneader

Putting Compounding Into Perspective
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Conductive carbon black surface area = 130 m²/gram
- 34 grams carbon black = surface area of football field (4460m²)
- Dispersing a 20% carbon black compound is similar to evenly coating a football field with 136 grams of plastic!

Resin Selection

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

The Dilemma
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- 60 Thermoplastic Resins + 100 Additives = 1000's of Potential Compounds

Which **ONE** Do I Choose For My Application?

Plastic Selection Process
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Step 1 – Use Resin Morphology
- Step 2 – Use Thermal & Cost Requirements
- Step 3 – Fine Tune & Special Features

Morphology
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Amorphous

Semi-Crystalline


Morphology
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Amorphous

Semi-Crystalline

Compare

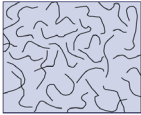
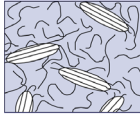
- Molecular Packing (Shrinkage)
- Resistance to Molecular Disentanglement (Chemical/Abrasion Resistance)
- Light Refraction (Opacity)
- Melting Characteristics (Flow)




Morphology Characteristics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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




Morphology Characteristics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

- Lens?
- Precision Printer Chassis?
- Fuel Float?
- Intake Manifold?
- Lamp Housing?
- Grease Fitting?
- Tool Housing?
- Laptop Cover?
- Pulley?



Morphology Of Thermoplastics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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



Plastic Selection Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Step 1 – Use Resin Morphology
- **Step 2 – Use Thermal & Cost Requirements**
- Step 3 – Fine Tune & Special Features

Morphology Vs Thermal/Cost
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

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

Plastic Selection Process
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Step 1 – Use Resin Morphology
- Step 2 – Use Thermal & Cost Requirements
- Step 3 – Fine Tune & Special Features

Engineered & Commodity Resins
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

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

Styrenic Features
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent (except HIPS & ABS), Poor Chemical & Abrasion

- PS → Good Transparency @ Low Cost, Brittle
- HIPS → Moderate Impact Resistance @ Low Cost
- SAN → Good Transparency, Slightly Better Chemical Resistance, Brittle, Low Cost
- ABS → Excellent Impact Resistance & Gloss, Slightly Better Chemical Resistance, Low-Moderate Cost



Acrylic Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Chemical & Abrasion

PMMA → Optical Quality Transparency, Excellent UV Stability, Brittle, Low Cost



Polycarbonate Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Chemical & Abrasion

PC → Optical Quality Transparency, High Impact Resistance, Moderate Cost



Olefin Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

PP → Low Density, Better Thermal Resistance Than PE, Living Hinge Capable, Brittle @ Low Temperatures, Low Cost

HDPE → Good Low Temp Impact Performance (Tg = -77°C vs -9°C for PP), Low Cost



Polyamide Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections (Except Amorphous Nylon), Poor Dimensions

Nylon 6 → Strong/Stiff (But Humidity Dependent), Good Surface Finish Even When Reinforced, Moderate Cost

Nylon 66 → Strong/Stiff (But Humidity Dependent), Higher Thermal Than 6, Moderate Cost

Nylon 6/12, → Less Sensitive to Humidity, High Cost



Amorphous Nylon Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Abrasion

Amorphous Nylon → Good Chemical Resistance for Amorphous Morphology, Moderate-High Cost



Polyester Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

- PET** → Difficult to Mold (Poor Nucleation & Hydrolysis), Good Electrical Resistance, Mod. Cost
- PBT** → Easy to Mold, Good Electrical Resistance, Properties & Dimensions Do Not Fluctuate With Humidity (Same For PET), Moderate Cost
- PLA** → “Green” Polymer, Poor Impact, Poor Heat Resistance, Difficult to Mold (Poor Nucleation & Hydrolysis), Low Cost



Polyoxymethylene (Acetal) Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Acetal → Low Friction & Wear, Excellent Resiliency & Fatigue Endurance, Moderate Cost



Putting It All Together

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Step 1 – Use Resin Morphology**
- **Step 2 – Use Thermal & Cost Requirements**
- **Step 3 – Fine Tune & Special Features**

Test Your Knowledge With Application Examples

RTP Co. **Case Study**
Engineering Plastics YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **CD Jewel Case**
 - Transparent
 - Flat & Dimensionally Stable
 - Low Cost
- **PS**




RTP Co. **Case Study**
Engineering Plastics YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Gas Tank**
 - Good Chemical Resistance
 - Good Low Temperature Impact
 - Low Cost
- **HDPE**




RTP Co. **Case Study**
Engineering Plastics YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Auto Tail Lamp Cover**
 - Transparent Colors
 - Dimensionally Stable
 - Excellent UV
 - Low Cost
- **PMMA**



RTP Co. **Case Study**
Engineering Plastics YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Plastic Glass Tumblers**
 - Transparent
 - Reasonable Thermal & Chemical Resistance (Dishwasher Cycles)
 - Low Cost
- **SAN**



RTP *Imagining Plastics* **Case Study**
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Sump Pump Housing**
 - Chemical Resistance
 - Reasonable Thermal Resistance
 - Low Cost
- **PP + GF**




RTP *Imagining Plastics* **Case Study**
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Safety Glasses**
 - Optical Transparency
 - High Impact
 - Moderate Cost OK
- **PC**




RTP *Imagining Plastics* **Case Study**
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Truck Wheel Odometer Lens**
 - Transparent
 - Good Chemical Resistance
 - Moderate-High Cost OK
- **Amorphous Nylon**




RTP *Imagining Plastics* **Case Study**
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Chemical Beakers**
 - Excellent Chemical Resistance
 - Low Cost
 - Transparent
- **??????????**



RTP *Imagineering Plastics* **Case Study**
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Nail Gun Housing**
 - Good Chemical Resistance
 - Excellent Strength, Stiffness & Impact
 - Good Surface Finish When Reinforced
 - Moderate Cost OK
- **Nylon 6 + GF**




RTP *Imagineering Plastics* **Case Study**
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Automotive Intake Manifold**
 - Chemical Resistance
 - Excellent Strength, Stiffness & Impact
 - Moderate Heat Resistance
 - Moderate Cost OK
- **Nylon 66 + GF**




RTP *Imagineering Plastics* **Case Study**
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Oil Pan**
 - Chemical Resistance
 - Excellent Strength, Stiffness & Impact
 - Moderate Heat Resistance
 - Moderate Cost OK
 - Extremely Tight Dimensions & Flat
- **??????????**



RTP *Imagineering Plastics* **Case Study**
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Electrical Connectors**
 - Good Flow in Thin Walls
 - Excellent Electrical Properties
 - Dimensionally Stable in Humidity
 - Moderate Cost OK
- **PBT (PET) + GF + FR**




RTP *Imagineering Plastics* **Case Study**
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Conveyor Rollers**
 - Good Abrasion Resistance
 - Low Wear & Friction
 - Moderate Cost OK
- **Acetal**



RTP *Imagineering Plastics* **Case Study**
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Printer Gears**
 - Extremely Tight Dimensions
 - Moderate Cost OK
 - Good Abrasion Resistance
 - Low Wear & Friction
- ?????????



RTP *Imagineering Plastics* **Case Study**
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Lawn Tractor Hood**
 - Tight Dimensions & Low Warp
 - Moderate Cost OK
 - Chemical Resistance
 - Good Mold Flow
 - High Impact
- ?????????



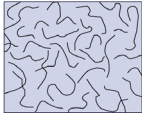
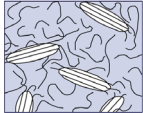
RTP *Imagineering Plastics* **THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR**
CONDUCTIVE • COLOR • FLAME RETARDANT

Overcoming Morphology Deficiencies Via Compounding



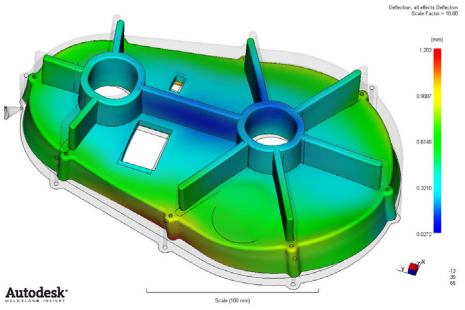
Morphology Deficiencies
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

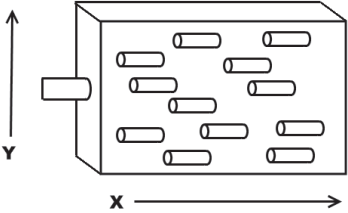



Dimensional Stability
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

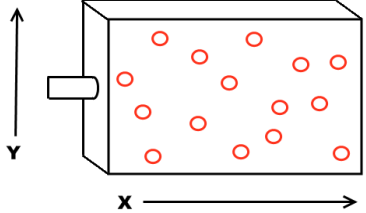


Fiber Reduces Shrink
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Shrink Rate X ≠ Shrink Rate Y → Warp

Warp Control
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



**Shrink Rate X = Shrink Rate Y → Flat Part
But Low Strength!**

Strength & Warp Control
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Case Study
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Oil Pan**
 - Chemical Resistance
 - Excellent Strength, Stiffness & Impact
 - Good Heat Resistance
 - Moderate Cost OK
 - Extremely Tight Dimensions & Flat
- **Nylon 66 + 15% GF + 25% Mineral**

Transparency
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Can We Make A Semi-Crystalline Resin Transparent?**

Nucleation/Clarification
 YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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


Melt Phase	"Nucleation Phase"	Semi-Crystalline Phase
Normal	[Small spherulites]	[Large spherulites]
Milled N ^o 8000 Clarified PP	[Small spherulites]	[Small spherulites]

Courtesy Milliken Chemical

RTP Imengineering Plastics
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Case Study

- **Chemical Beakers**
 - Excellent Chemical Resistance
 - Low Cost
 - Transparent
- **PP + Nucleator**



RTP Imengineering Plastics
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Chemical Resistance/Mold Flow

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

RTP Imengineering Plastics
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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, °F	270	210
Fuel Resistance	Poor	Poor
Melt Flow, gm/10 min	10	15
Clarity	Transparent	Opaque

RTP Imengineering Plastics
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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, °F	270	250
Fuel Resistance	Poor	Fair
Melt Flow, gm/10 min	10	20
Clarity	Transparent	Opaque



Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Lawn Tractor Hood**
 - Tight Dimensions & Low Warp
 - Moderate Cost OK
 - Chemical Resistance
 - Good Mold Flow
 - High Impact

- **PC/PBT Alloy**





Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **GPS Housing**
 - Tight Dimensions & Low Warp
 - Moderate Cost OK
 - Good Mold Flow
 - High Impact
- **PC/ABS or PC/PBT Alloy**
 - Want Sustainability
- **PC/PLA Alloy (30% Bio)**
 - Want More Sustainability
- **Recycled (PCR) PC/PLA Alloy (30%Bio + 60% PCR = 90% Sustainable)**






Wear Resistance

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Can We Make An Amorphous Resin Wear Resistant?**



PTFE Lubricated

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **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

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Printer Gears**
 - Extremely Tight Dimensions
 - Moderate Cost
 - Good Abrasion Resistance
 - Low Wear & Friction

PC + PTFE





Review

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Intro To Compounding**
- **The Dilemma**
- **Resin Selection Procedure**
 - Resin Morphology
 - Resin Performance (including cost)
 - Unique Resin Features
- **Application Case Studies**
- **Compounding in Performance**
 - Overcoming Resin Deficiencies



THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT



Questions?

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Introduction

Duncan Hogg
Energy Market Manager
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12:50 p.m.

Introduction

Duncan Hogg
Energy Market Manager

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Profile

- RTP Company is an **independent**, privately owned compounder
- Global manufacturing and engineering support
- Worldwide sales representation/distribution
- Established in 1982
- 1000+ employees
- \$400+ million annual sales

Custom Solutions

- **High-Tech to High Volume**
 - 60+ resins, 100's of modifiers
 - Broadest range of competitive compounds
 - From talc polypropylene to nanotube PEEK
- **Annual Production**
 - 6000+ commercial products
 - 1750+ new products each year

Our Goal

Satisfy Our Customers With:

- Solutions
- Technology
- Flexibility
- Speed

RTP *Imagineering Plastics* **Flexibility To Meet YOUR Needs**
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Bags to Bulk
 The Most Competitive Lead Times in the Industry

RTP *Imagineering Plastics* **Our Culture**
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Entrepreneurial
- “Bureaucracy-Less”
- Delegate Authority

RTP *Imagineering Plastics* **Independence**
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS


Objectivity In:

- Raw Materials
- Formulations
- Solutions

RTP *Imagineering Plastics* **Global Sales**
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

80+ RTP Company Sales Engineers


- **Americas**
 Canada, United States, Mexico, Brazil + distributors
- **Asia/Pacific**
 China, Korea, Singapore, Japan, Taiwan, India + distributors
- **Europe**
 Benelux, France, Germany, Italy, United Kingdom + distributors



Product Development/R&D

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- 40+ Product Development Engineers worldwide
- Regional engineers for local support
- Dedicated pilot plants in each region of the world
 - Product development
 - Process development
 - Customer trials and samples
 - Equipped for easy scale-up to production





Technical Service

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

20+ Technical Service engineers and specialists worldwide:

- Molding trials
- Process optimization
- Problem resolution
- CAE support





Customer Service

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Real people regionally located
- 20+ worldwide
- Avg. 15+ years of experience
- Dedicated to serving our customers





Your GLOBAL Compounder

OF CUSTOM ENGINEERED THERMOPLASTICS

Global Manufacturing



United States • Mexico • France • Germany • China • Singapore

/// RTP Co. *Imagineering Plastics* **Your GLOBAL Compounder**
OF CUSTOM ENGINEERED THERMOPLASTICS

Winona, Minnesota "Corporate Headquarters"

South Boston, Virginia	Fort Worth, Texas	Indianapolis, Indiana	Sauk Rapids, Minnesota	Dupro, Illinois
Monterrey, Mexico	Besune, France	Ladenburg, Germany		
Singapore	Suzhou, China	Shenzhen, China		

/// RTP Co. *Imagineering Plastics* **Your GLOBAL Compounder**
OF CUSTOM ENGINEERED THERMOPLASTICS

Develop it anywhere...
make it anywhere...
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 Co. *Imagineering Plastics* **Product Families**
COMPREHENSIVE PRODUCT LINE

STRUCTURAL	WEAR RESISTANT	CONDUCTIVE	THERMOPLASTIC ELASTOMERS
FLAME RETARDANT	COLOR	FILM AND SHEET	

Compounds formulated to meet your needs

/// RTP Co. *Imagineering Plastics* **YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS**

- Customer focused
- Speed
- "Bureaucracy-less"
- Independent / objective
- Global

Your Global Compounder of Custom Engineered Thermoplastics

<http://www.rtpcompany.com>

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Questions?

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High Temperature Structural Products, Improved Performance at Elevated Temperatures and Harsh Environments

Matt Torosian

Product Manager, High Temperature Materials

mtorosian@rtpcompany.com

(317) 663-4364

1:00 p.m.

High Temperature Structural Products, Improved Performance at Elevated Temperatures and Harsh Environments

*Matt Torosian,
Product Manager, High Temperature Structural Products*

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Presentation Overview

- What are Ultra Performance products?
- Highlights
- Review of competing materials
 - Metals
 - Conventional engineering thermoplastics
 - VLF Products
 - Vs. Conventional reinforced TP compounds

Ultra Performance Structural

Dictionary: "Ultra" - Very or extreme. (descriptive)

Ultra Performance Structural

Built upon RTP Company's current standard product portfolio of industry-leading reinforced compounds by

- Optimizing reinforcement technology
- Optimizing process technology

•Ultra Performance structural products are in addition to and do not replace our current high temperature structural products

Ultra Performance Highlights

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- 10-30% higher strength and modulus in the RTP Company high temperature portfolio.
 - Greatest gains in CF compounds
- PPA and PPS w/CF demonstrate a 30-40% improvement in room temperature physical properties.
- 40%CF PEEK with exceptional properties Vs. Victrex 90 HMF 40, the only other High Modulus PEEK available.
 - Targeted metal replacement in energy and D&A
- VLF products have 3-4 times the impact of short glass products
 - Improved creep, fatigue and CLTE
- Technology is transferable to other polymer systems**

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR CONDUCTIVE • COLOR • FLAME RETARDANT

Ultra Performance Structural Compounds for Greene Tweed, Houston TX

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Ultra Performance Structural

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Competitive metals

- Die cast aluminum
- Heat treated T-6 aluminum
- Die cast zinc alloy (Zamak 3)

Competitive Materials

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

A-380 die cast aluminum and 6061 T-6 heat treated aluminum

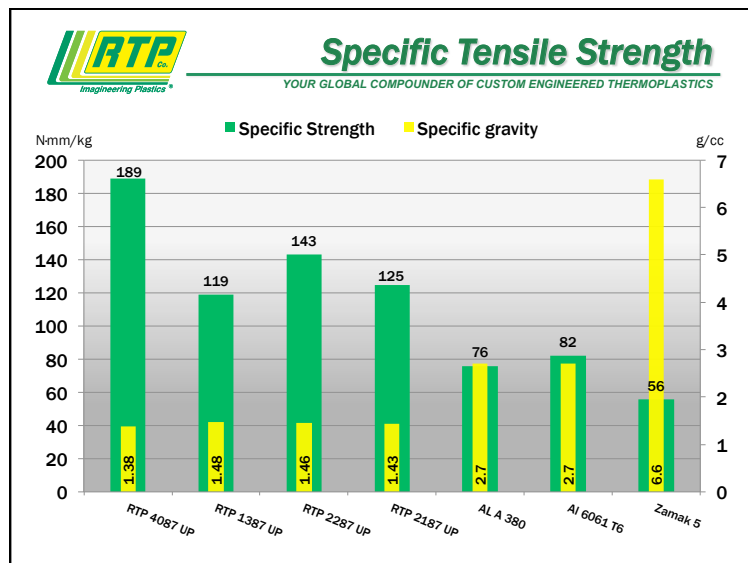
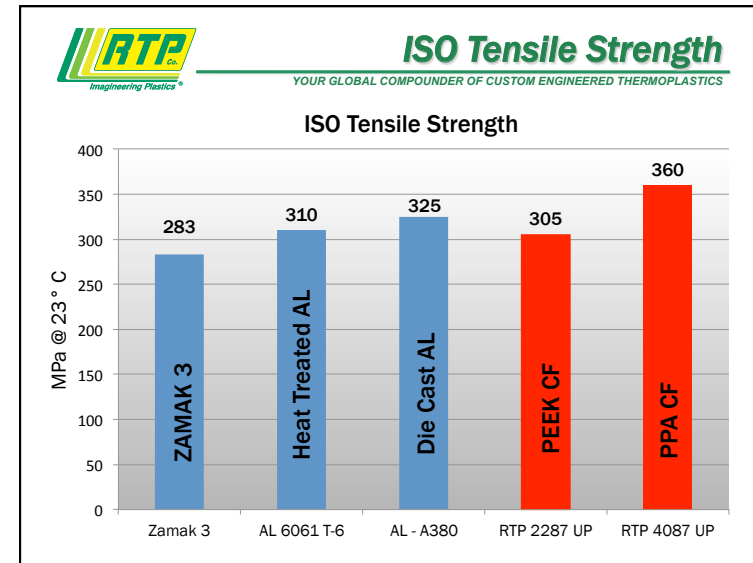
- A-380 accounts for over 85% of the Al die cast market

- **Pros**
 - Excellent high temperature performance
 - Very good thermal conductivity
 - Very good EMI shielding capabilities
 - Good corrosion resistance
 - Light: good strength-to-weight ratio (specific strength)
- **Cons**
 - Poor chemical resistance
 - Poor fatigue resistance
 - Subject to attack by galvanic corrosion when in contact with carbon fiber, carbon fiber composites, and other metals

Competitive Materials
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

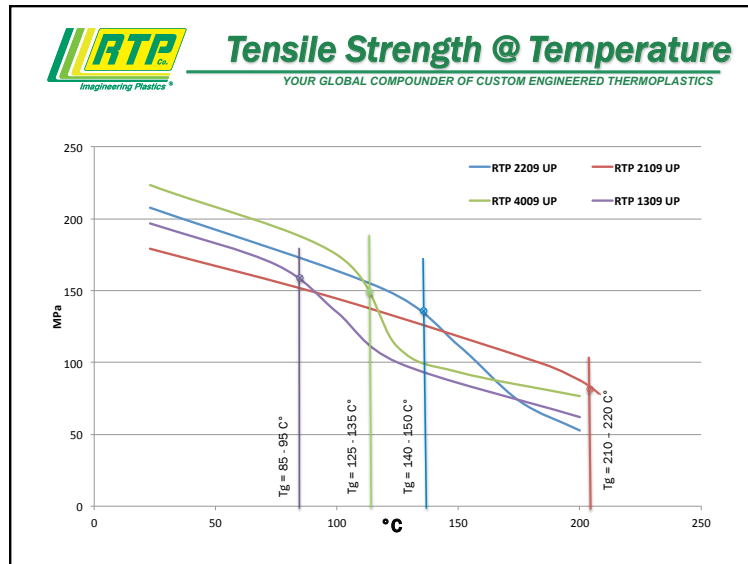
ZAMAK alloys are widely used in die casting

- **Pros**
 - Very good EMI shielding
 - Very good conductivity
 - Good strength
- **Cons**
 - Poor creep resistance under load
 - Poor strength-to-weight ratio
 - Difficult to process vs. injection moldable plastics



What about Tg and Tm
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Tg or glass transition temperature is critical when comparing materials for High Temp applications
- **Conventional semi-crystalline thermoplastics are usable above their Tg but physical properties begin to deteriorate quickly**
- **Amorphous materials have defined Tg but have a more gradual drop off in properties below the Tg(see graph)**
- Creep and fatigue have increased effects above the TG of thermoplastic materials
 - Crystallinity is critical and affects the Tg
 - End use testing is the best measure of performance

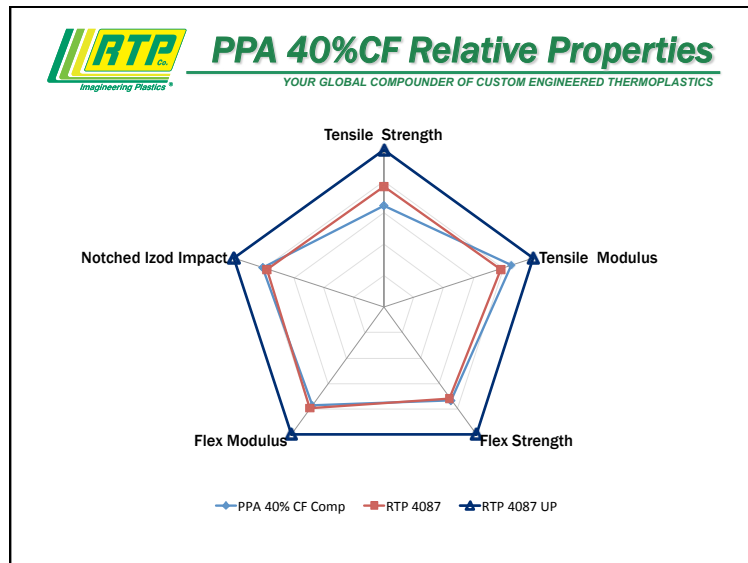


Ultra Performance Structural Compounds vs. Competitive Thermoplastics

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CONDUCTIVE • COLOR • FLAME RETARDANT

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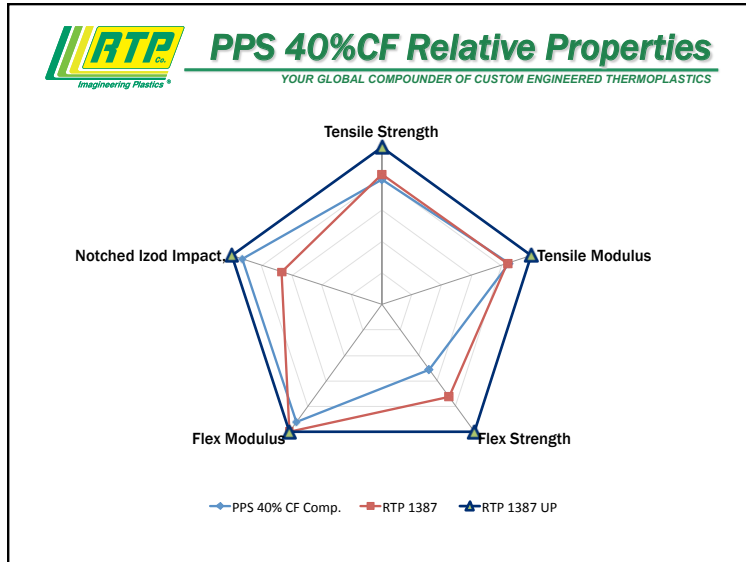
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Data Table of Ultra Performance PPA
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Material	RTP 4087	RTP 4087 UP	Comp. PPA 40% CF	Units
Tensile Strength	275	360	232	MPa
Tensile Modulus	32500	41500	35500	MPa
Flexural Strength	415	580	425	MPa
Flexural Modulus	27500	34500	26600	MPa
Notched Izod Impact	7.0	9.0	7.0	KJ/m ²

Note: Properties tested using ISO test methods

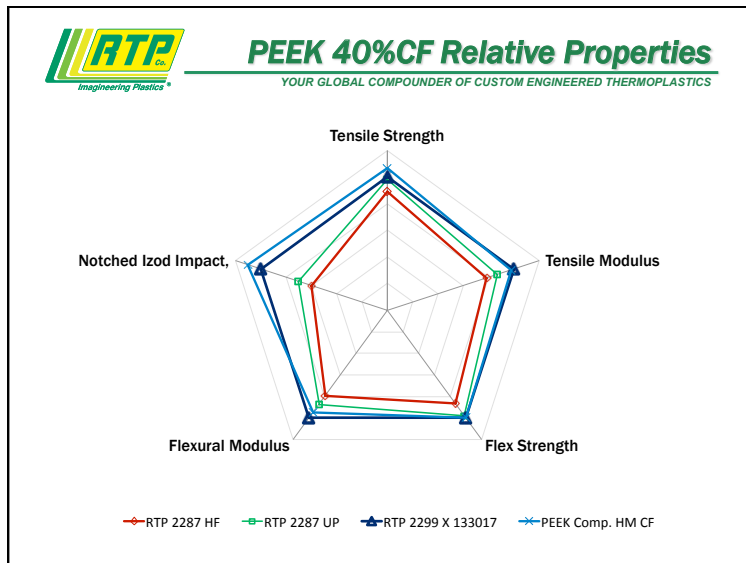


Data Table of Ultra Performance PPS

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Material	RTP 1387	RTP 1387 UP	Comp. PPS 40% CF	
Tensile Strength	215	260	207	MPa
Tensile Modulus	34000	40500	34500	MPa
Flexural Strength	295	405	209	MPa
Flexural Modulus	32500	32500	30000	MPa
Notched Izod Impact,	5.0	7.5	9.0*	KJ/m ²

Note: Properties tested using ISO test methods
* Competitive material is a PPS alloy (no other 40% CF PPS competitive data available)




Data Table of Ultra Performance PEEK


YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Material	RTP 2287 HF	RTP 2287 UP	RTP 2299 X 133017	Comp. PEEK 40% CF	
Tensile Strength	270	275	310	330	MPa
Tensile Modulus	27500	36000	46200	45000	MPa
Flexural Strength	385	415	480	480	MPa
Flexural Modulus	24000	31000	39300	37000	MPa
Notched Izod Impact,	6.5	6	10	11	KJ/m ²

Note: Properties tested using ISO test methods



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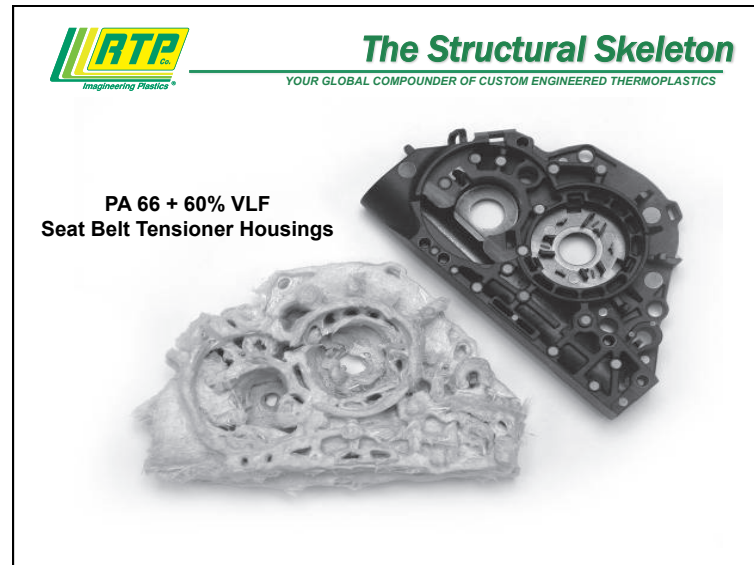
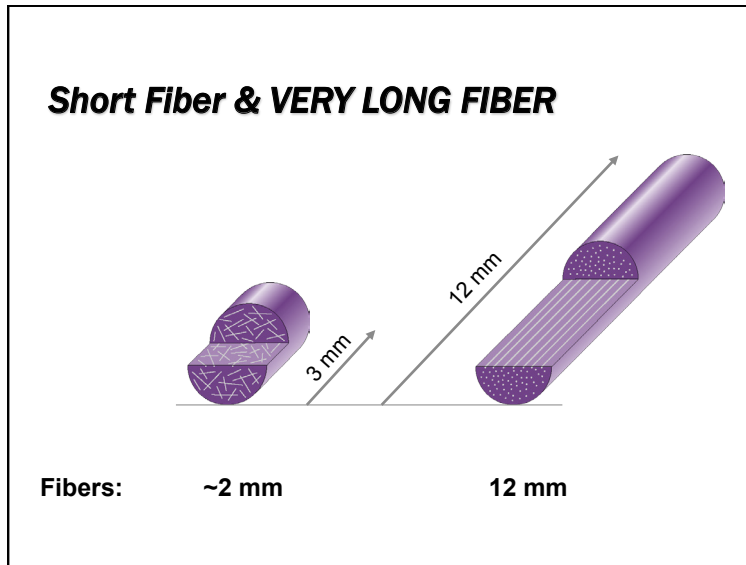


An Introduction to VLF – Very Long Fiber Composites in High Temperature Materials

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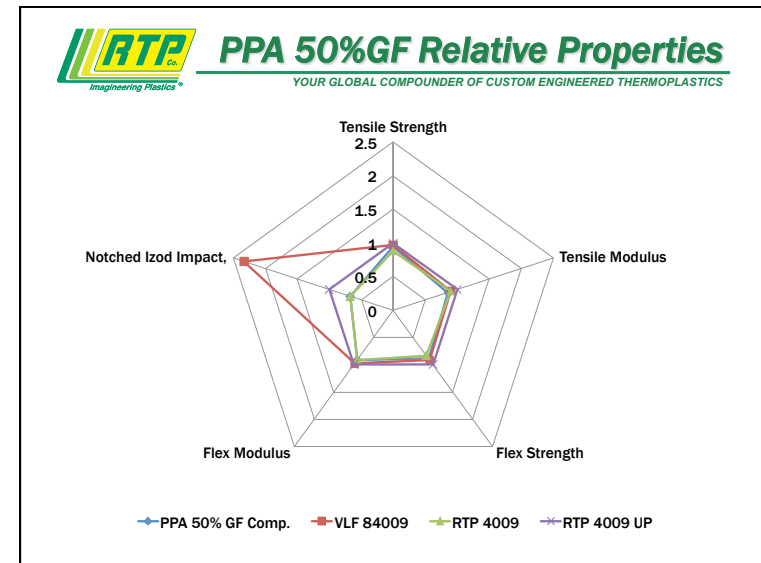
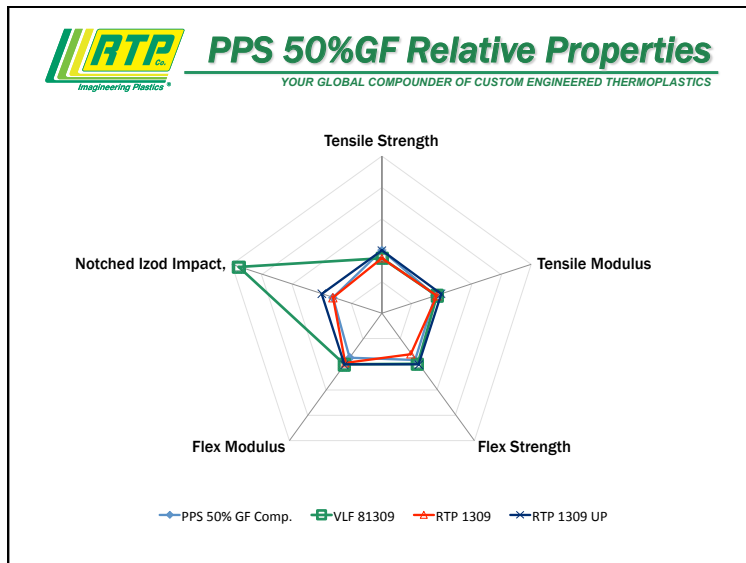
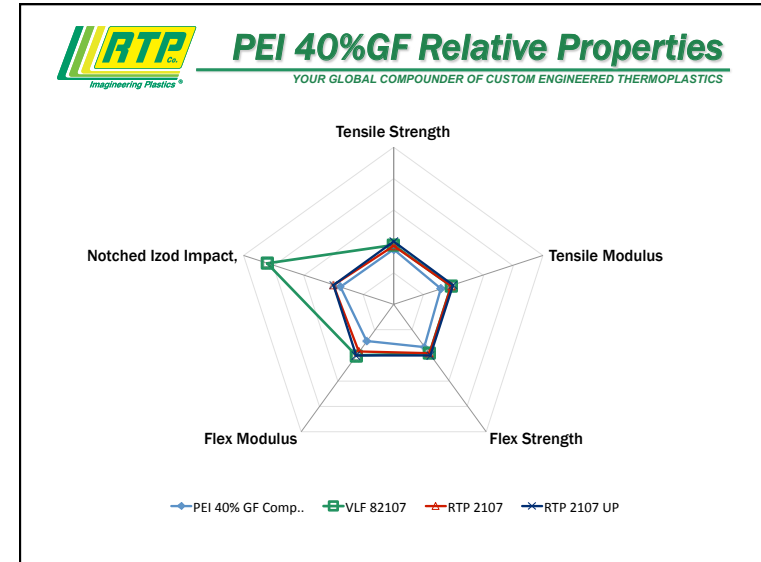
Masterbatch VLF Technologies
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Steel

Carbon

Glass

Polymers	Additives	“Long Cut” technology
PEEK PPS PBT TPU PP PA	Your color – Your way™ Flame retardants Wear & lubricity Heat stabilizers Nano particles UV resistance Conductivity Anti-stat	



PPA 50%GF Actual Properties
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	PPA 50% GF Competitive	VLF 84009 50% VLF GF	RTP 4009 50% GF	RTP 4009 UP 50% UP GF	Units
Tensile Strength	270	275	250	285	MPa
Tensile Modulus	17000	18000	18000	20000	MPa
Flex Strength	390	400	370	440	MPa
Flex Modulus	17000	18000	17000	18500	MPa
Notched Izod Impact,	10	35	10	15	KJ/m ²

Note: Properties tested using ISO test methods

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Questions?

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Wear and Friction, Beyond the Fundamentals

Gregg Newby
Product Manager, Wear Products
gnewby@rtpcompany.com
(843) 425-7633

1:45 p.m.




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Wear and Friction, Beyond the Fundamentals

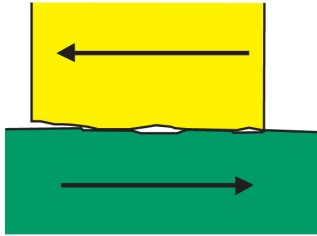

Gregg Newby
Global Business Manager
Wear and Friction Technologies



Definitions
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Adhesive Wear Mechanism

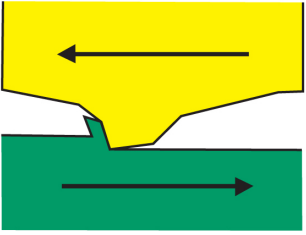

- The primary mechanism for thermoplastic wear
- Characterized by transfer of material from one part to the other caused by frictional heat

Definitions
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Testing Wear Resistance
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

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

Wear Testing
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

ASTM D-3702 “Thrust Washer” Wear Test

Rotating
Molded or machined sample

Stationary
Thrust washer
(steel, aluminum, plastic, etc.)

Wear Testing
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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 Factor (K)
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

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

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
Lower Value = Better Wear Resistance

Definitions
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Standard conditions

- Steel thrust washer
- 40 psi : 50 ft/min (2000PV)
- Ambient temp
- 100 hour test

PV = (Pressure · Velocity)
Conditions often used together to characterize severity of a wear load
2,000 = (40 psi · 50 ft/min)

Wear Testing
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Wear data: typically shown at a specified PV**
 - Example: PV=2,000 (standard conditions)
 - 40 psi (P)
 - 50 ft./min(V)
- **Question: Does an equivalent PV always result in the same data?**
 - Let's consider PV=2,000 (nonstandard conditions)
 - 10 psi (P)
 - 200 ft./min (V)

Wear Testing
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

POM + 20% PTFE Steel Countersurface

Answer:

- No...Wear factor will change based on individual conditions.
- Generalizations may be helpful, but not always equivalent.

Wear Testing
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Wear factor generally increases with higher PV (But not always!)

Wear per ASTM D 3702 against Steel

Definitions
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Coefficient of Friction (μ)

- Ratio of the force of friction between two bodies and the force pressing them together

$\mu = F/N$

Types of Sliding Friction
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Coefficient of Friction (μ)

- Static coefficient of friction (μ_s) = F_x/F_y
 - F_x = Force to *initiate* motion
 - F_y = Normal force holding surfaces together
- Dynamic coefficient of friction (μ_k) = F_x/F_y
 - F_x = Force to *sustain* motion
 - F_y = Normal force holding surfaces together

Friction and Thermoplastics
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- In most non-plastic materials
 - $\mu_k < \mu_s$
- Thermoplastics are somewhat unique
 - $\mu_k > \mu_s$
- May cause “slip/stick”
- If $\mu_k \gg \mu_s$ you may have squeaking

Morphology Characteristics
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	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
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Semi-crystalline polymers generally outperform amorphous materials in tribological tests

Material	Wear Factor (in³-min/in²-ft-lb-hr) x 10E-10	Dynamic Friction Coefficient (μ_k)
PC	550	0.6
POM	95	0.4

Additive Technologies
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Additive Technologies
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

PTFE – Polytetrafluoroethylene (5-20%)

- Workhorse additive – solid white powder
- Homogeneously distributed throughout the polymer matrix
- Forms a lubricious layer at polymer surface – requires a “Break-in” period
- Compatible with nearly all thermoplastic resins

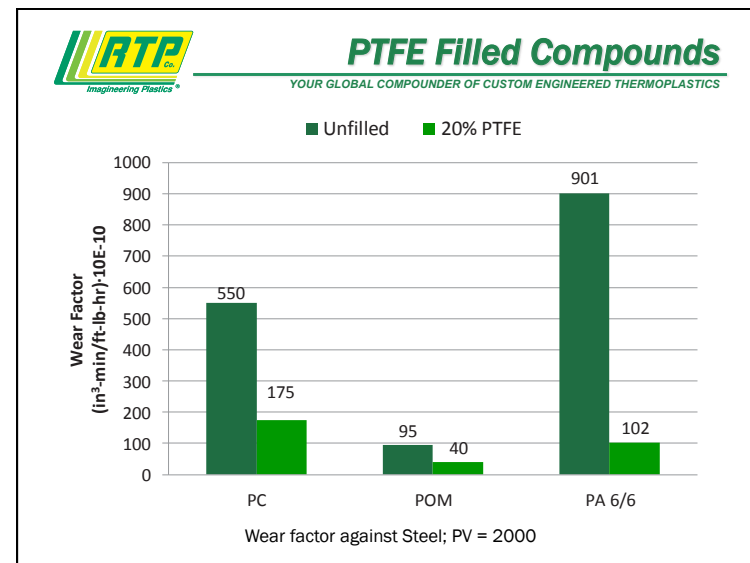
Limitations

- Fluorine content
- Die plate-out
- Relatively high loadings
- Becoming very expensive

PTFE Wear Mechanism
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Part – As Molded


Part – After break-in period
Exposed PTFE shears form layer



Additive Technologies
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Silicone – Polydimethylsiloxane (1-3%)

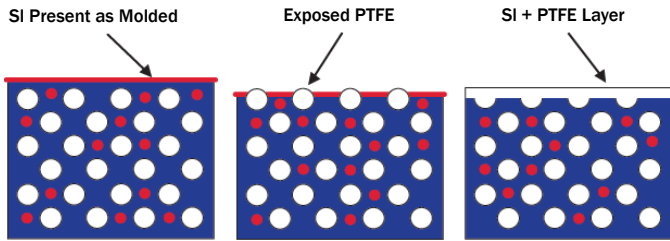
- Boundary lubricant which migrates to the surface over time
- Migration rate is viscosity dependent
- Excellent friction reducer
- Best in high speed/low load applications
- Used with PTFE to eliminate “Break-in” period



Limitations

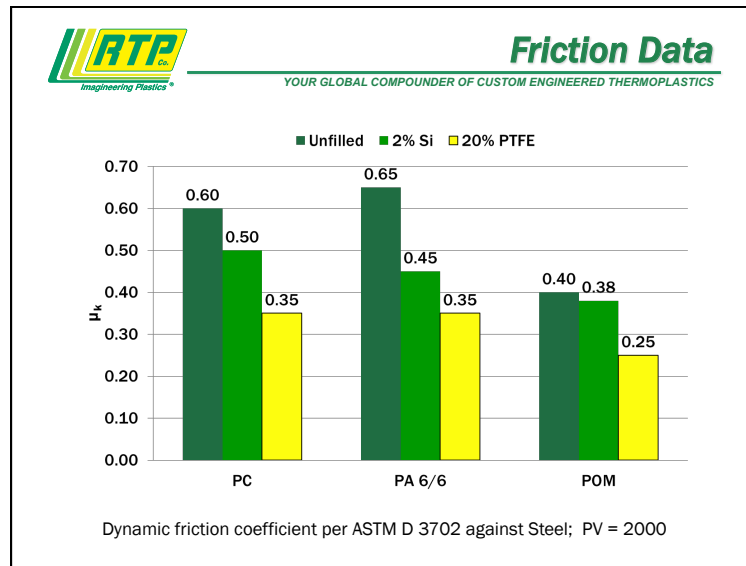
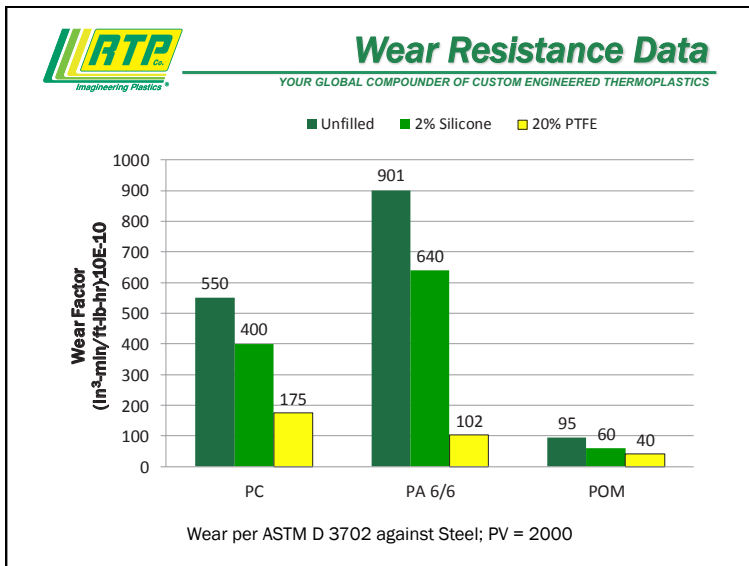
- **Limited use in decorated parts**
 - Poor adhesion of paint or print inks
- **Bad for electrical applications**
 - Can foul contacts

Additive Technologies
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



SI Present as Molded Exposed PTFE SI + PTFE Layer

Part – As Molded Part – After break-in period



Physical Property Comparison
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS


	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

Values per ASTM test methods

Additive Technologies
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

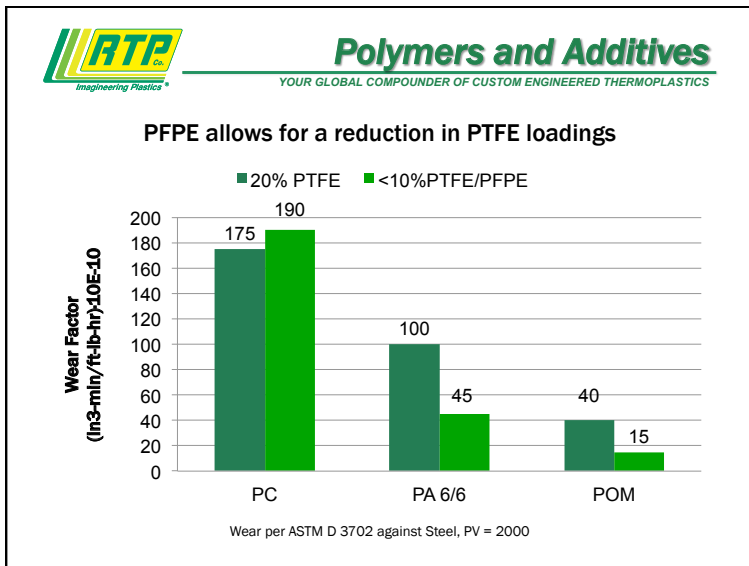
PFPE – Perfluoropolyether Oil (< 1%)

- Thermally stable up to PEEK processing temps
- Differentiates RTP Company from others
- Physical properties maintained
- Minimized die plate-out
- Synergy with PTFE
- Specific gravity benefits
- Improved fatigue resistance



Limitations


- Limited effectiveness in amorphous resins
- Needs PTFE “kick” to deliver optimum friction reduction



Additive Technologies
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS


Graphite Powder (5-30%)

- Aqueous environments
- Excellent temperature resistance
- Black color



Molybdenum Disulfide - MoS₂ (1-5%)

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

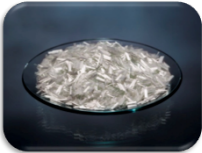




Limitations

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




RTP Co. **Fibers and Wear Resistance**
Imagineering Plastics® YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Reinforcing Fibers

<p>Glass Fiber</p> 	<p>Carbon Fiber</p> 	<p>Aramid Fiber</p> 
<ul style="list-style-type: none"> • Improved bearing capabilities/wear resistance • Very abrasive 	<ul style="list-style-type: none"> • Higher bearing capabilities • Excellent thermal resistance • Conductive • Less abrasive 	<ul style="list-style-type: none"> • Little strength improvement • Very gentle to mating surface

RTP Co. **Fibers and Wear Resistance**
Imagineering Plastics® YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

 <p>Glass</p>	 <p>Carbon</p>	 <p>Aramid</p>
Aluminum Contact Surface		

RTP Co. **THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR**
Imagineering Plastics® **CONDUCTIVE • COLOR • FLAME RETARDANT**



RTP Company
Ultra Wear & Friction Compounds

RTP Co. **What is Ultra Wear & Friction?**
Imagineering Plastics® YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

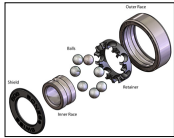
- RTP has developed a family of **Ultra Wear & Friction (W&F) Compounds** that have been tested and proven to support applications requiring
 - Excellent wear performance at very high loads
 - Excellent friction performance at very high speeds

What is Ultra Wear & Friction?
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS


- In addition to high load and high speed performance, Ultra W&F Compounds also exhibit
 - Resistance to a broad range of chemicals
 - Resistance to high temperatures
 - Improved thermal conductivity
 - Excellent long term creep and fatigue properties

Broad Application
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

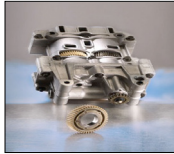
Bearings and Bushings




Seals and Rings



Gears



Thrust Washers



Broad Markets
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Automotive

- Transmissions
- Braking
- Steering
- Pulleys



Energy

- Down Hole,
- Chemical Processing Equipment



Industrial

- Pumps
- Conveyors



Wear Testing Conditions
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Typical Test Conditions	Ultra Testing
1. 2000 PV: 40 psi · 50 ft/min	• 10,000 PV
2. 2000 PV: 10 psi · 200 ft/min	• 25,000 PV
3. 5000 PV: 50 psi · 100 ft/min	• 50,000 PV
4. 10,000 PV: 200 psi · 50 ft/min	• 75,000 PV (+400F)
5. 10,000 PV: 50 psi · 200 ft/min	• 100,000 PV (+400F)

Fifteen "Ultra" Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Polymer	Description	Grade
PPS	PPS-AF/TFE	RTP 1300 AR 15 TFE 15
PPS	PPS-GF/TFE	RTP 1305 TFE 15
PPS	PPS-CF/TFE	RTP 1385 TFE 15
PPS	PPS-CF/Proprietary Wear	RTP 1399 X 91160
PEEK	PEEK-AF/TFE	RTP 2200 AR 15 TFE 15
PEEK	PEEK-CF/TFE	RTP 2285 HF TFE 15
PEEK	PEEK-CF/GRPH/TFE	RTP 2299 X 81382
PEEK	PEEK-CF/GRPH/TFE/PFPE	RTP 2299 X 113763 B
PEEK	PEEK-CF/CF/AF/TFE	RTP 2299 X 113783 A
PEEK	PEEK-CF/PFPE	RTP 2299 X 120337
PEEK	PEEK-CF/GRPH/TFE (CGP) ←	RTP 2299 X 125106
PEEK	PEEK-CF/Ceramic	RTP 2299 X 125404 A
PPA	PPA-CF/TFE	RTP 4085 TFE 15
PPA	PPA-CF/Proprietary Wear	RTP 4099 X 105534
PPA	PPA-CF/AF/TFE/SI	RTP 4099 X 123510 A

Please note the inclusion of RTP CGP technology

Non-RTP Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Compound	Polymer	Additive	Registered Trademark of
Rulon® J	PTFE (High Mol Wt)	Proprietary	St. Gobain Performance Plastics
Rulon® LR	PTFE (High Mol Wt)	Proprietary	St. Gobain Performance Plastics
Torlon® 4301	PAI (Pseudo TS)	PTFE, Graphite	Solvay Specialty Polymers
Torlon® 4630	PAI (Pseudo TS)	PTFE, Graphite	Solvay Specialty Polymers
VespeI® SP-21	TS PI (TS)	Graphite	E.I. du Pont de Nemours
VespeI® SP-211	TS PI (TS)	PTFE, Graphite	E.I. du Pont de Nemours
Stanyl® TW371	PA 4/6 (TP)	PTFE	DSM Engineering Plastics

10,000 PV : 100 psi @ 100 ft/min

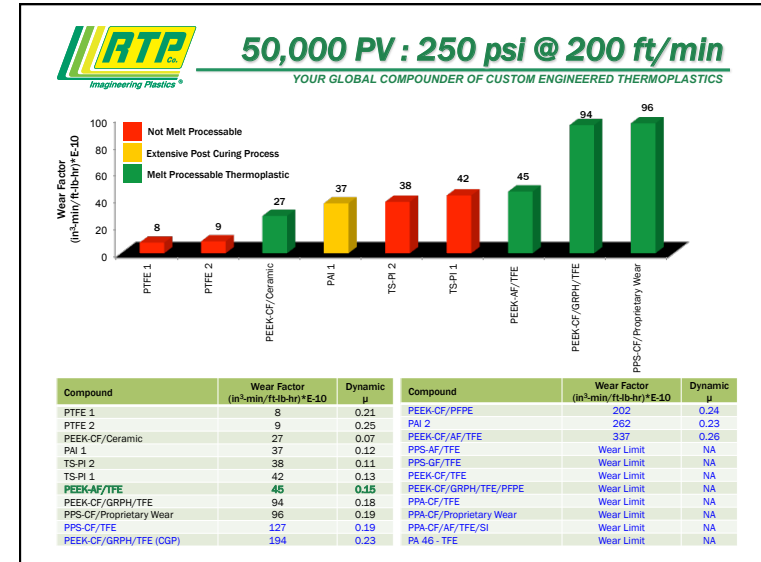
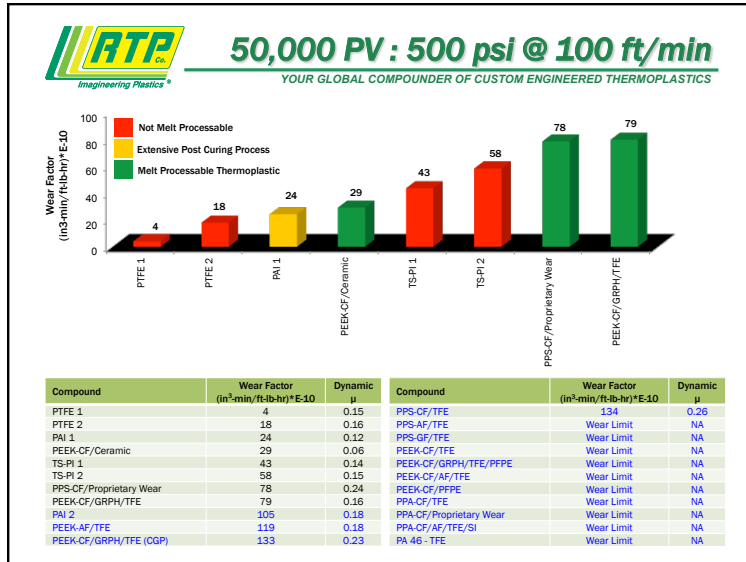
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Compound	Wear Factor (in³·min/(ft·lb·hr)·E-10)	Dynamic μ
PTFE 1	3	
PTFE 2	11	
TS-PI 1	18	
PAI 1	21	
PPS-CF/Proprietary Wear	23	
PPA-CF/AF/TFE/SI	31	
PPS-AF/TFE	33	
TS-PI 2	34	
PEEK-CF/GRPH/TFE/PFPE	42	
PAI 2	46	
PA 4/6/TFE	59	
PEEK-CF/GRPH/TFE	63	
PPA-CF/TFE	65	
PEEK-CF/GRPH/TFE (CGP)	79	
PEEK-CF/PFPE	81	
PEEK-CF/AF/TFE	86	

10,000 PV : 50 psi @ 200 ft/min

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Compound	Wear Factor (in³·min/(ft·lb·hr)·E-10)	Dynamic μ
PTFE 2	9	
PTFE 1	11	
PA 4/6/TFE	14	
PEEK-CF/AF/TFE	18	
PPS-AF/TFE	19	
TS-PI 1	23	
PEEK-CF/GRPH/TFE	25	
PPA-CF/AF/TFE/SI	39	
PPA-CF/TFE	43	
PEEK-CF/GRPH/TFE/PFPE	49	
PAI 2	51	
PEEK-CF/PFPE	54	
TS-PI 2	69	
PAI 1	70	
PEEK-CF/TFE	97	



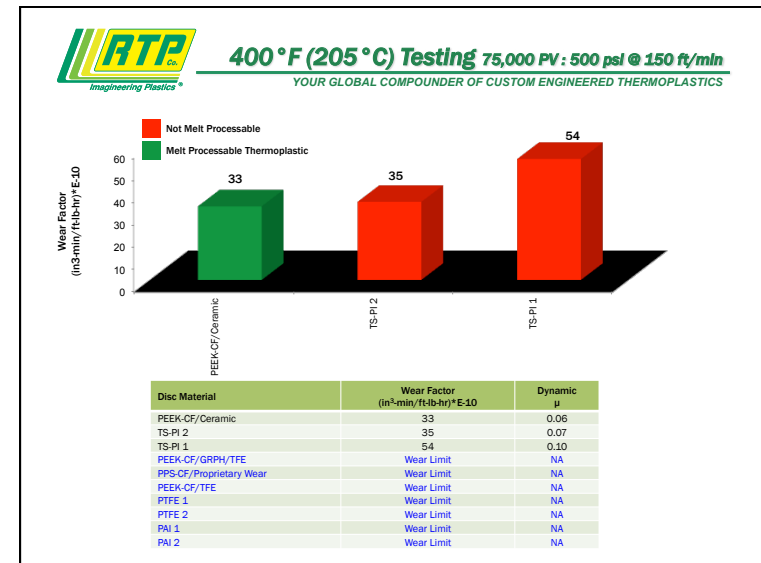
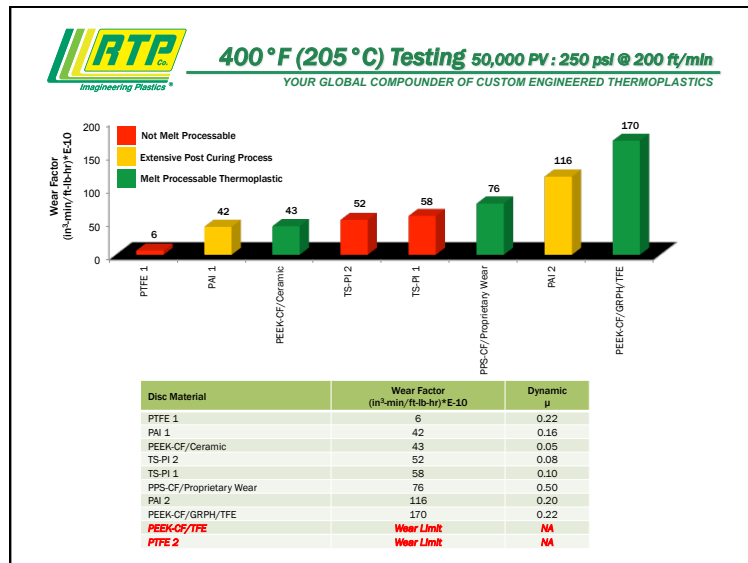
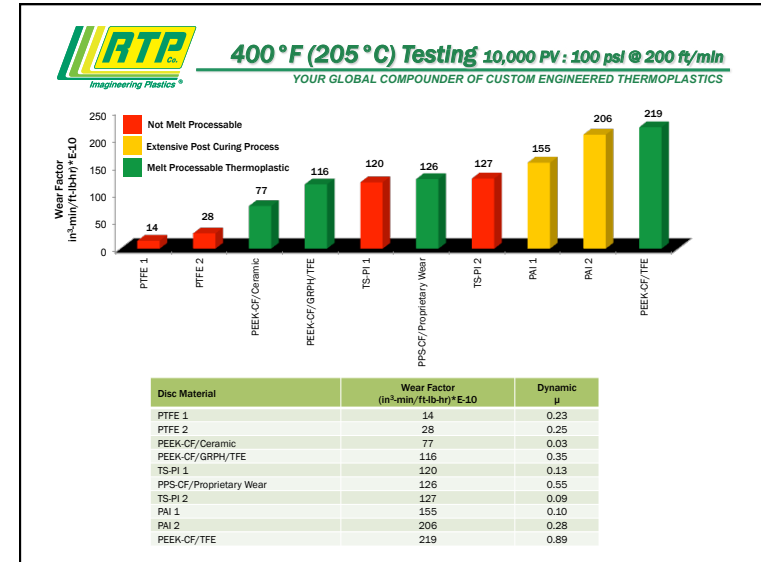
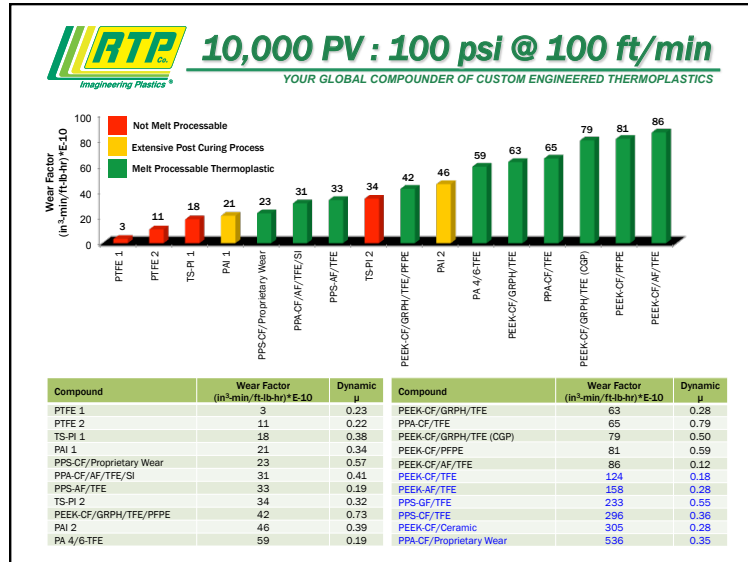
THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

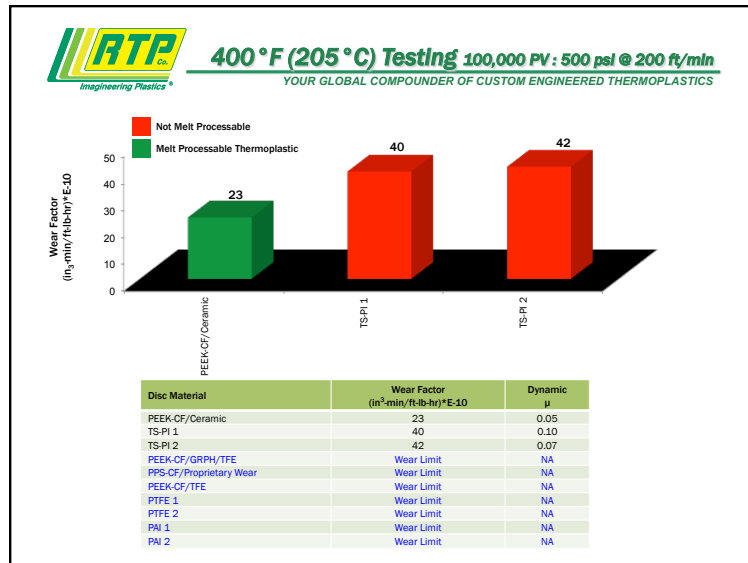
Elevated Temperature
400°F / 205°C
Test Results

Elevated Temperature Testing
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Tested at 200 ft/min (1.01 m/s)

- 10,000 PV: 50 psi (350 PV: 2.25 N)
- 50,000 PV: 250 psi (1750 PV: 11.24 N)
- 75,000 PV: 375 psi (2625 PV: 16.86 N)
- 100,000 PV: 500 psi (3500 PV: 22.48 N)





What's Next?
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Identify compounds optimized for resistance to wear in extremely abrasive environments
 - Work with an outside laboratory to develop a series of abrasive tests to identify best performing compounds

Planned Abrasion Testing Project
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

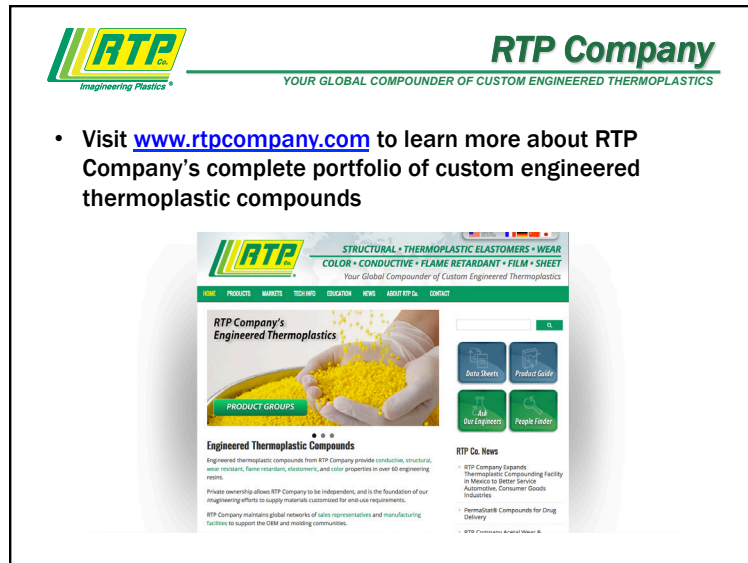
Two Test Methods for Initial Screening:

- ASTM G75 (Miller Abrasion)
- ASTM G105 dry abrasive with and without slurry adaptor
- Abrasives to be used:
 - AL₂O₃ for “down-hole”/energy applications
 - AFS 50-70 test sand for automotive/industrial applications

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CONDUCTIVE • COLOR • FLAME RETARDANT**

Questions?

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RTP Company
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Visit www.rtpcompany.com to learn more about RTP Company's complete portfolio of custom engineered thermoplastic compounds

The screenshot shows the RTP Company website with the following content:

- Navigation menu: HOME, PRODUCTS, MARKETS, TECH INFO, EDUCATION, NEWS, ABOUT RTP Co., CONTACT
- Header: RTP Co. logo, tagline, and product categories: STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR COLOR • CONDUCTIVE • FLAME RETARDANT • FILM • SHEET
- Main content area: "RTP Company's Engineered Thermoplastics" with a "PRODUCT GROUPS" button and a search bar.
- Product Groups: Auto Sheets, Product Guide, Add Our Engineers, People Finder
- Engineered Thermoplastic Compounds: A section describing the company's capabilities in providing custom engineered thermoplastic compounds.
- RTP Co. News: A section with news items, including "RTP Company Expands Thermoplastics Compounding Facility in Mexico to Better Service Automotive Consumer Goods Industries" and "Manufacture Compounds for Drug Delivery".



Closing Remarks and Questions

Duncan Hogg
Energy Market Manager
dhogg@rtpcompany.com
(507) 429-2262

2:30 p.m.