An Engineer's Guide to Specifying the Right Thermoplastic

Jason Becker

Development Engineer

jbecker@rtpcompany.com

(817) 615-2028

11:10 a.m.

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

An Engineer's Guide to Specifying the Right Thermoplastic

Jason Becker
Application Development Engineer

Independent Specialty Compounder

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **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

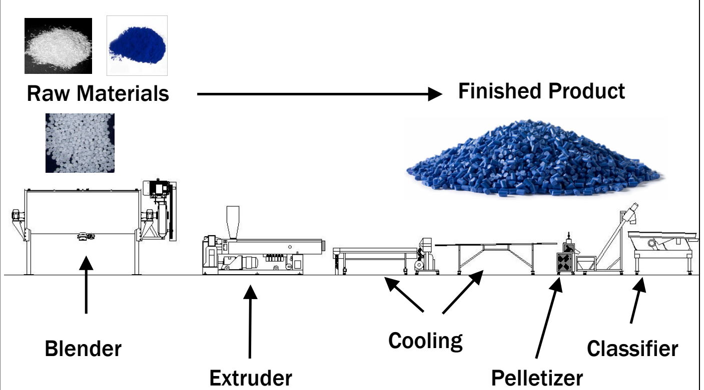
Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Compounding Process

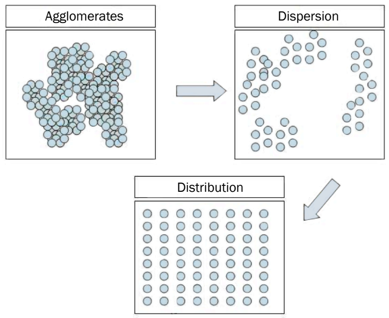
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Compounding Objectives

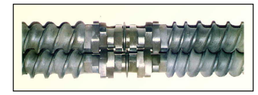
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

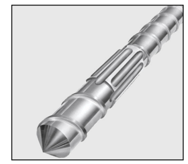
- **Mixing**
  - Distributive
  - Dispersive



Compounding Extruders

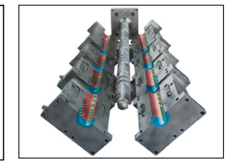
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS





Single Screw

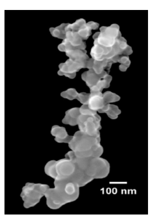
Twin Screw

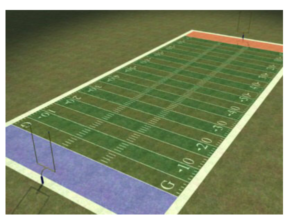


Co-Kneader

Putting Compounding Into Perspective

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS





- Conductive carbon black surface area = 130 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!

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

Resin Selection

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

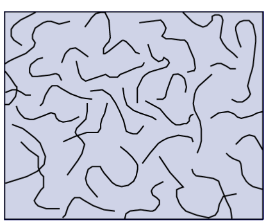
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

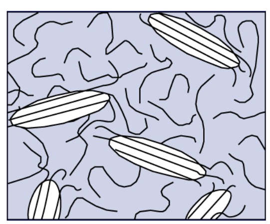
Morphology

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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



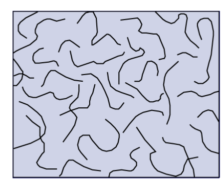
Amorphous



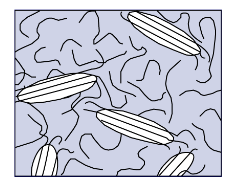
Semi-Crystalline

Morphology

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Amorphous



Semi-Crystalline

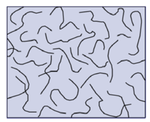
Compare

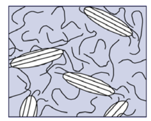
- Molecular Packing (Shrinkage)
- Resistance to Molecular Disentanglement (Chemical/Abrasion Resistance)
- Light Refraction (Opacity)
- Melting Characteristics (Flow)

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

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)	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)

Thermal & Cost Increases

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^{0}C vs -9^{0}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

Case Study
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Case Study
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Case Study
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

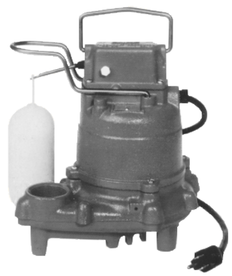
Case Study
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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



Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Case Study

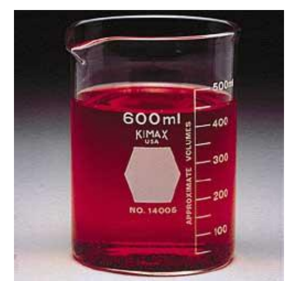
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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



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

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

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

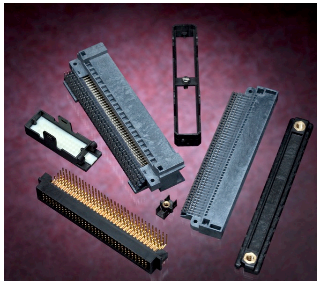
- Oil Pan
  - Chemical Resistance
  - Excellent Strength, Stiffness & Impact
  - Moderate Heat Resistance
  - Moderate Cost OK
  - Extremely Tight Dimensions & Flat

- ?????????

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

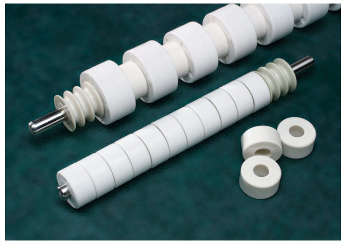


- PBT (PET) + GF + FR

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

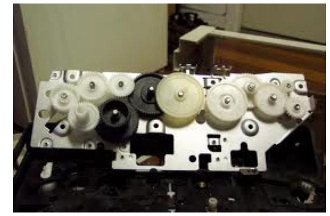
- **Conveyor Rollers**
  - Good Abrasion Resistance
  - Low Wear & Friction
  - Moderate Cost OK
- **Acetal**



Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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



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
- ?????????

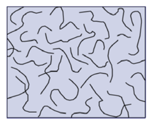
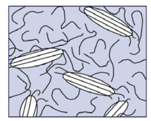
THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Overcoming Morphology Deficiencies Via Compounding

Morphology Deficiencies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

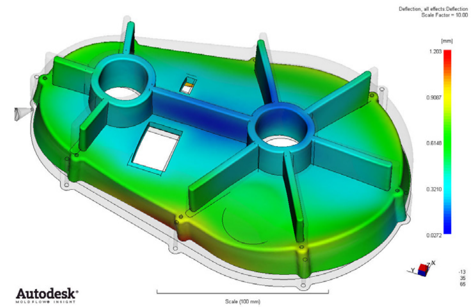
	Amorphous	Semi-Crystalline
Low Shrinkage	✷	D
Low Warpage	✷	D
Tight Tolerances	✷	D
Transparency	✷	D
Mold Flow Ease	D	✷
Chemical Resistance	D	✷
Wear Resistance	D	✷

Dimensional Stability

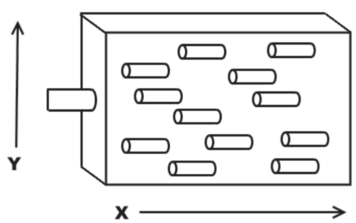
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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



Fiber Reduces Shrink

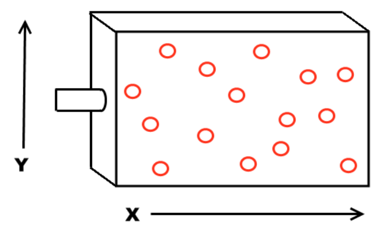
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Shrink Rate X ≠ Shrink Rate Y ⟶ Warp

Warp Control

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

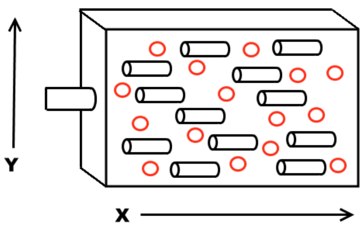


Shrink Rate X = Shrink Rate Y ⟶ Flat Part

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

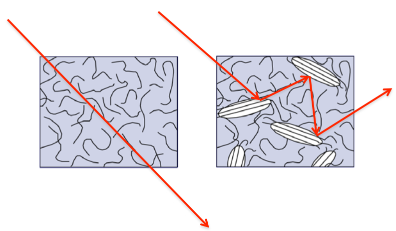
- Oil Pan
  - Chemical Resistance
  - Excellent Strength, Stiffness & Impact
  - Good Heat Resistance
  - Moderate Cost OK
  - Extremely Tight Dimensions & Flat

- Nylon 66 + 15% GF + 25% Mineral

Transparency

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

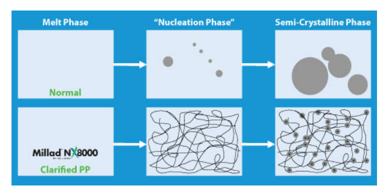
- Can We Make A Semi-Crystalline Resin Transparent?



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



Courtesy Milliken Chemical

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Chemical Resistance/Mold Flow

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Alloying

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- 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,^{0}F	270	210
Fuel Resistance	Poor	Poor
Melt Flow, gm/10 min	10	15
Clarity	Transparent	Opaque

Alloying

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- 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, ^{0}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

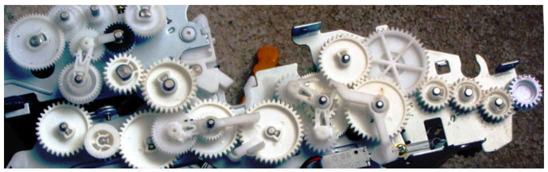
	PC	PC/15 PTFE	Acetal
Wear Factor	560	130	90
Dynamic Coef. of Friction	0.60	0.33	0.40

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?

Jason Becker
jbecker@rtpcompany.com
(817) 293-5880

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383