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

# An Engineer's Guide to Specify the Right Thermoplastic

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# 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

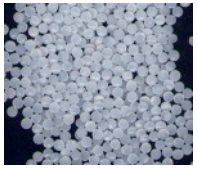
# Agenda

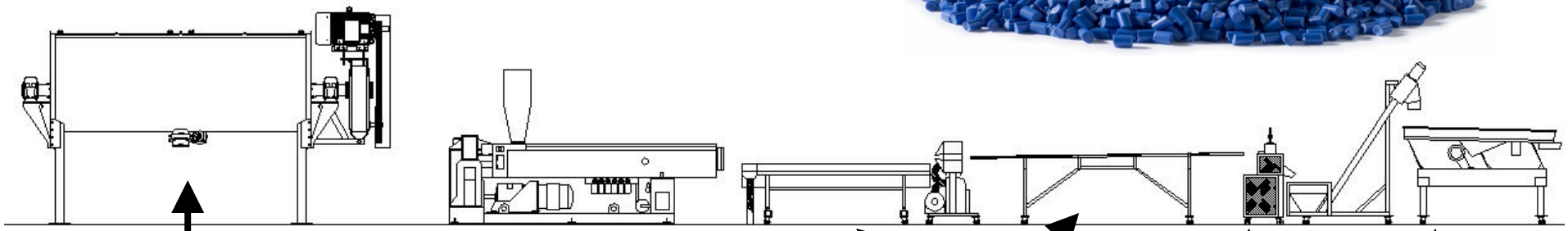
- Define Compounding
- Plastic Resin Selection Process
- Application Case Studies
- Compounding Performance
- Engineered Thermoplastic Compounds

# Compounding Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Raw Materials → Finished Product





Blender

Extruder

Cooling

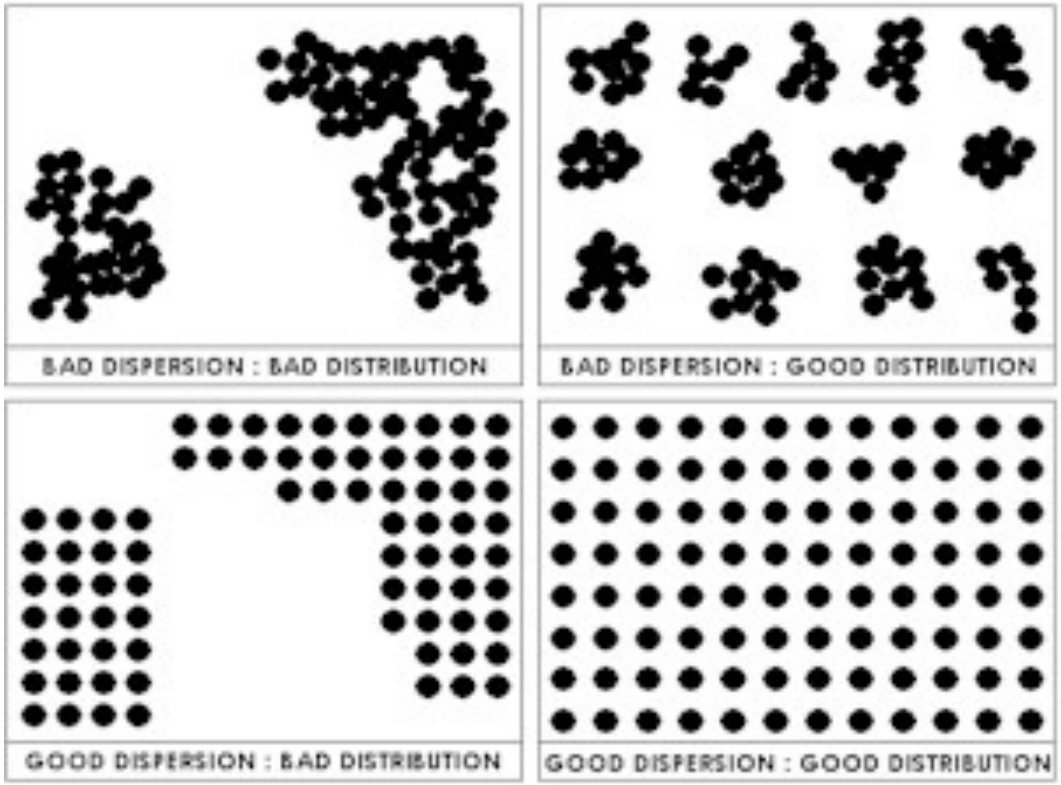
Pelletizer

Classifier

# Compounding Objectives

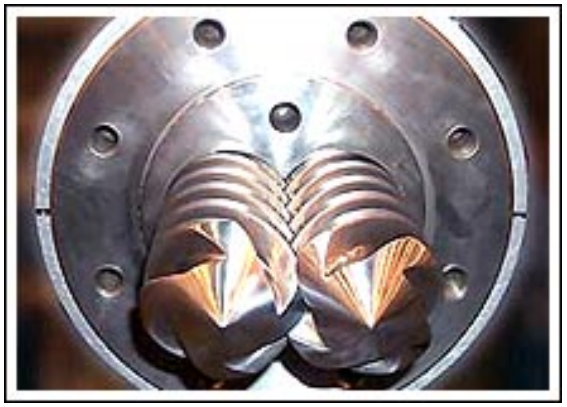
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

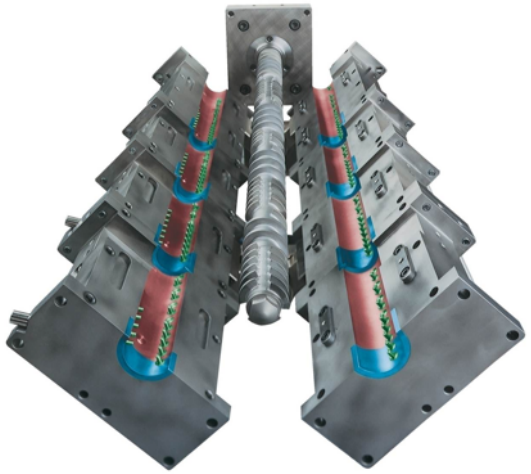
- **Mixing**
  - Distributive
  - Dispersive



# Compounding Extruders

*YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS*





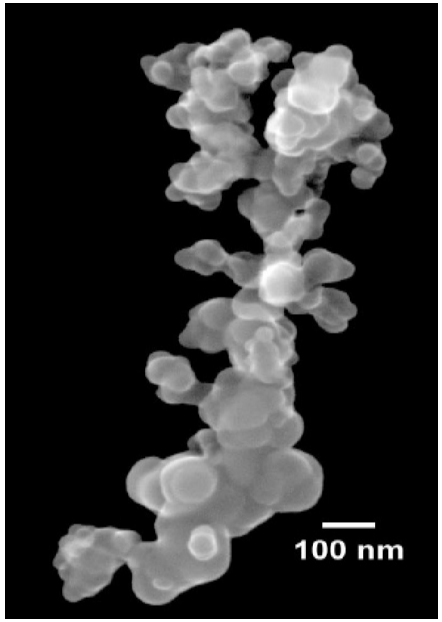
Single Screw

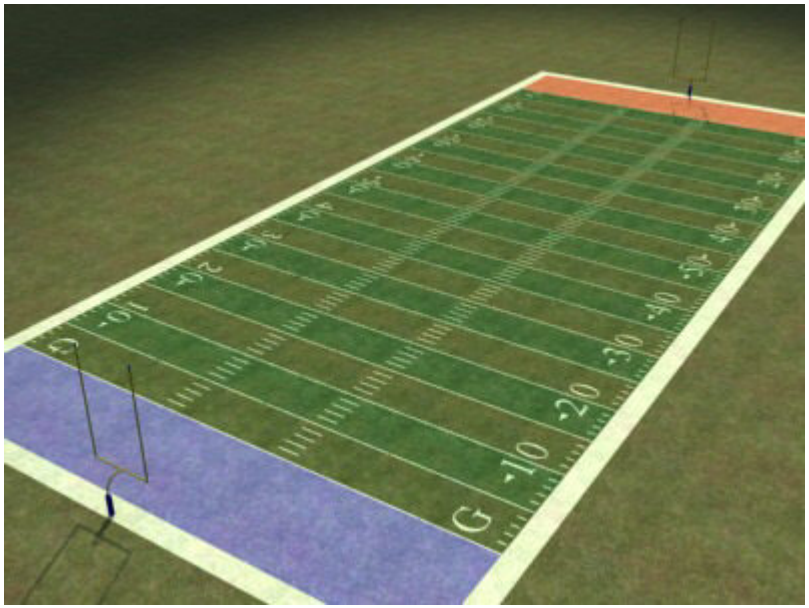
Twin Screw

Co-Kneader

# Putting Compounding Into Perspective

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



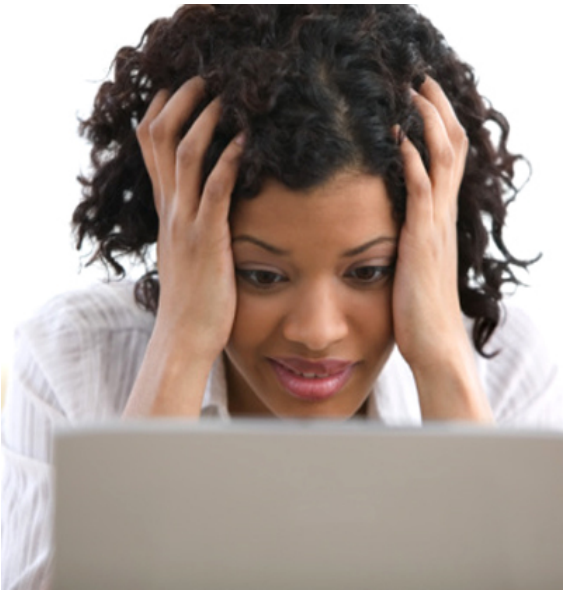
- Conductive carbon black surface area = 130 $m^2$/gram
- 34 grams carbon black = surface area of football field (4460$m^2$)
- Dispersing a 20% carbon black compound is similar to evenly coating a football field with 136 grams of plastic!

# Resin Selection

# The Dilemma

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- 60 Thermoplastic Resins + 100 Additives = 1000's of Potential Compounds
- Which 1 Do I Choose For My Application???

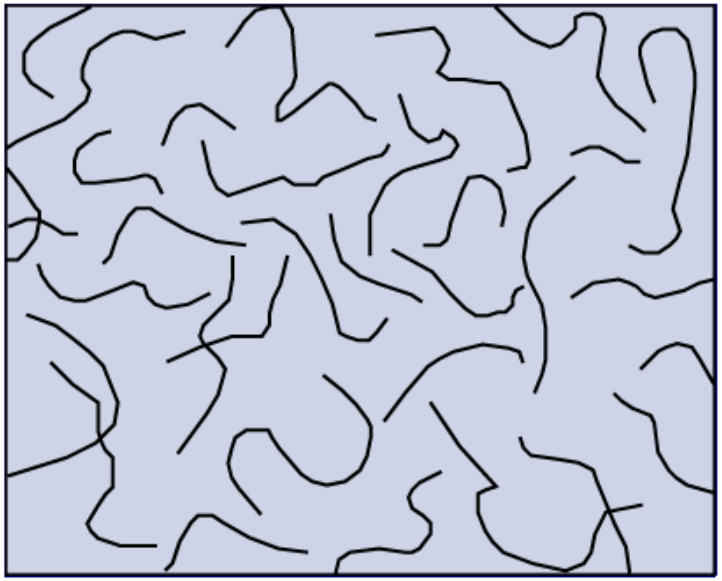


# Plastic Selection Process

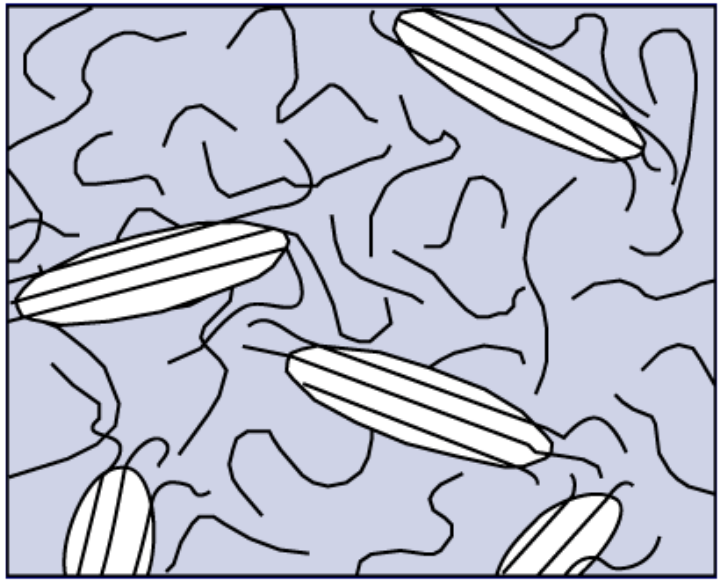
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

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



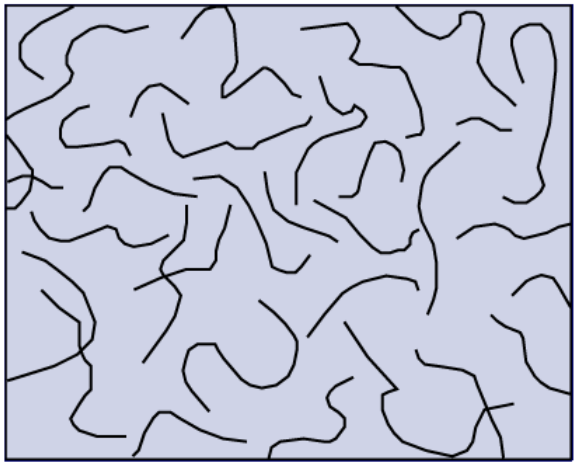
Amorphous



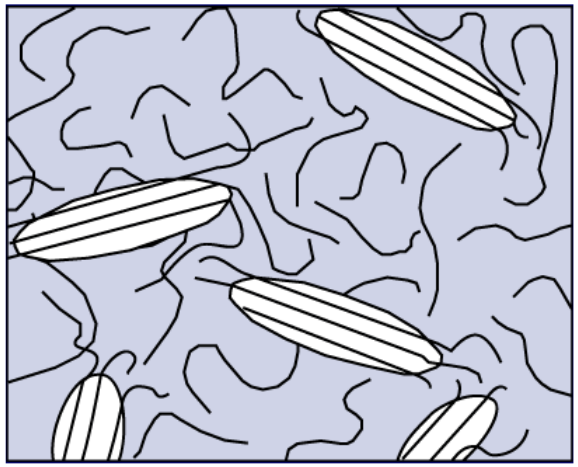
Semi-Crystalline

# Morphology





Amorphous



Semi-Crystalline

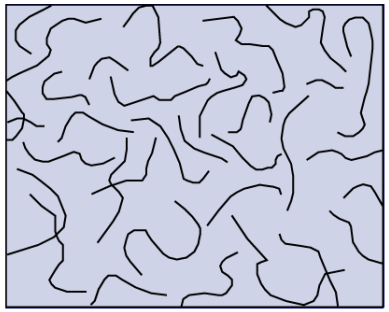
**Compare**

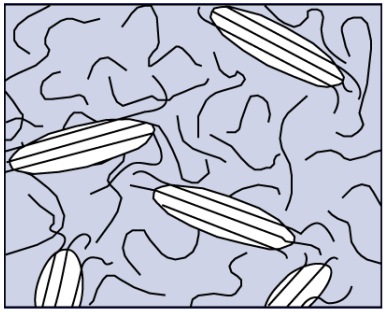
- **Molecular Packing (Shrinkage)**
- **Resistance to Molecular Disentanglement (Chemical/Abrasion Resistance)**
- **Light Refraction (Opacity)**
- **Melting Characteristics (Flow)**

# 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

Polyetherimide (PEI)

Polyethersulfone (PES)

Polysulfone (PSU)

Amorphous Nylon

Polycarbonate (PC)

Acrylonitrile Butadiene Styrene (ABS)

Styrene Acrylonitrile (SAN)

Polystyrene (PS)

High Impact Polystyrene (HIPS)

Acrylic (PMMA)

## Semi-Crystalline

Polyetheretherketone (PEEK)

Polyphenylene Sulfide (PPS)

Polyphthalamide (PPA)

Polyamide (PA/Nylons)

Polyethylene Terephthalate (PET)

Polybutylene Terephthalate (PBT)

Acetal (POM)

Polylactic Acid (PLA)

Polypropylene (PP)

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
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- 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



- **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



- **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, Mod. Cost
  - Nylon 6/12, 11, 12, etc. – 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***

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

- **PS**

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

- **HDPE**

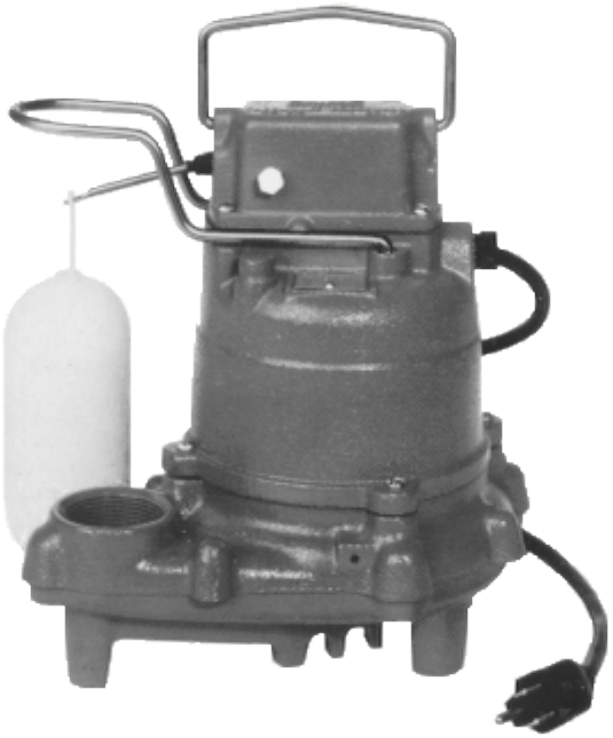
- **Auto Tail Lamp Cover**
  - Transparent Colors
  - Dimensionally Stable
  - Excellent UV
  - Low Cost
- **PMMA**

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

- **SAN**

- **Sump Pump Housing**
  - Chemical Resistance
  - Reasonable Thermal Resistance
  - Low Cost

- **PP + GF**



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


- **PC**

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

- **Amorphous Nylon**

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

- **??????????**

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


- **Nylon 6 + GF**

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

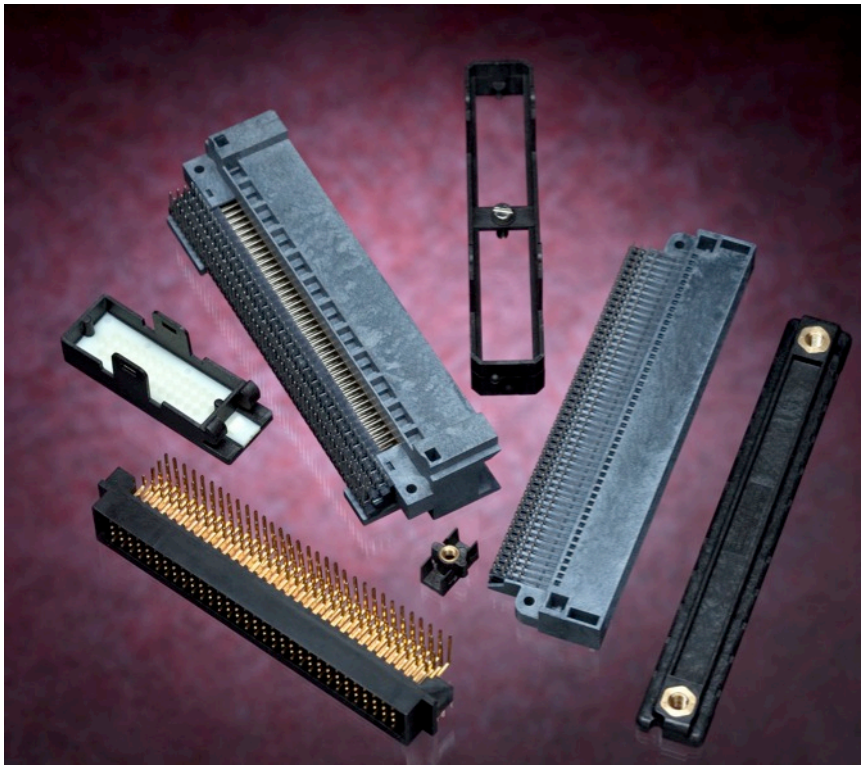
2008 6.2L V-8 (LS3)
Intake Manifold with Acoustic Co

- **Nylon 66 + GF**

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

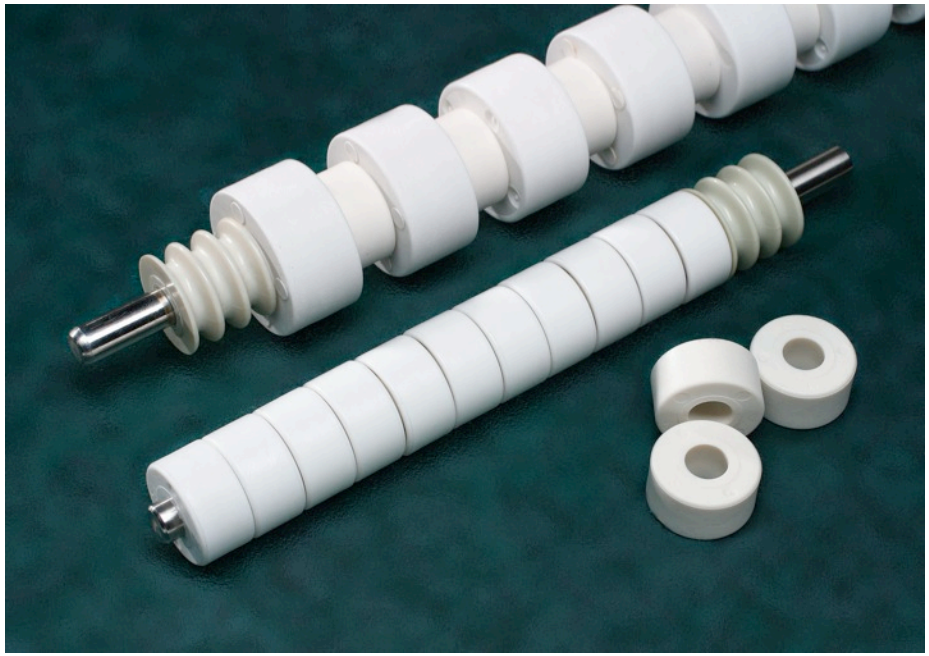
- **??????????**

- **Electrical Connectors**
  - Good Flow in Thin Walls
  - Excellent Electrical Properties
  - Dimensionally Stable in Humidity
  - Moderate Cost OK



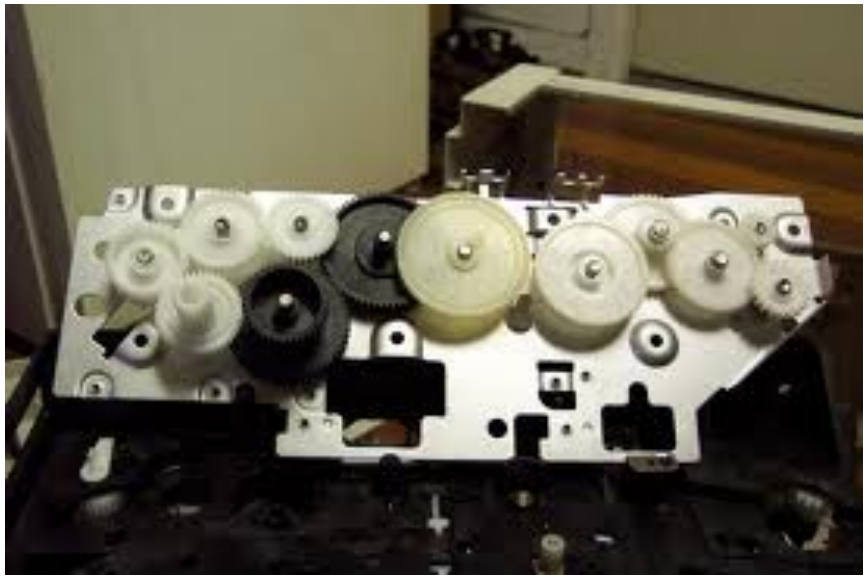
- **PBT (PET) + GF + FR**

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



- **Acetal**

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



- **??????????**

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

- **??????????**

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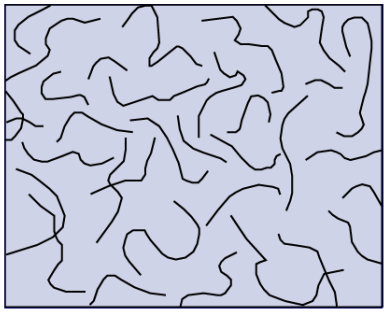
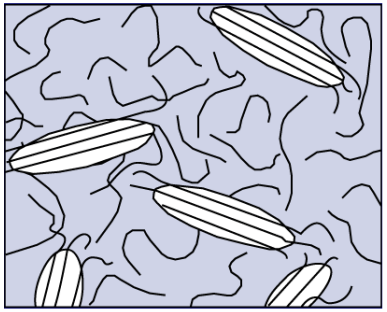
# Overcoming Morphology Deficiencies Via Compounding

# Morphology Deficiencies

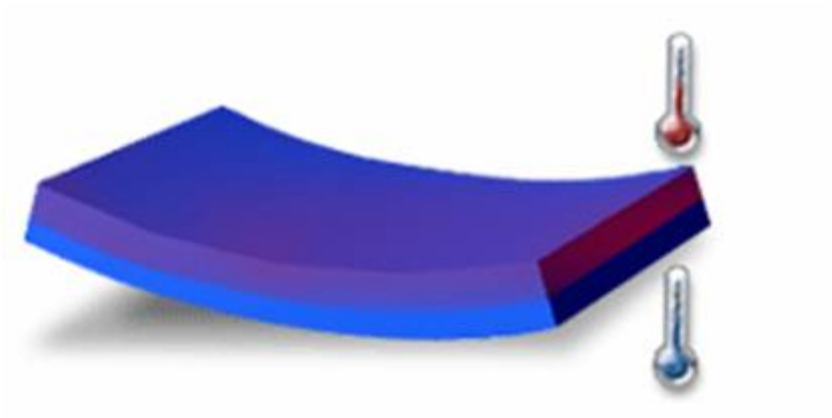
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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



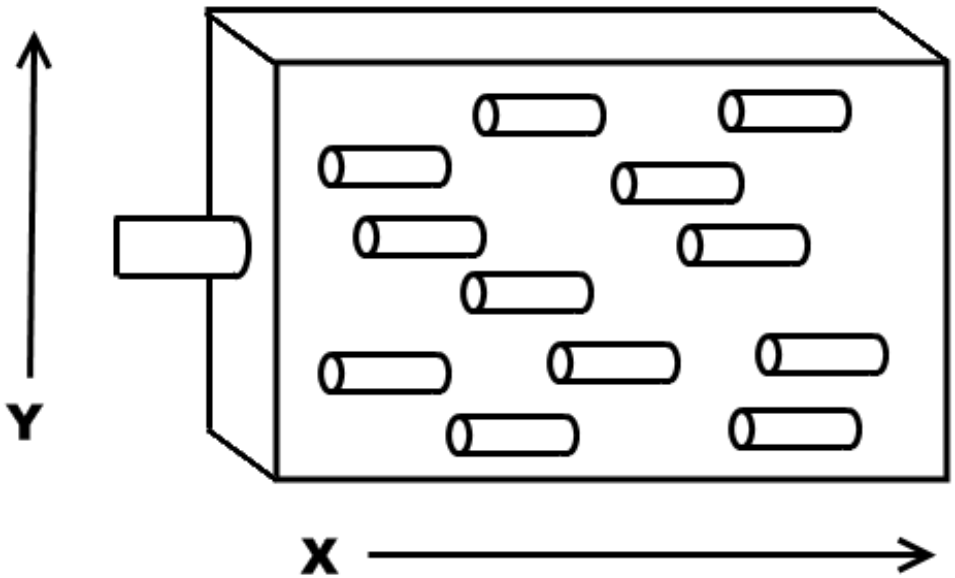


- Can We Reduce Shrink Rate & Improve Dimensional Stability of Semi-Crystalline Resins?



# Fiber Reduces Shrink

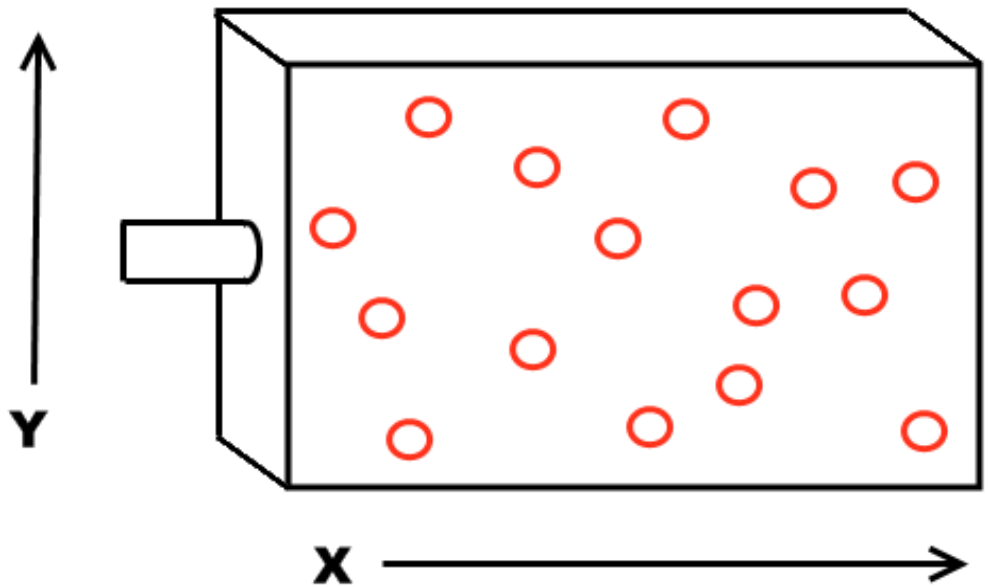
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS




**Shrink Rate X ≠ Shrink Rate Y → Warp**

# Warp Control

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

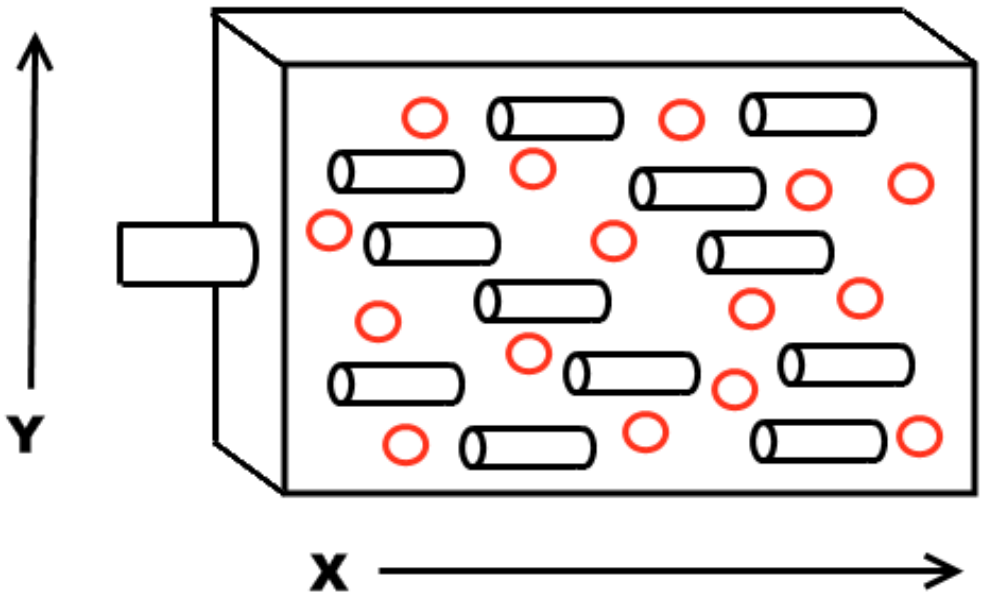



**Shrink Rate X = Shrink Rate Y → Flat Part**

***But Low Strength!***

# Strength & Warp Control

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

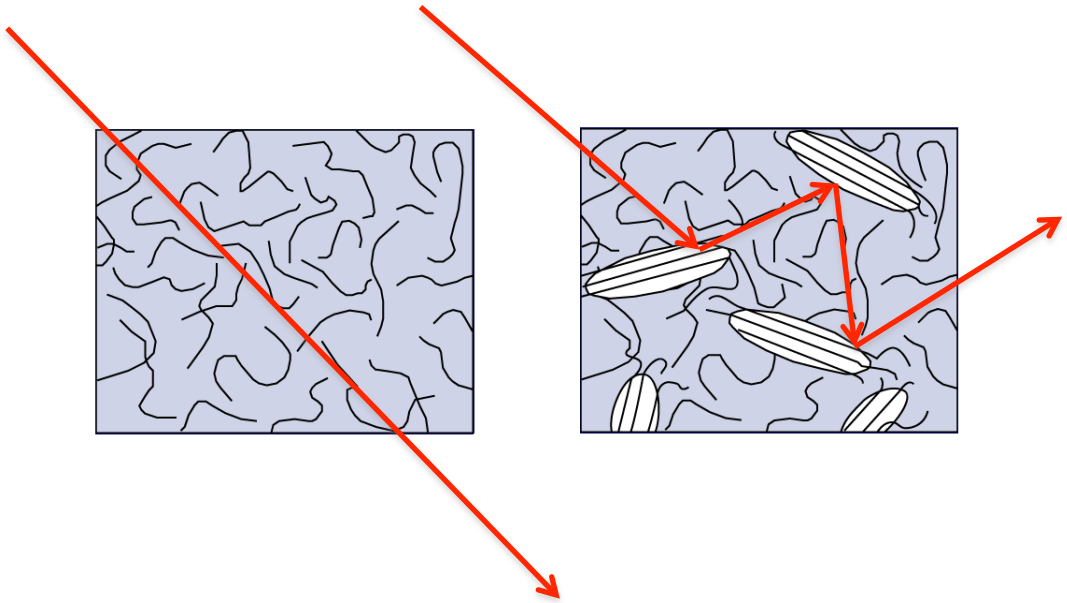



**Common Loading = 15% Glass Fiber & 25% Mineral or Beads**

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

- **Nylon 66 + 15% GF + 25% Mineral**

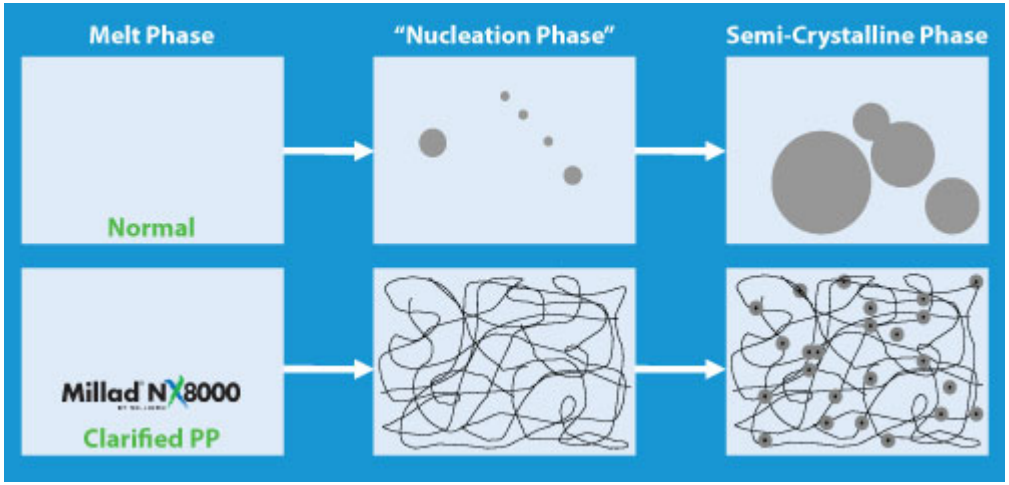
- Can We Make A Semi-Crystalline Resin Transparent?



# 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

- **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?

- **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 |

- **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 |

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

- **PC/PBT Alloy**

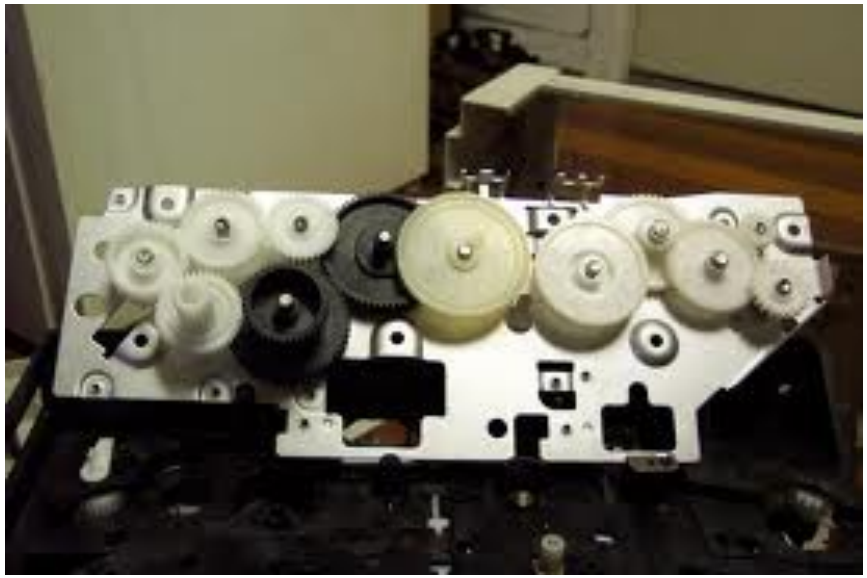
- **GPS Housing**
  - Tight Dimensions & Low Warp
  - Moderate Cost OK
  - Good Mold Flow
  - High Impact
- **PC/ABS or PC/PBT Alloy**
  - Want Sustainability
- **PC/PLA Alloy (30% Bio)**
  - Want More Sustainability
- **Recycled (PCR) PC/PLA Alloy (30%Bio + 60% PCR = 90% Sustainable)**

- Can We Make An Amorphous Resin Wear Resistant?

- **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 |

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



- **PC + PTFE**

# Review

- **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

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# Questions?


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