ENGINEERED PLASTICS WORKSHOP

Learn About Thermoplastics | Connect with Experts

2016 TENNESSEE / NORTH CAROLINA

YOUR GLOBAL COMPOUNDER OF
CUSTOM ENGINEERED THERMOPLASTICS

RTP Co.
Imagineering Plastics®

RTP Company
Engineered Plastics Workshop

PDF copies of the presentations from today's workshop can be downloaded from our website at **www.rtpcompany.com/workshoppresentations**

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

Kevin Jennings | Regional Sales Manager
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(864) 723-9162

8:45 a.m.

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

RTP Company

Your Global Compounder of Custom Engineered Thermoplastics

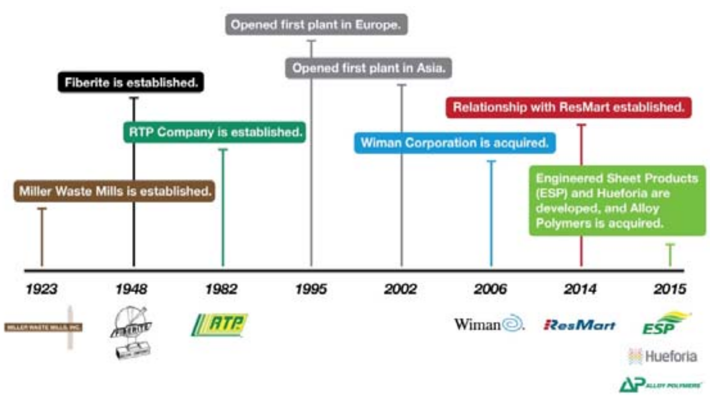
rtpcompany.com • rtp@rtpcompany.com

ABOUT RTP COMPANY

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

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

ABOUT RTP COMPANY



CUSTOM SOLUTIONS

High-Tech Compounds to Unfilled Resins

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

Annual Production

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

CUSTOM SOLUTIONS

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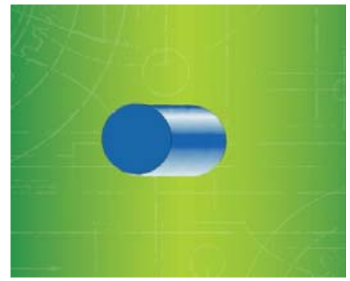

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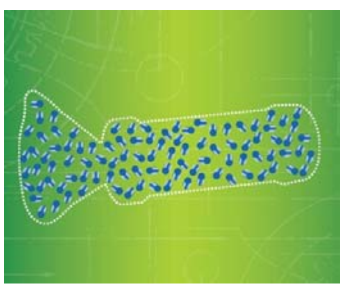

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GLOBAL MANUFACTURING

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

GLOBAL MANUFACTURING

RTP Company is a global compounder of **custom engineered thermoplastics**.

ALLOY POLYMERS LOCATIONS

ALLOY POLYMERS

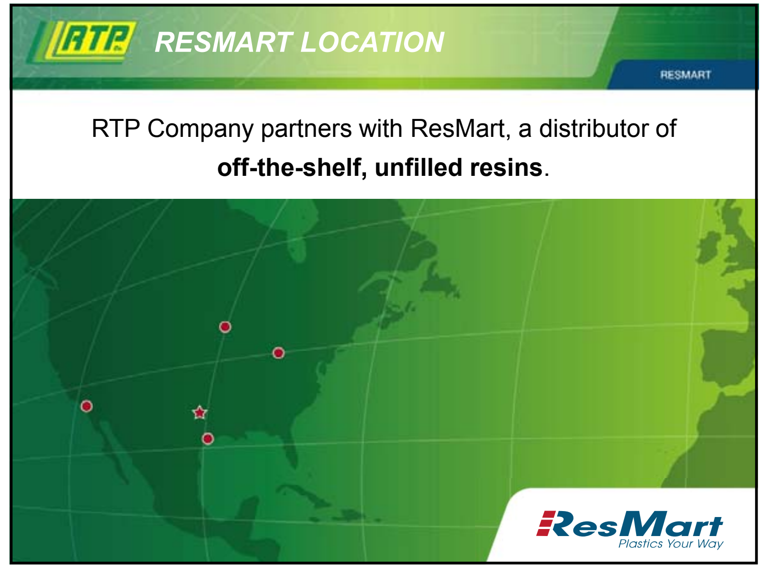
Alloy Polymers, a division of RTP Company, provides **contract manufacturing** and **high volume processes**.

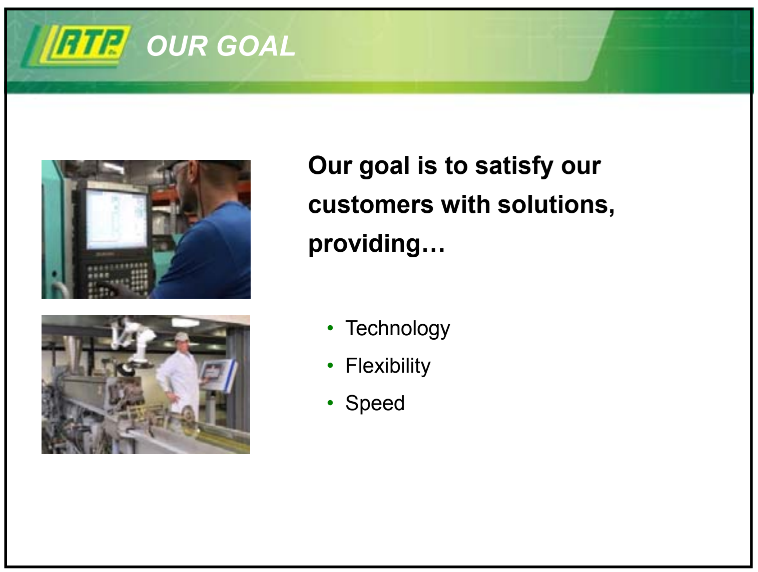
WIMAN LOCATIONS

WIMAN

Wiman Corporation, a wholly-owned subsidiary of RTP Company, produces customized, high quality **plastic films** and **film laminates**.


ESP™ LOCATIONS
ESP™
Engineered Sheet Products™ (ESP™), a division of RTP Company, manufactures **specialty engineered sheet**.
WINONA, MINNESOTA
WAUKESHA, WISCONSIN
ESP Engineered Sheet Products


RESMART LOCATION
RESMART
RTP Company partners with ResMart, a distributor of **off-the-shelf, unfilled resins**.
ResMart
Plastics Your Way


OUR GOAL
Our goal is to satisfy our customers with solutions, providing…
Technology
Flexibility
Speed


FLEXIBLE VOLUMES
Bags to Bulk
RTP Company offers the most competitive lead times in the industry.

OUR CULTURE

Our culture can be described as…

- A close-knit organization
- Generational/long term thinkers
- Entrepreneurial
- High spirited with a sense of urgency
- "Bureaucracy-less"

WE ARE INDEPENDENT

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

- Raw materials
- Formulations
- Solutions

GLOBAL SUPPORT

RTP Company has **100+ sales & support employees** worldwide:

Americas – Canada, United States, Mexico, Brazil
Asia/Pacific Rim – China, Korea, Singapore, Japan, Taiwan, India
Europe – Austria, Netherlands, France, Germany, United Kingdom

PRODUCT DEVELOPMENT / R&D

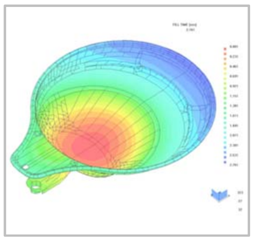
RTP Company has **50+ development engineers** worldwide, including regional engineers for local support.

At RTP Company, our development engineers:

- Apply the most current research
- Aggressively seek new resins and additives
- Have a passion for creating the best solution for you

PRODUCT DEVELOPMENT / R&D

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



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

TECHNICAL SERVICE

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

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

CUSTOMER SERVICE

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

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

Each year, RTP Company measures how satisfied customers are with the accessibility and helpfulness of their RTP Company Customer Service Representative. ***In 2015, 96% of respondents indicated that they were satisfied with the service they received.***

GLOBAL COMPOUNDING

We develop it anywhere…

make it anywhere…

and support it everywhere!

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

PRODUCT FAMILIES

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

RESMART

ResMart Plastics Your Way

Looking for unfilled plastic resins?

We partner with ResMart to fulfill your needs!

www.resmart.com

ResMart Resins:

Ultra, Plus, and Utility grades:

- Polypropylene
- Nylon 6, 6/6
- Clear Nylon (Amorphous Nylon)
- Polycarbonate
- SAN
- ABS
- Polystyrene
- Clear ABS (MABS)
- ACETAL
- PBT
- Polypropylene
- ASA
- Black Masterbatch
- TPU

Specialty grades:

- Solvay Udel® PSU
- Solvay Radel® PPSU
- Solvay Ketaspire® PEEK

MARKETS

YOUR GLOBAL COMPOUNDER

RTP Company is your **global compounder** of custom engineered thermoplastics… and **much more!**

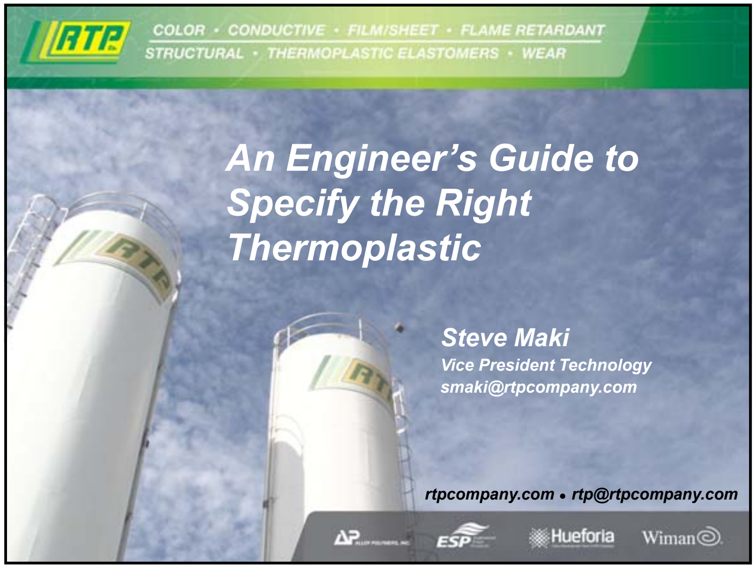

COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR
Thank You!
rtpcompany.com • rtp@rtpcompany.com
Hueforia
Wiman

RTP Co.
Imagineering Plastics®

An Engineer's Guide to Specifying the Right Thermoplastics

Steve Maki | VP of Technology
smaki@rtpcompany.com
(507) 474-5371

9:00 a.m.



AGENDA

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

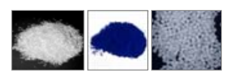
INDEPENDENT SPECIALTY COMPOUNDER

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

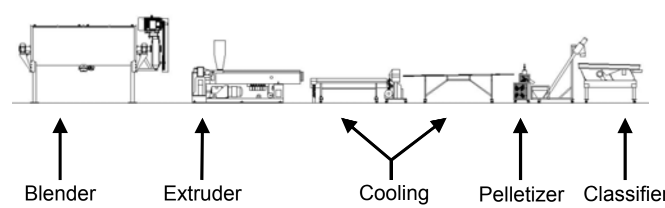
Specialty → We create engineered formulations

Independent → We are unbiased in our selection of raw materials

COMPOUNDING PROCESS

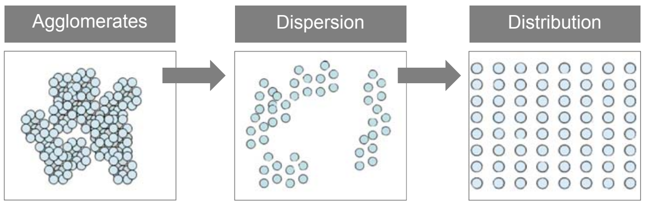


Raw Materials → **Finished Product**

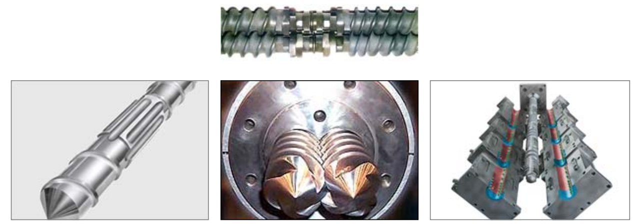


COMPOUNDING OBJECTIVES

Mixing
- Dispersive
- Distributive

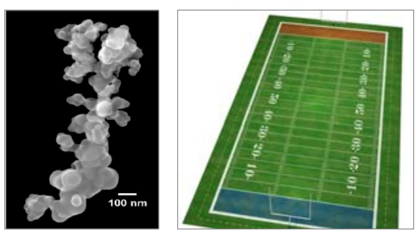


COMPOUNDING EXTRUDERS



Single Screw | Twin Screw | Co-Kneader

PUTTING COMPOUNDING INTO PERSPECTIVE



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

Resin Selection

THE DILEMMA

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

Which ONE Do I Choose For My Application???

PLASTIC SELECTION PROCESS

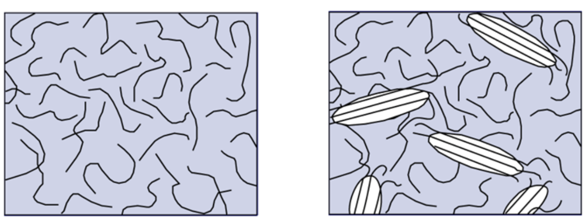
Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

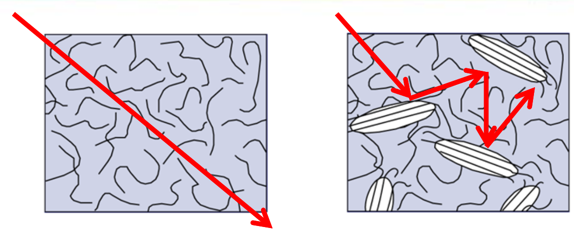
MORPHOLOGY

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



Amorphous — Semi-Crystalline

MORPHOLOGY

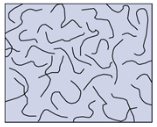
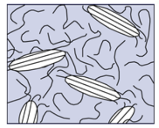


Amorphous — Semi-Crystalline

Compare

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

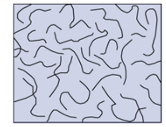
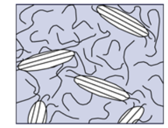
MORPHOLOGY CHARACTERISTICS

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

MORPHOLOGY CHARACTERISTICS

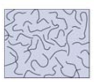
Lens?
Fuel Float?
Precision Printer Chassis?
Tool Housing?
Multiple Pin Connector?
Pulley?
Grease Fitting?
Laptop Cover?

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

MORPHOLOGY OF THERMOPLASTICS

Amorphous



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

Semi-Crystalline

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

PLASTIC SELECTION PROCESS

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

MORPHOLOGY VS. THERMAL/COST

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

Thermal & Cost Increases ↑

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

PLASTIC SELECTION PROCESS

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

ENGINEERED & COMMODITY RESINS

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

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

AMORPHOUS RESINS

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

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

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

SEMI-CRYSTALLINE RESIN

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

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

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

PUTTING IT ALL TOGETHER

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

Test Your Knowledge With Application Examples

CASE STUDY

CD Jewel Case

- Transparent
- Flat & Dimensionally Stable
- Low Cost

PS

CASE STUDY

Gas Tank

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

HDPE

CASE STUDY

Auto Tail Lamp Cover

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

PMMA

CASE STUDY

Plastic Glass Tumblers

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

SAN

CASE STUDY

Sump Pump Housing

- Chemical resistance
- Reasonable thermal resistance
- Low cost

PP + GF

CASE STUDY

Safety Glasses

- Optical transparency
- High impact
- Moderate cost OK

PC

CASE STUDY

Hub Odometer Lens

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

Amorphous Nylon

CASE STUDY

Chemical Beakers

- Excellent chemical resistance
- Low Cost
- Transparent

?????????

CASE STUDY

Nail Gun Housing

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

Nylon 6 + GF

CASE STUDY

Automotive Intake Manifold

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

Nylon 66 + GF

CASE STUDY

Oil Pan

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

?????????

CASE STUDY

Electrical Connectors

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

PBT (PET) + GF + FR

CASE STUDY

Conveyor Rollers

Good abrasion resistance

Low wear & friction

Moderate cost OK

Acetal

CASE STUDY

Printer Gears

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

?????????

CASE STUDY

Lawn Tractor Hood

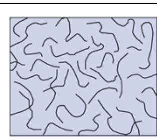
- Tight dimensions & low warp
- Moderate cost OK
- Chemical resistance
- Good mold flow

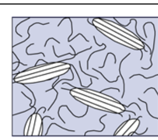
?????????

Overcoming Resin Deficiencies Via Compounding

MORPHOLOGY DEFICIENCIES

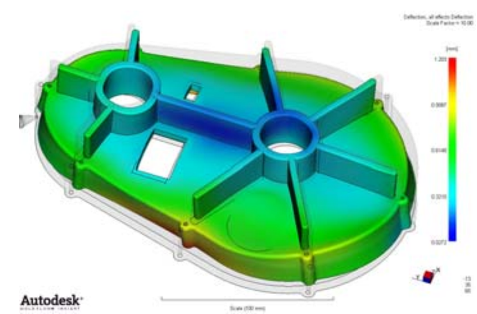
	Amorphous	Semi-Crystalline
Low Shrinkage	X	D
Low Warpage	X	D
Tight Tolerances	X	D
Transparency	X	D
Mold Flow Ease	D	X
Chemical Resistance	D	X
Wear Resistance	D	X



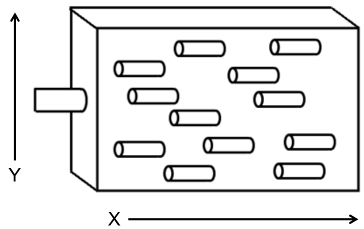


DIMENSIONAL STABILITY

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

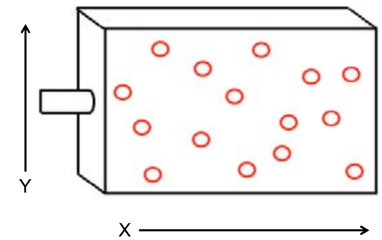


FIBER REDUCES SHRINK



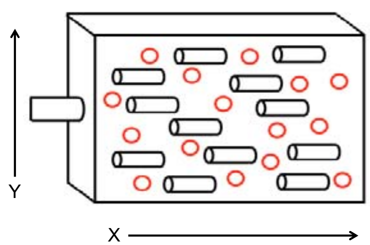
Shrink Rate X ≠ Shrink Rate Y ⟶ Warp

WARP CONTROL



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

STRENGTH & WARP CONTROL



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

CASE STUDY

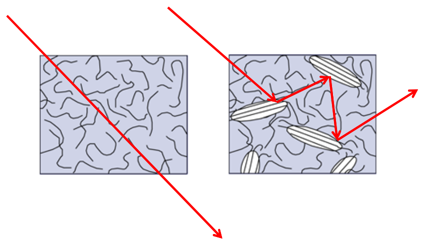
Oil Pan

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

Nylon 66 + 15% GF + 25% Mineral

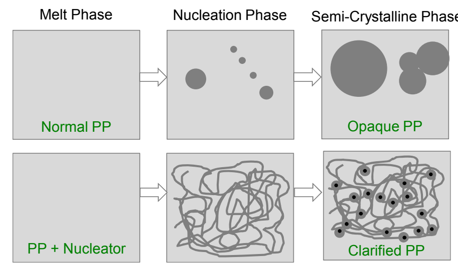
TRANSPARENCY

Can We Make A Semi-Crystalline Resin Transparent?



NUCLEATION/CLARIFICATION

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



CASE STUDY

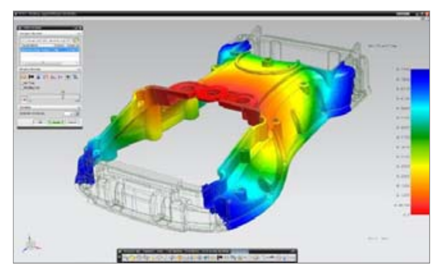
Chemical Beakers

- Excellent chemical resistance
- Low Cost
- Transparent

PP + Nucleator

CHEMICAL RESISTANCE/MOLD FLOW

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



ALLOYING

Alloy PC with ABS

RTP 2500 A Series

	PC	PC/ABS
Tensile Strength, psi	9000	8900
Flexural Mod, E6 psi	0.34	0.40
Izod Impact, ft lb/in	15	13
HDT @ 264 psi,^{0}F	270	210
Fuel Resistance	Poor	Poor
Melt Flow, gm/10 min	10	15
Clarity	Transparent	Opaque

ALLOYING

Alloy PC With Polyester (PBT or PET)

RTP 2099 X 63578 B

	PC	PC/PBT
Tensile Strength, psi	9000	8700
Flexural Mod, E6 psi	0.34	0.35
Izod Impact, ft lb/in	15	15
HDT @ 264 psi, ^{0}F	270	250
Fuel Resistance	Poor	Fair
Melt Flow, gm/10 min	10	20
Clarity	Transparent	Opaque

CASE STUDY

Lawn Tractor Hood

Tight dimensions & low warp

Moderate cost OK

Chemical resistance

Good mold flow

PC/PBT Alloy

WEAR RESISTANCE

Can We Make An Amorphous Resin Wear Resistant?

PTFE LUBRICATED

Compound PTFE Into PC
RTP 300 TFE 15

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

CASE STUDY

Printer Gears

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

PC + PTFE

WHAT'S NEW?

New Technologies

NEW TECH (HEALTHCARE)

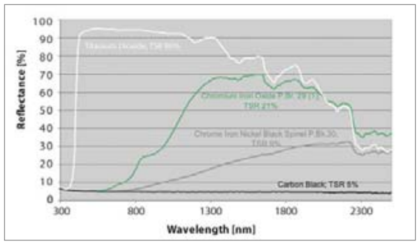
RTP 2000 HC Series

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

NEW TECHNOLOGIES (COLOR)

IR Reflecting Colors

Allows Dark Colored Plastics To Remain Cool When Exposed To Sunlight



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

NEW TECHNOLOGIES (FR)

FR Compounds for Plenum Applications (UL 2043)

Low Heat/Smoke Release Grades

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

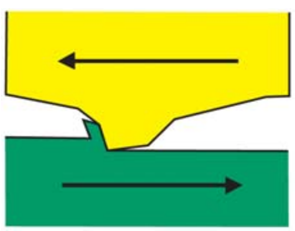
Opportunities

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

NEW TECHNOLOGIES (WEAR)

Abrasion Resistant Compounds

To Compete With UHMWPE (Not Moldable)



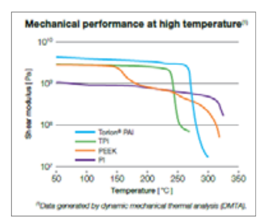
- Injection Moldable Polyolefin Alloy
- Similar Abrasion Resistance To UHMWPE
  - → Gears
  - → Cams
  - → Slides
  - → Wear Liners

NEW TECH (HIGH TEMPERATURE)

Specialty Torlon Compounds

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

SOLVAY
asking more from chemistry®



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

REVIEW

Intro To Compounding

The Dilemma

Resin Selection Procedure

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

Application Case Studies

Compounding in Performance

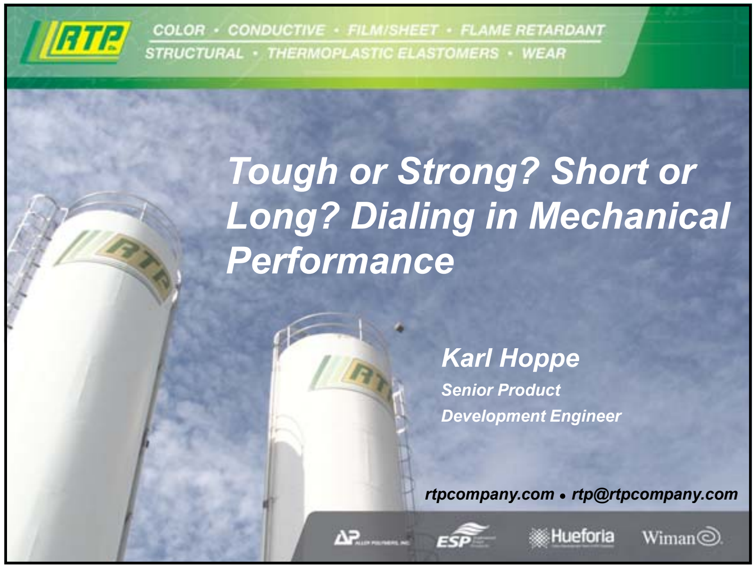
- Overcoming Resin Deficiencies

Introduction To New Technologies

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

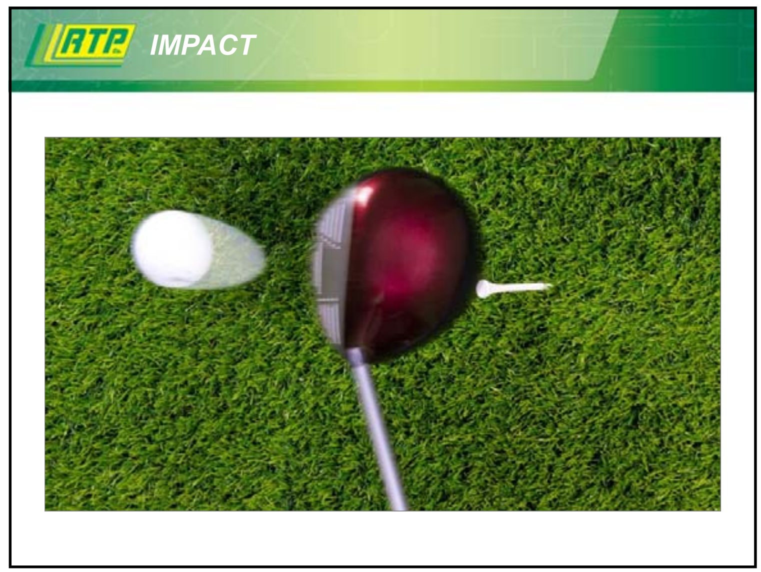
Karl Hoppe | Senior Product Development Engineer
khoppe@rtpcompany.com
(507) 474-5367

10:00 a.m.


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


STRENGTH


STIFFNESS


IMPACT

THE FORMULA

Resin + Additives = Change in Properties

THE FOUNDATION

THE ADDITIVES TOOLBOX

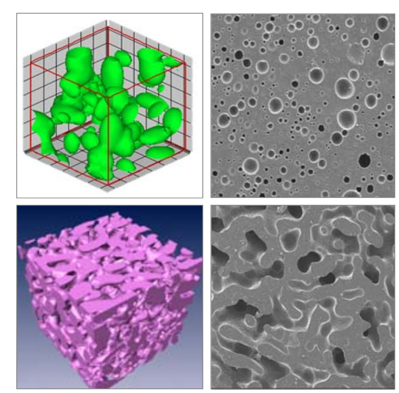
Modifiers

Fillers

MODIFIERS

Polymer blends

Impact modifiers



POLYMER BLENDS

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

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

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

POLYMER BLENDS

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

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

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

POLYMER BLENDS

	PC	PC/ABS (RTP 2500 A)	ABS
Specific Gravity	1.19	1.15	1.05
Tensile Strength (MPa)	59	59	45
Notched Izod Impact (J/m)	850	740	250

POLYMER BLENDS

Housing for Hearing Tester

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

MODIFIERS

Impact properties

Impact Modifiers

Strength/stiffness

IMPACT MODIFIERS

	PA 6/6	Impact Modified PA 6/6
Specific Gravity	1.14	1.08
Notched Izod Impact (J/m)	55	900
Tensile Strength (MPa)	80	45
Flexural Modulus (GPa) (Stiffness)	2.8	1.8

IMPACT MODIFIERS

ATV Wheel Bead Lock Ring

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

IMPACT MODIFIERS

Limitations

Base resin
- Lose Performance
- Temperature

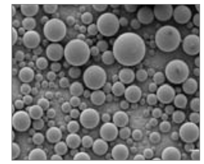
Environment
- Chemical Resistance
- UV Resistance

THE ADDITIVES TOOLBOX

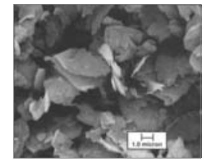
Modifiers

Fillers

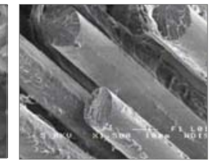
FILLERS



Beads
(Glass)
Photo: Potters, Inc.



Minerals
(Talc)

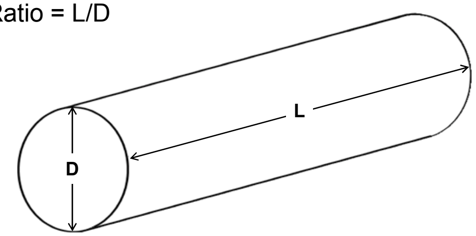


Fibers
(Glass)

ASPECT RATIO

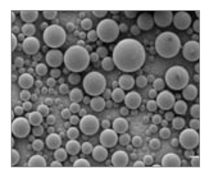
Property change determined by:

Aspect Ratio = L/D



↑ Aspect Ratio ↑ Reinforcing

LOW ASPECT RATIO

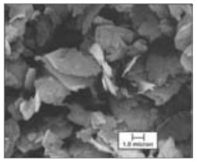


Beads
(Glass)
Photo: Potters, Inc.

Aspect Ratio = 1

	PC	PC + 10% Glass Beads	PC + 30% Glass Beads
Specific Gravity	1.19	1.27	1.42
Tensile Strength (MPa)	59	55	48
Notched Izod Impact (J/m)	850	100	80
Flexural Modulus (GPa)	2.4	2.6	3.4

LOW ASPECT RATIO

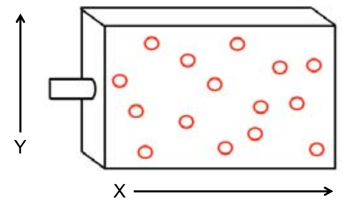


Minerals
(Talc)

Aspect Ratio = 2 - 50

	PC	PC + 20% Talc	PC + 40% Talc
Specific Gravity	0.91	1.05	1.25
Tensile Strength (MPa)	32	32	30
Notched Izod Impact (J/m)	47	45	34
Flexural Modulus (GPa)	1.5	2.5	3.8

LOW ASPECT RATIO

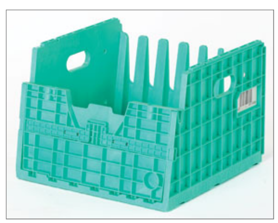


Shrink Rate X = Shrink Rate Y ⟹ Flat Part

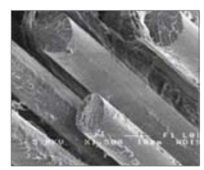
LOW ASPECT RATIO

Reusable Handling Container

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



HIGH ASPECT RATIO

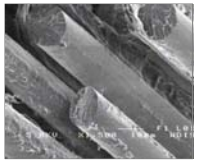


Fibers
(Glass)

Aspect Ratio = 50 - 250

	PC	PC + 30% Glass Beads	PC + 30% Glass Fiber
Specific Gravity	1.19	1.42	1.42
Tensile Strength (MPa)	59	48	124
Notched Izod Impact (J/m)	850	80	160
Flexural Modulus (GPa)	2.4	3.4	7.6

HIGH ASPECT RATIO



Fibers
(Glass)

Aspect Ratio = 50 - 250

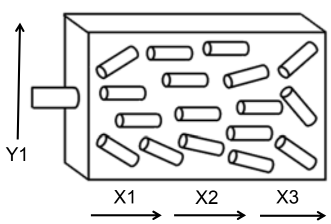
	PP	PP + 40% Talc	PP + 40% Fiber
Specific Gravity	0.91	1.25	1.22
Tensile Strength (MPa)	32	30	84
Notched Izod Impact (J/m)	47	34	108
Flexural Modulus (GPa)	1.5	3.8	7.5

HIGH ASPECT RATIO

Surgery Drill Guide

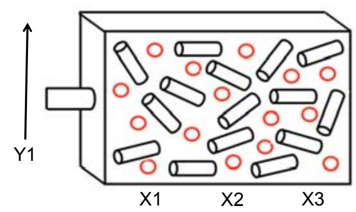
Problem:	Stiffness and dimensional stability
Solution:	Glass fiber reinforced Polycarbonate
Benefits:	• Rigidity • Tight tolerances

HIGH ASPECT RATIO - WARP



Shrinkage X1 & X2 ≠ X3 ⟶ Warp

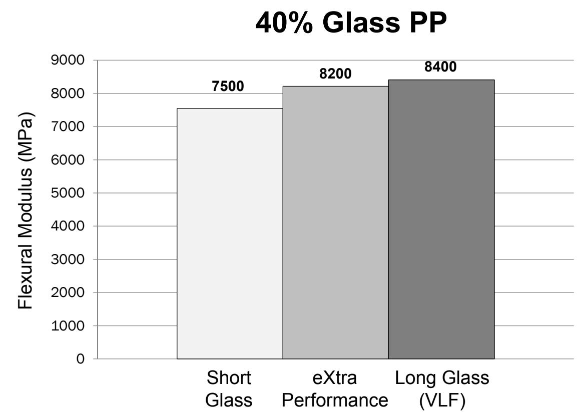
HIGH ASPECT RATIO - FLAT



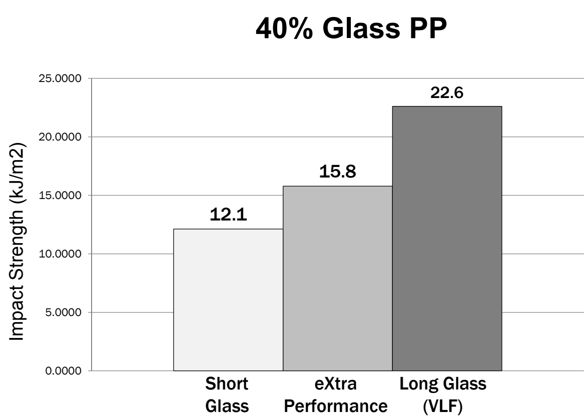
Shrinkage X1 = X2 = X3 ⟶ Flat Part

IMPROVEMENTS IN SGF PP

IMPROVEMENTS IN SGF PP



IMPROVEMENTS IN SGF PP



HIGH ASPECT RATIO

Carbon Fibers

Aspect Ratio = 50 - 250

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

FIBER COMPARISON- PP

	PP 40% GF	PP 40% VLF	PP 30% CF
Flexural Modulus (MPa)	6900	8250	9000
Tensile Strength (MPa)	85	120	90
Notched Izod Impact (kJ/m^2)	12.1	22.8	6
Specific Gravity	1.21	1.21	1.00

FIBER COMPARISON – PA 6/6

	PA 6/6 60% VLF (Long Fiber)	PA 6/6 35% Carbon Fiber
Flexural Modulus (MPa)	19.3	19.0
Tensile Strength (MPa)	275	244
Tensile Elongation (%)	2.0	2.0
Specific Gravity	1.71	1.29

FIBER COMPARISON – PPS

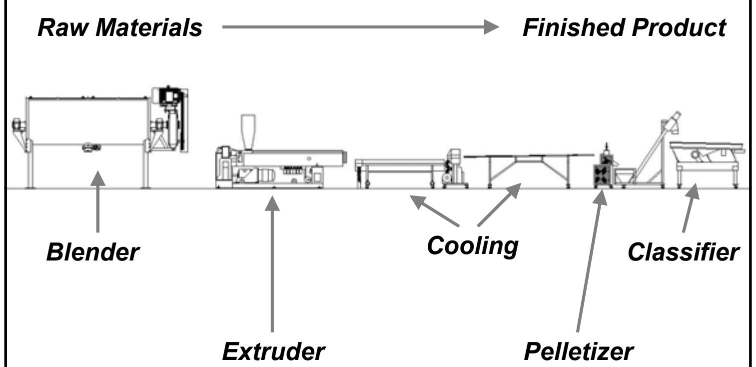
	PPS 40% Glass	PPS 20% Carbon
Flexural Modulus (MPa)	15.1	15.8
Tensile Strength (MPa)	169	172
Tensile Elongation (%)	1.5	1.0
Specific Gravity	1.68	1.40

CARBON FIBER APPLICATION

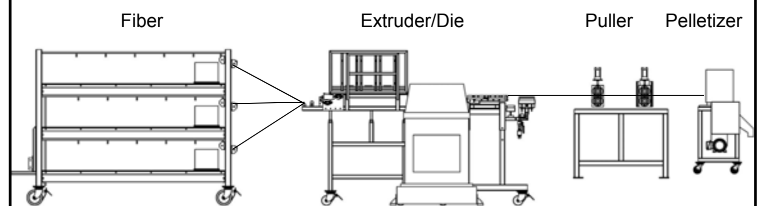
Brake Rotor Measuring Probe

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

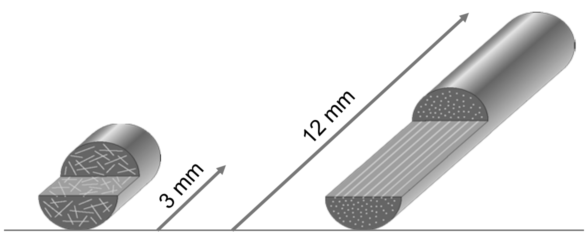
STANDARD COMPOUNDING PROCESS



EXTREME ASPECT RATIO - VLF



EXTREME ASPECT RATIO - VLF



Short Fiber

Fiber length: ~ 1-2 mm

Long Fiber

Fiber length: 12 mm

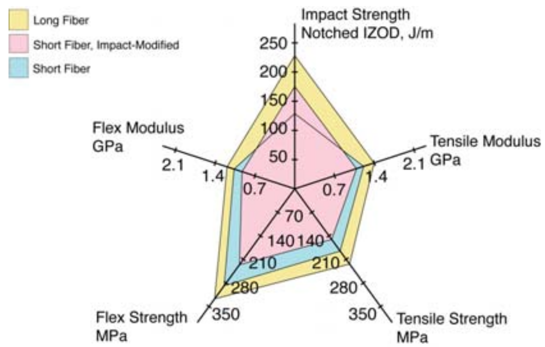
EXTREME ASPECT RATIO -VLF

Long Glass Fiber

Aspect Ratio = 300+

	PP + 40% Short Glass	PP + 40% Long Glass
Specific Gravity	1.22	1.22
Tensile Strength (MPa)	84	124
Notched Izod Impact (J/m)	108	228
Flexural Modulus (GPa)	7.5	8.4

EXTREME ASPECT RATIO - VLF



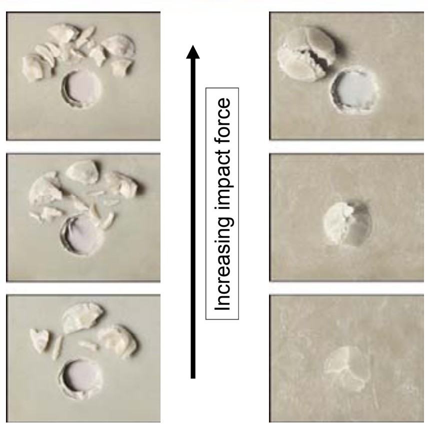
EXTREME ASPECT RATIO - VLF

Secret to success: ***the fiber skeleton***

PA 66 + 60% VLF
Seat Belt Tension Housing

DROP IMPACT TEST

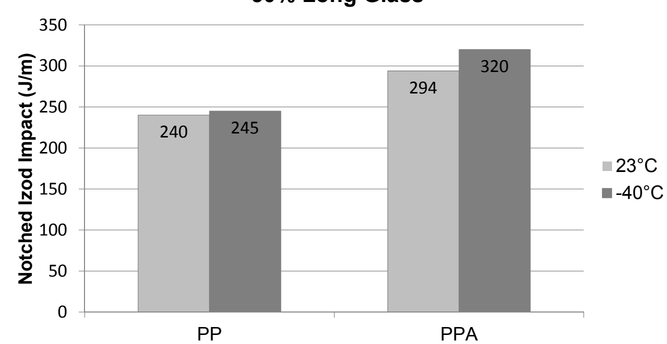
Short Fiber PA



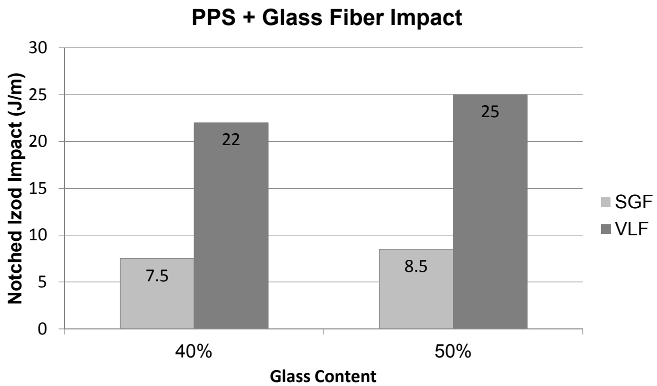
VLF PA

LOW TEMPERATURE IMPACT

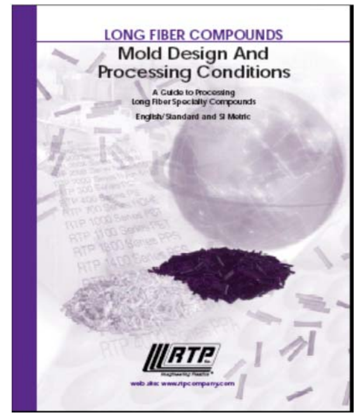
VLF Compounds
50% Long Glass



VLF PPS



MOLDING CONSIDERATIONS



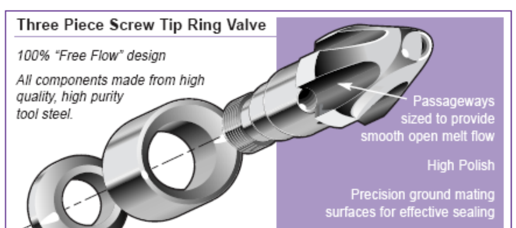
Avoid starting with long fiber and finishing with short fiber!

MOLDING CONSIDERATIONS

General guidelines:

1. General purpose screw OK (low compression preferred)
2. Reduce shear: low back pressure and rpm's
3. Reverse barrel temperature profile

Preferred:



HIGH TEMPERATURE POLYMERS

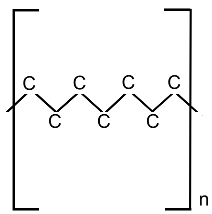
Amorphous	Semi-Crystalline
Polyetherimide (PEI)	Polyetheretherketone (PEEK)
Polyethersulfone (PES)	Polyphenylene Sulfide (PPS)
Polysulfone (PSU)	Polyphthalamide (PPA)
Amorphous Nylon	Polyamide (PA/Nylons)
Polycarbonate (PC)	Polybutylene Terephthalate (PBT)
Acrylic (PMMA)	Polyethylene Terephthalate (PET)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

Thermal & Cost Increases

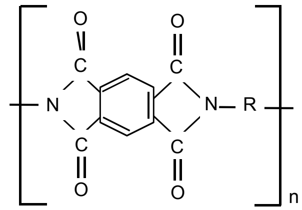
Commodity • Engineered • High Performance

CHEMICAL STRUCTURE

Polyethylene
Tg -5 °F

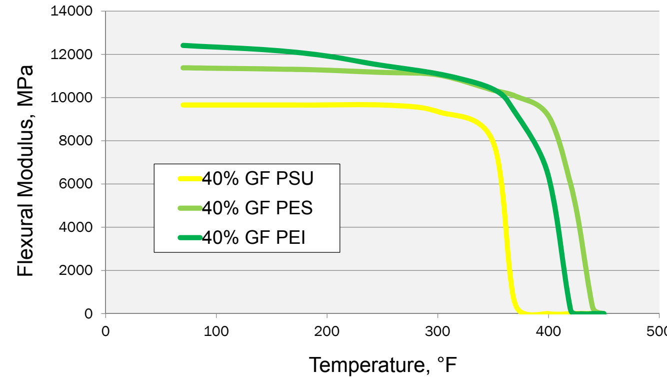


Polyimide
Tg 482 °F



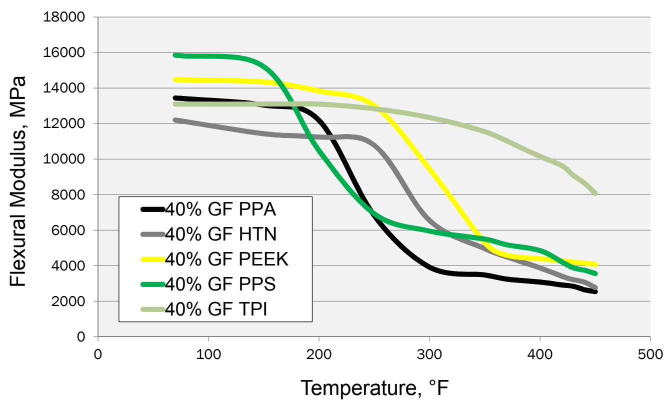
AMORPHOUS MATERIALS

Flexural Modulus Vs. Temperature



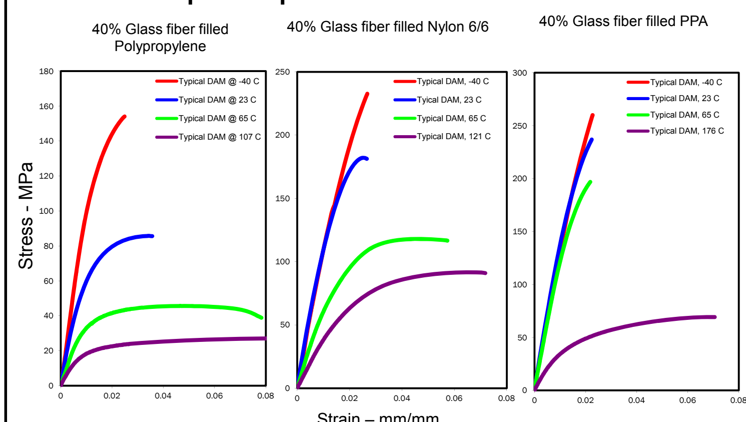
SEMI-CRYSTALLINE MATERIALS

Flexural Modulus Vs. Temperature

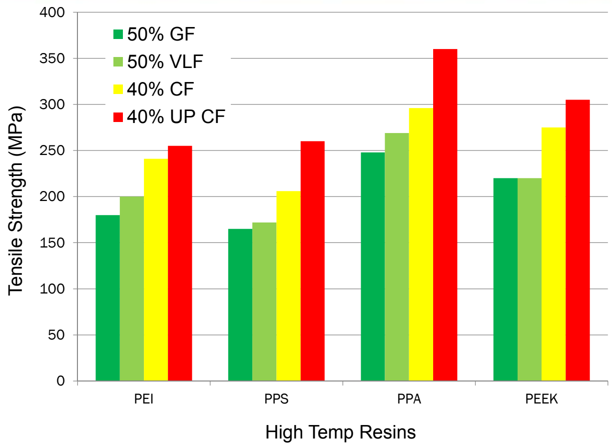


ELEVATED TEMP PROPERTIES

Multiple Temperature Tensile Stress/Strain



ULTRA PERFORMANCE PRODUCTS



HIGH TEMPERATURE APPLICATION

Surgical Head Restraint

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

SUMMARY

Modifiers

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

Fillers

- Performance driven by aspect ratio

High Temperature

- Range of polymers offer array of performance

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

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

Answers to Your Burning Questions: Flame Retardants and Regulations

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

11:00 p.m.

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

Answers to Your Burning Questions: Flame Retardants and Regulations

Jesse Dulek
Product Development Engineer, Flame Retardant Products

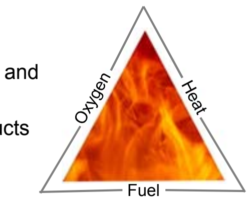
rtpcompany.com • rtp@rtpcompany.com

FLAME RETARDANT (FR) MATERIALS

Definition

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

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



Fire Triangle

GOALS OF FLAME RETARDANT COMPOUNDS

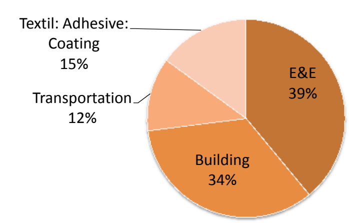
- Increase resistance to ignition
- Reduce rate of flame spread
- Reduce rate of heat release
- Reduce smoke emission

End Goal:

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

MARKETS FOR FR THERMOPLASTICS

Segmentation of FR Consumption by Value



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

OVERVIEW

Thermoplastic Flammability

- **Flame Retardant Additive Chemistries and Mechanisms**

Regulatory Landscape

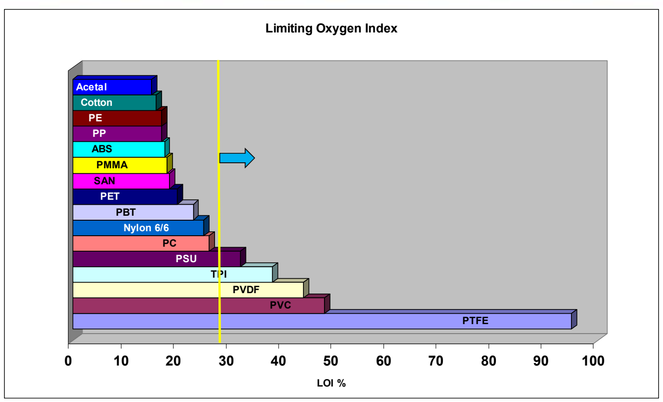
Testing Standards

Case studies

THERMOPLASTIC RESIN FLAMMABILITY

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

CHALLENGES OF FLAME RETARDING PLASTICS



COMMON TYPES OF FR ADDITIVES

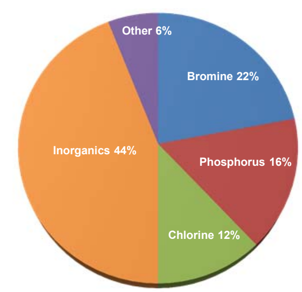
Halogenated FR's

- Brominated
- Chlorinated

Halogen Free FR's

- Metal hydroxides
- Phosphorous Based
- Melamine Based

Flame Retardant Additive Usage, 2011



HALOGENATED FR MECHANISM

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

Additive Type	Polymeric Type
• Higher Halogen Content • Lower Loadings • High Thermal Stability	• Melt Blendable • Less effect on physical properties • Enhanced Flow

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

NON-HALOGEN MECHANISMS

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

HALOGEN VS. HALOGEN-FREE

Halogenated	Halogen Free
• Lower Cost • Better Processing • Better Efficiency • Better Physical Properties	• Evolving Economics • Improved Processability • Wide Variety of Products • Low Smoke • Lower Toxicity • Less Corrosive • Lower Specific Gravity

CHOOSING A FR SYSTEM

How do we decide which FR mechanism to use?

- Resins System
- FR Specification
- Part Function
- Fillers/Additives
- Regulatory Concerns
  - Halogen, RoHS, etc

OVERVIEW

Thermoplastic Flammability

– Flame Retardant Additive Chemistries and Mechanisms

Regulatory Landscape

Testing Standards

Case studies

EVOLUTION OF HALOGEN-FREE TECHNOLOGIES

- More “self-policing”/customer driven bans
- New FR standards
- Green Movement
- More Effective/Economical FR Chemicals
- Increased Performance
- Competition in the Market

HALOGEN RESTRICTIONS

OEM Driven Ban on Halogenated Chemicals

- HP, DELL, IBM etc.

Eco Labels

- Blue Angel, White Swan, Ecolabel etc.

IMPACT OF HALOGEN-FREE

- Resin Limitations
- Physical Properties
  - Strength/Impact
  - Flow
  - Heat Resistance
  - Resin Dependent
- Flammability
- Cost
- Reduction in Specific Gravity

30% GF NYLON 6/6

Mechanical Properties	RTP 205 FR	RTP 205 FR Halogen Free
Tensile Strength, psi	21000	19500
Tensile Modulus, psi E6	1.65	1.45
Tensile Elongation, %	2-4%	2-4%
Flexural Strength, psi	33000	31500
Flexural Modulus, psi E6	1.55	1.45
Impact Notched, ft-lb/in	2	1.8
Impact Un-notched, ft-lb/in	16	16
HDT @ 264 psi	470	470
Specific Gravity	1.66	1.41
Flammability	V-0 @ 1/32	V-0 @ 1/32

OVERVIEW

Thermoplastic Flammability

- Flame Retardant Additive Chemistries and Mechanisms

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INDUSTRY AND MARKET DRIVEN

Electrical and Electronics (E&E)

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

UL94 RATINGS

UL94 Ratings

HB

V-2

V-1

V-0

5VB

5VA

Ratings in order of difficulty to meet!

UL94 RATINGS

HB
- Handheld electronics
- Cell Phone

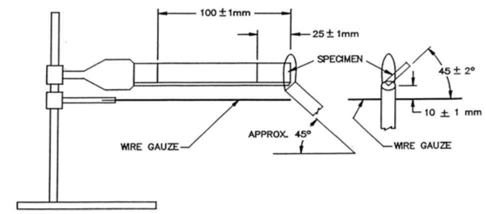
V-2
- Low-voltage, attended
- Electric shaver

V-1/V-0
- High-voltage, un-attended
- Electronic connectors

5VB/5VA
- Electronic enclosures

UL94 - HB

Horizontal burning test for HB classification



Classification Criterion

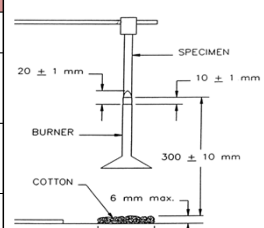
3.0 mm to 13.0 mm thickness
- *slower than 40 mm/minute or…*
- *combustion ceases prematurely*

< 3.0 mm thickness
- *slower than 75 mm/minute or…*
- *combustion ceases prematurely*

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

UL94 - VB

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



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

UL94 VERTICAL BURN DEMO

Flame Retardant – V-0

Non- Flame Retardant – No Rating

RTP COMPANY UL CERTIFICATION

RTP Company has 600+ UL Yellowcards
- Continuous expansion of UL listed products

UL Certified Laboratory under Client Test Data Program (CTDP)
- Short term properties to UL94
- Long term thermal aging (RTI)

RTP Company offers custom UL certifications to achieve full commercialization
- Quick turnaround
- Compress your Time to Market!

AEROSPACE

FAR 25.853
- **F**lammability:
  - 15-Second Horizontal Burn
  - 12-Second Vertical Burn
  - 60-Second Vertical Burn
- **S**moke Density:
  - Ds@4min <200
  - ABD0031 or BSS 7238 or ASTM E-662
- **O**hio **S**tate **U**niversity Heat Release:
  - Calorimetry Test Measures Peak and Total Heat Release
  - <100/100, <65/65, & <55/55 are common

OEM Driven Requirements
- **T**oxic Gas Emission:
  - Varies by OEM
  - ABD0031 or BSS 7239

Requirements vary by part size and location

BUILDING / INDUSTRIAL

- Requirements focus on:
  - Low Smoke, Heat Release, Burn Rate, Flame Spread
- Various standard that apply:
  - UL2043, UL723/ASTM E84, ASTM E1354, NFPA 701, FM 4996, CAL TB133
- Applications
  - Wall coverings, Furniture, Plenum, Pallets, Storage systems, Roofing, Floor coverings, Ventilation

RECAP

Designing for an FR application

Regulatory Landscape
- RoHS, Halogen Restrictions

Specifications
- UL94, FAR, ASTM, etc.

Part Function
- Performance Requirements, Application Environment, etc.

Economics
- Price is a Property

OVERVIEW

Thermoplastic Flammability

- Flame Retardant Additive Chemistries and Mechanisms

Regulatory Landscape

Testing Standards

Case studies

FR MEETS TRANSPARENCY

Market
Consumer

Application
LED Lens Cover

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

Solution
PC – Transparent, Flame retardant, Specialty pigment package

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

FR MEETS OUTDOORS / UV

Market
Consumer

Application
Marine Connector

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

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

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

FR BREAKS THROUGH THE CEILING

Market
Industrial

Application
Speaker Unit

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

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

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


COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR
Thank You!
Jesse Dulek
jdulek@rtpcompany.com
(507) 474-5502
rtpcompany.com • rtp@rtpcompany.com
ESP
Hueforia
Wiman

Live in the Wall Section: Product Design Principles for Structural Composites

Barbara Matousek | CAE Analyst
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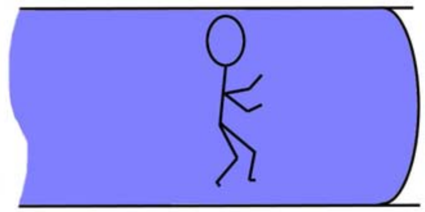
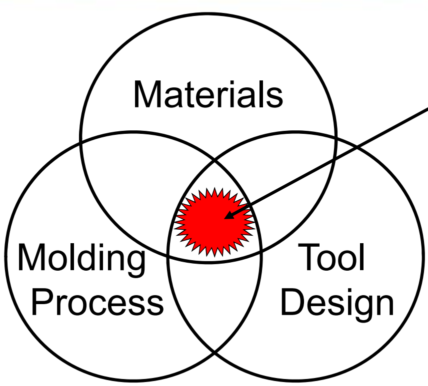
12:45 p.m.



Live in the Wall Section

DESIGN FOR INJECTION MOLDING



WHAT WE WILL COVER

- Material Issues/Concerns with Structural Composites
- Part Design Guidelines – Common Mistakes
- Warpage
- Structural Failures

AMORPHOUS VS. SEMI-CRYSTALLINE

Random Structure	Ordered Structure
Broad Melting Point	Sharp Melting Point
Often Solvent Sensitive	Solvent Resistant
Impact Resistant	Fatigue Resistant
Low Shrink	High Shrink
Better Dimensional Stability	More Difficult Dimensional Control

AMORPHOUS VS. SEMI-CRYSTALLINE

ABS	Acetals
PC	Nylons
Polystyrene	Polyesters (PET, PBT)
Thermoplastic Urethanes	PP
PSU	PE
PEI	PEEK

LIVE IN THE WALL SECTION

Many plastics are anisotropic

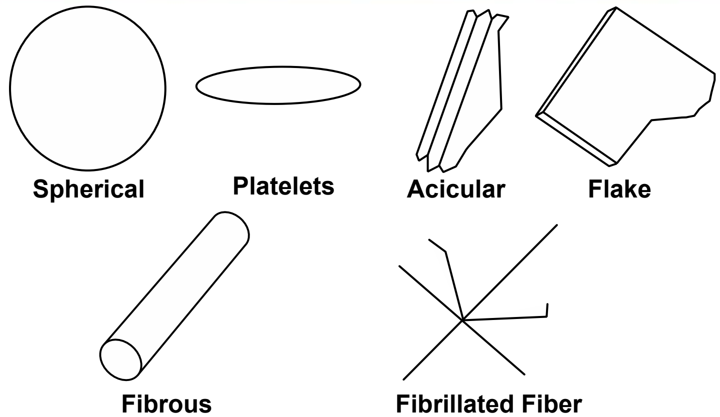
Plastics are non-Newtonian

ISOTROPIC VS. ANISOTROPIC

Isotropic: Material properties (including shrink) are **uniform** in flow and cross-flow direction

Anisotropic: Material properties (including shrink) are **not uniform** in every direction

FILLER & REINFORCEMENT GEOMETRY



FILLER/REINFORCEMENT CLASSIFICATION

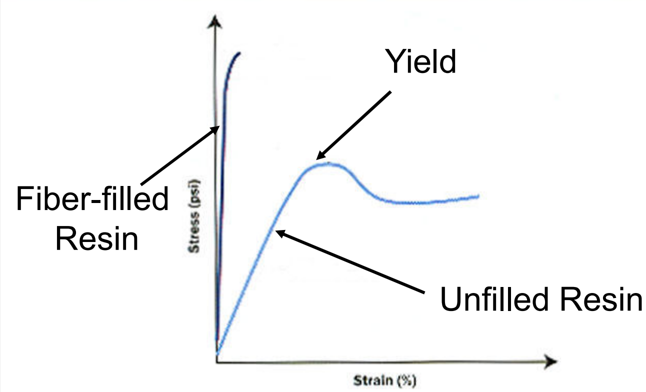
Type	Geometry	Aspect Ratio	Classification
Glass Beads	Spherical	1	Filler
Clay	Platelet	1-3	Filler
Calcium Carbonate	Platelet	1-3	Filler
Talc	Platelet	2-5	Filler
Wollastonite	Acicular	5-20	Transition
Mica	Flake	30-50	Transition
Milled Glass	Fibrous	10-50	Transition
Glass Fiber	Fibrous	50+	Reinforcement
Carbon Fiber	Fibrous	50+	Reinforcement
Nickel Coated Carbon Fibers	Fibrous	50+	Reinforcement
Stainless Steel	Fibrous	50+	?
Aramid	Fibrillated Fiber	50+	Reinforcement

PROPERTIES AFFECTED BY ADDITIVES

Tensile Strength
Impact Strength

Specific Gravity
Viscosity
Thermal Conductivity
Specific Heat
Shrinkage

STRESS-STRAIN OF POLYMERS



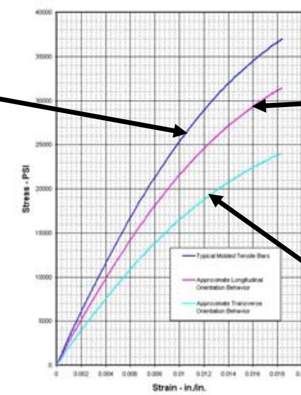
STRESS-STRAIN OF POLYMERS

Dilemma:

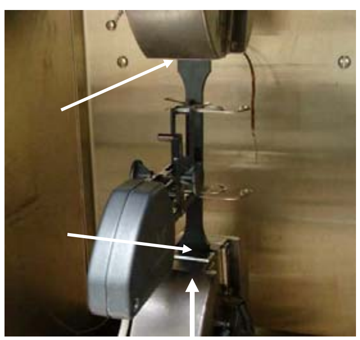
Fiber filled materials are not isotropic.

How do we account for this variation in mechanical properties during design?

BI-DIRECTIONAL STRESS-STRAIN



BI-DIRECTIONAL STRESS-STRAIN



FEA OF FILLED POLYMERS

Recommendations:

When possible do analysis that considers fiber orientation – Moldflow followed by FEA.

For FEA that doesn't use flow simulation inputs, use **60-80% of the modulus/strength** to account for property variations.

VISCOSITY OF POLYMERS

Plastics are non-Newtonian.

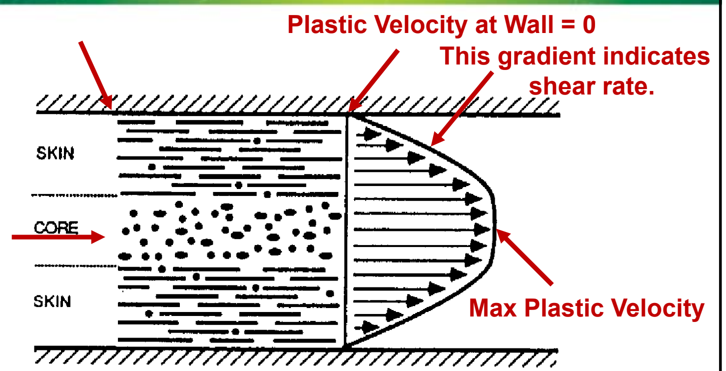
Viscosity varies not only with temperature but with shear rate.

WHAT IS SHEAR RATE?

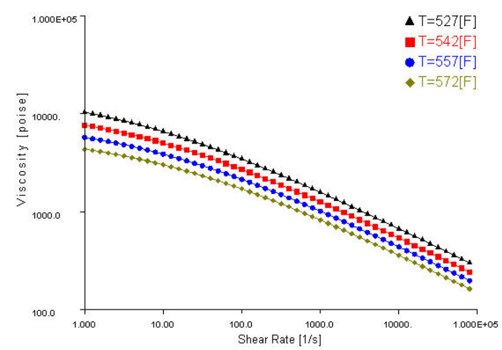
Shear: Friction between moving plastic and the mold wall

Shear Rate: Velocity gradient in a flowing material

INJECTION MOLDING PROCESS



VISCOSITY OF POLYMERS



VISCOSITY OF POLYMERS

Important things that will affect viscosity:

- Wall Thickness
- Velocity
- Temperature

LIVE IN THE WALL SECTION

Many plastics are anisotropic.

Plastics are non-Newtonian.

WHAT WE WILL COVER

- Material Issues/Concerns with Structural Composites
- **Part Design Guidelines – Common Mistakes**
- Warpage
- Structural Failures

COMMON PART DEFECTS

- Hesitation/Partialling
- Air/Gas Traps
- Weld Lines

Related to Fill Pattern

- Warpage
- Sinks and Voids
- Structural Weakness or Failure

COMMON PART DEFECTS

- Hesitation/Partialling
- Air/Gas Traps
- Weld Lines
- Warpage
- Sinks and Voids
- Structural Weakness or Failure

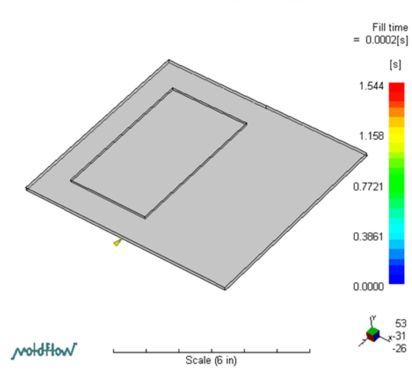
Related to Fill Pattern, Cooling, and Packing

COMMON PART DEFECTS

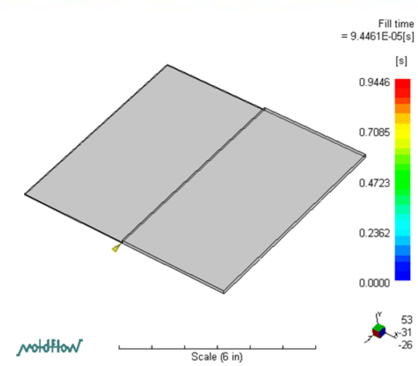
- Hesitation/Partialling
- Air/Gas Traps
- Weld Lines
- Warpage
- Sinks and Voids
- Structural Weakness or Failure

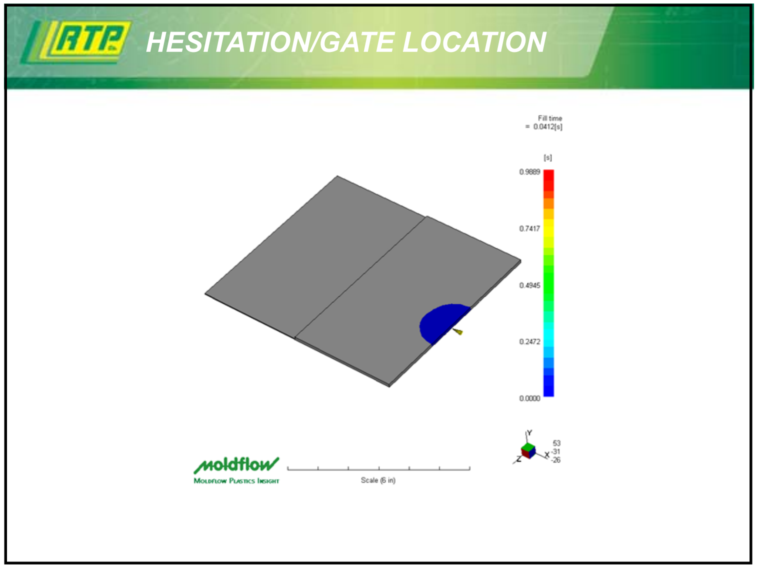
Related to Cooling and Wall Thickness

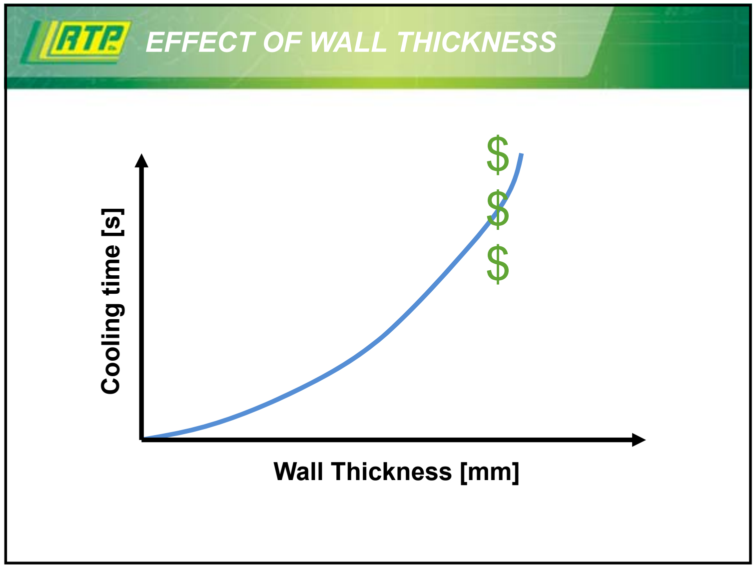
HESITATION/RACETRACKING

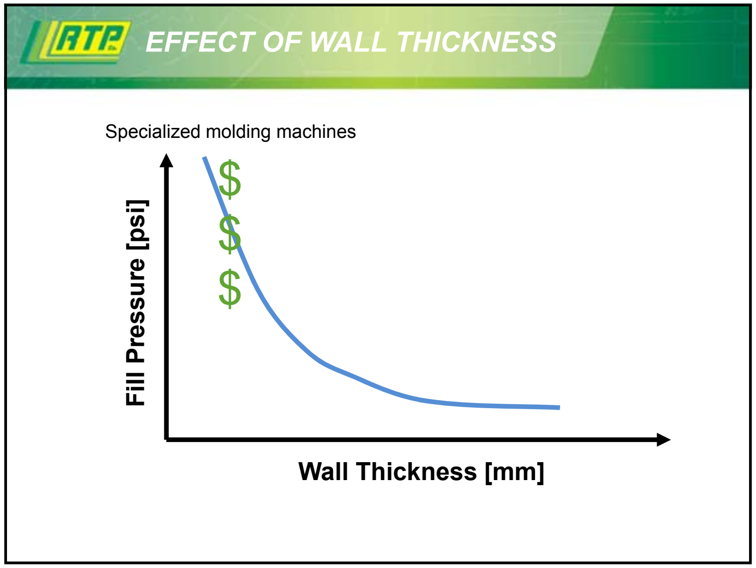


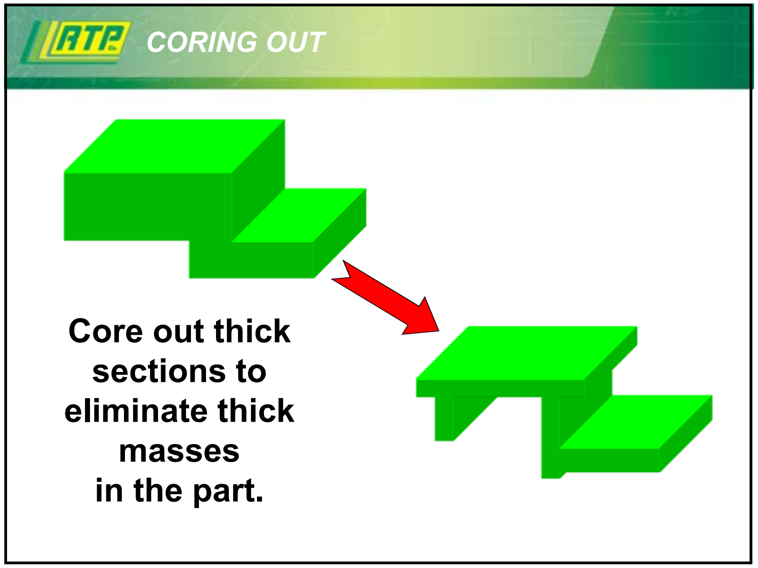
HESITATION/GATE LOCATION



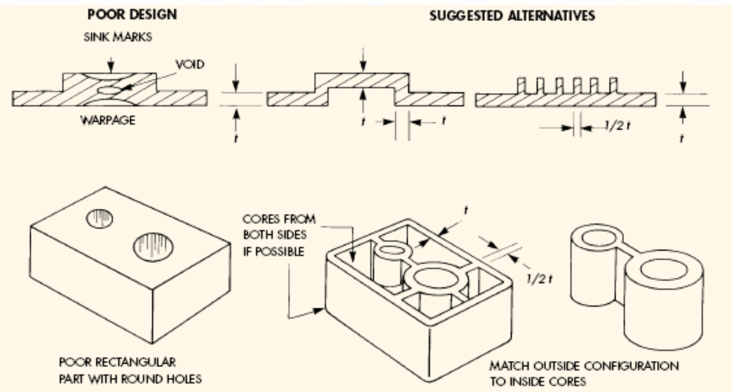

RTP
HESITATION/GATE LOCATION
Fill time
= 0.0412[s]
[s]
0.9889
0.7417
0.4945
0.2472
0.0000
moldflow
Scale (6 in)


RTP
EFFECT OF WALL THICKNESS
$
$
$
Cooling time [s]
Wall Thickness [mm]


RTP
EFFECT OF WALL THICKNESS
Specialized molding machines
$
$
$
Fill Pressure [psi]
Wall Thickness [mm]


RTP
CORING OUT
Core out thick
sections to
eliminate thick
masses
in the part.

"CORE OUT" - EXAMPLES



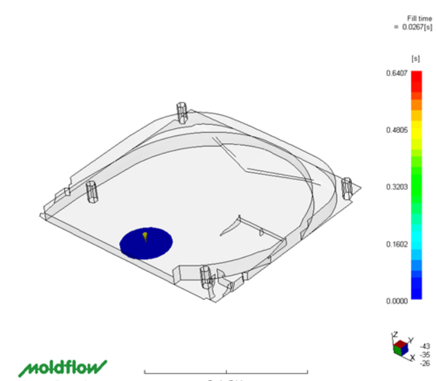
PART DESIGN GUIDELINES

- Keep nominal wall < 5mm (0.200")
- Avoid large variations in thickness
- Avoid abrupt changes in thickness
- Make thickness transitions gradual to avoid stress concentrations

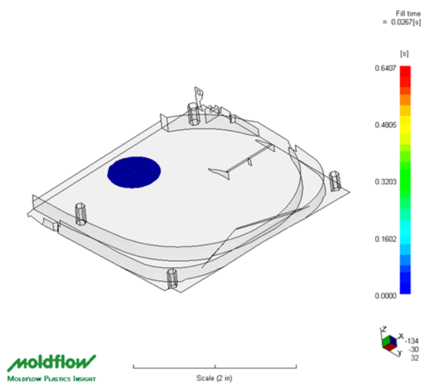
PART DESIGN GUIDELINES

- Constant nominal wall simplifies fill pattern
- Constant nominal wall minimizes stress and warp
- Avoid gating near areas with thickness variation

EXAMPLE

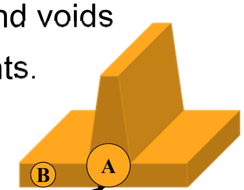


EXAMPLE



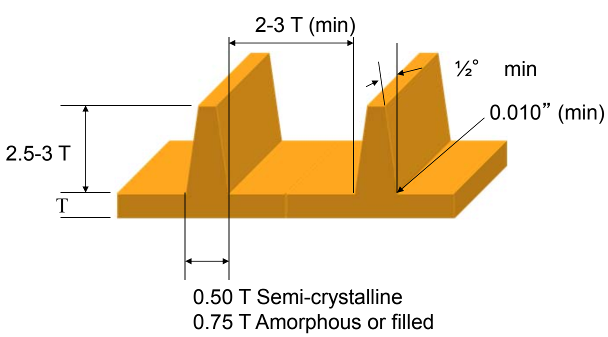
SINKS AND VOIDS

- Sinks and voids are both caused by wall sections that are too thick.
- Sinks are cosmetic flaws and voids can be structural weak points.

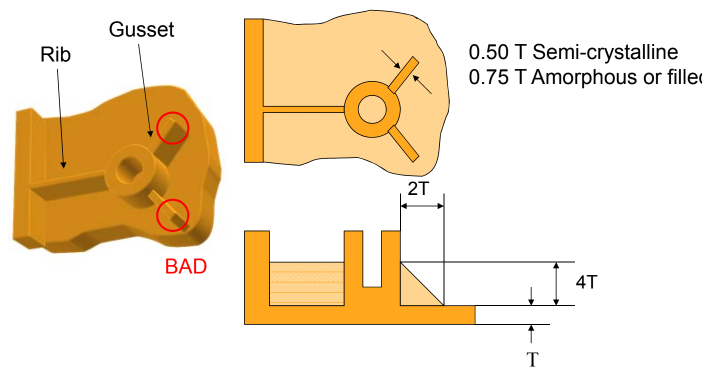


Sink or void

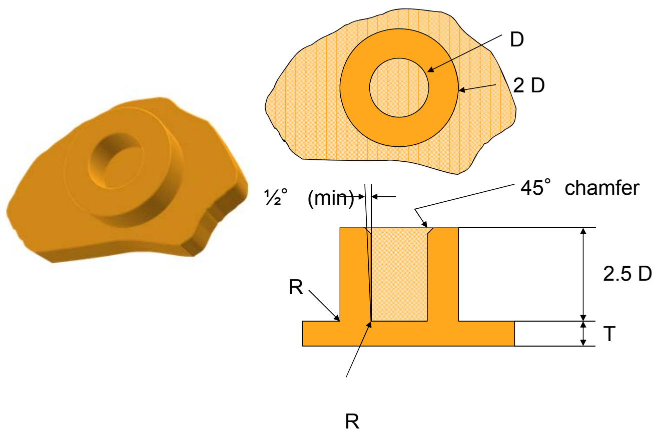
RECOMMENDED RIB DESIGN



RECOMMENDED GUSSET DESIGN



RECOMMENDED BOSS DESIGN



WHAT WE WILL COVER

- Material Issues/Concerns with Structural Composites
- Part Design Guidelines – Common Mistakes
- **Warpage**
- Structural Failures

WARPAGE

- Shrinkage itself doesn't cause warp.
- Warp is caused by **variations** in shrinkage.

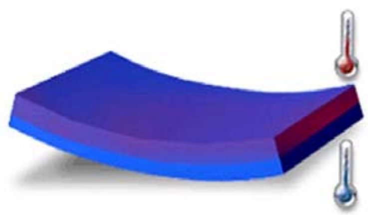
WARPAGE

Three Primary Causes

1. Non-uniform Cooling
2. Orientation Effects
3. Differential Area Shrinkage

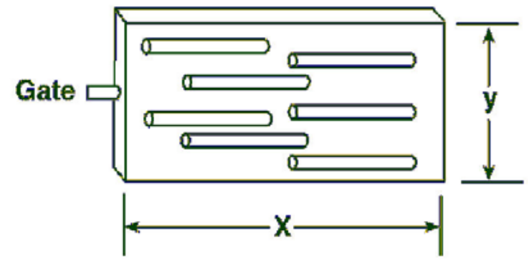
NON-UNIFORM COOLING

When the mold is hotter on one side than on the other side, the hotter side will take longer to cool so it will shrink more.



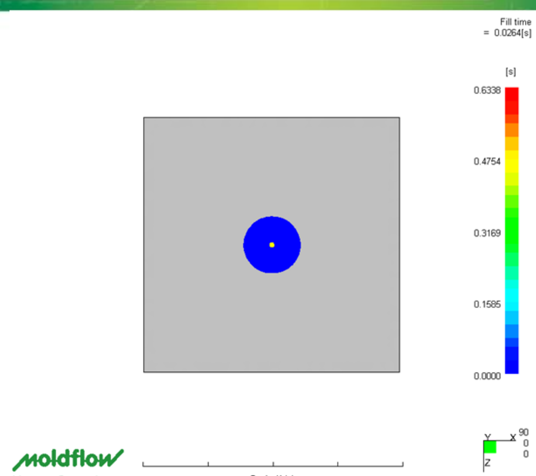
ORIENTATION EFFECTS

Some plastics shrink differently in the direction of flow than across flow.

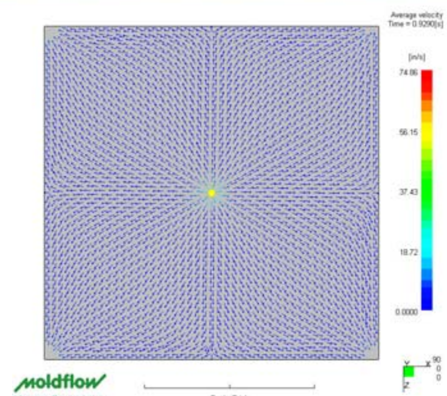


Shrink Rate x $\neq$ Shrink Rate y

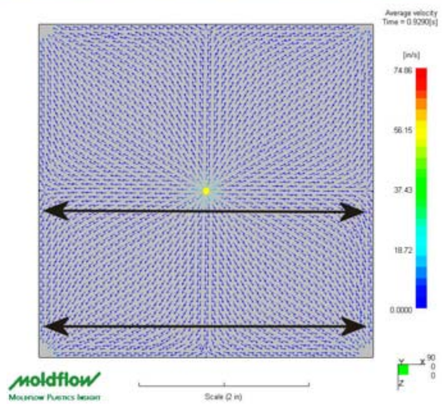
ORIENTATION EFFECTS



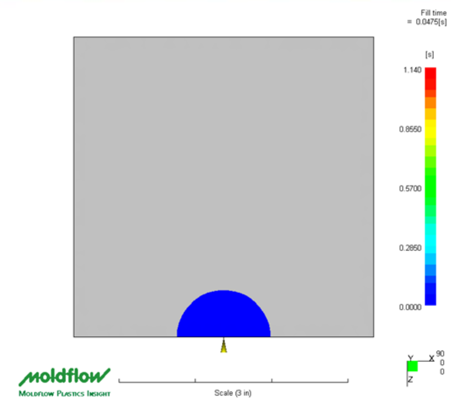
ORIENTATION EFFECTS



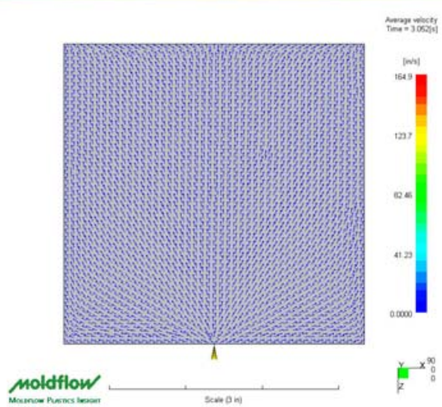
ORIENTATION EFFECTS



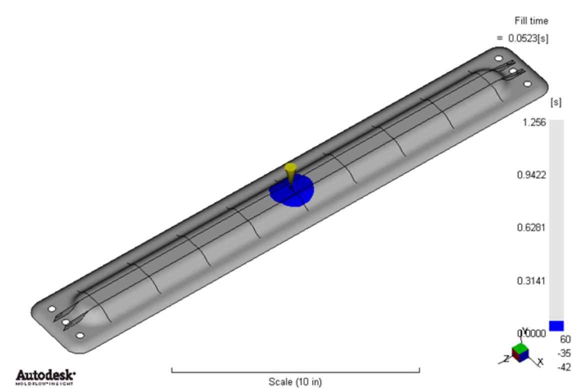
ORIENTATION EFFECTS



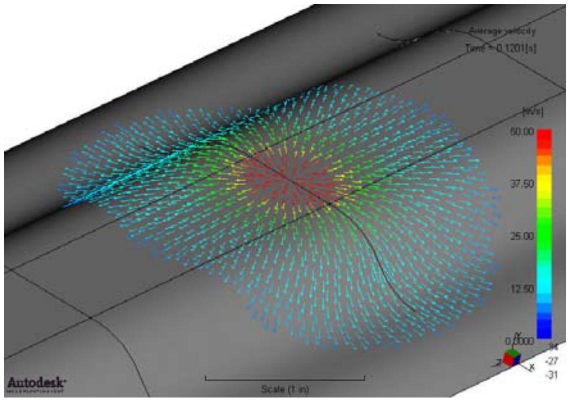
ORIENTATION EFFECTS



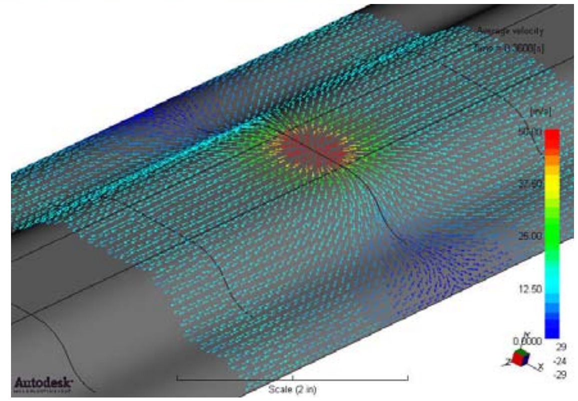
ORIENTATION EFFECTS



ORIENTATION EFFECTS



ORIENTATION EFFECTS



ORIENTATION EFFECTS

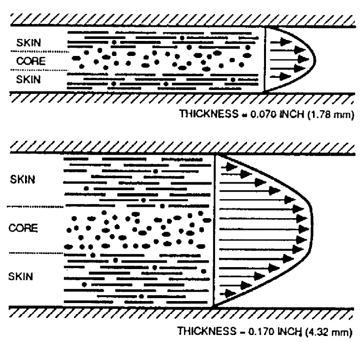
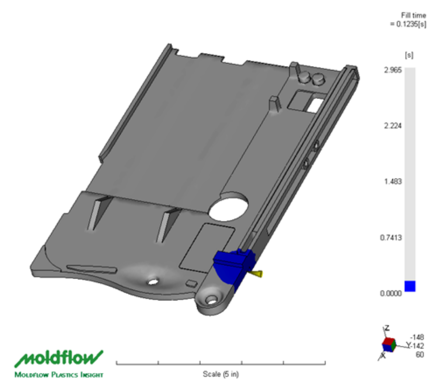
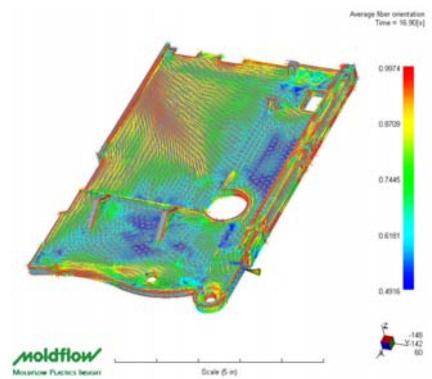


FIGURE 1 VELOCITY PROFILES AND THE RESULTING FIBER ORIENTATION

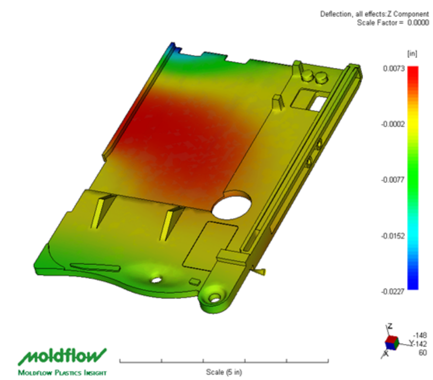
ORIENTATION EFFECTS EXAMPLE



ORIENTATION EFFECTS EXAMPLE



ORIENTATION EFFECTS EXAMPLE



EXAMPLE CONCLUSIONS

- Primary cause of warp is orientation due to a non-uniform fill pattern
- Different gate location will not improve the fill pattern or improve orientation warp
- Reducing the warp will require either major part design changes or a material change

DESIGN TO AVOID ORIENTATION EFFECTS

- Uniform wall thickness to allow simple fill pattern
- No major thin sections that could result in hesitation or racetracking

REDUCING ORIENTATION EFFECTS

- Gate for the most uniform flow
- Adjust molding conditions (often higher temps and faster injections will help)
- Adjust wall thickness
- Use more uniformly shrinking material (or sometimes a lower viscosity material)

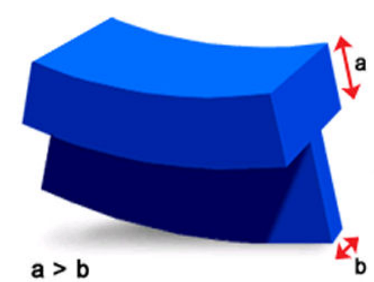
DIFFERENTIAL AREA SHRINKAGE

- Variations in **cooling rate** result in variations in shrinkage
- Slower cooling results in higher crystallinity and more shrink
- Faster cooling results in less crystallinity and less shrink

DIFFERENTIAL AREA SHRINKAGE

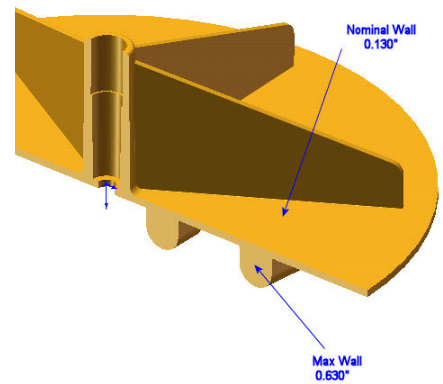
- Thick walls take longer to cool than thin walls resulting in non-uniform shrink
- More densely packed areas take longer to cool resulting in non-uniform shrink

DIFFERENTIAL AREA SHRINKAGE

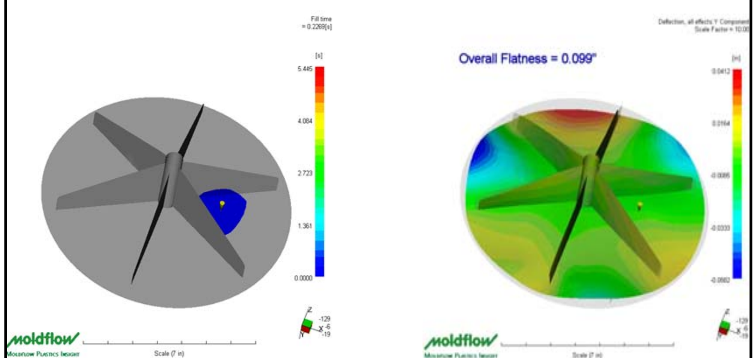


DIFFERENTIAL AREA SHRINKAGE EXAMPLE

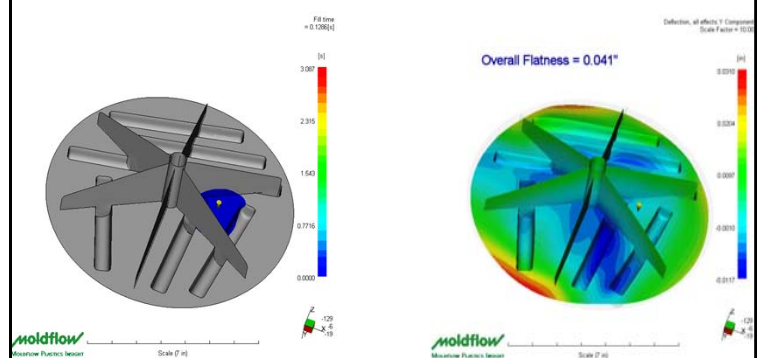
DIFFERENTIAL AREA SHRINKAGE EXAMPLE



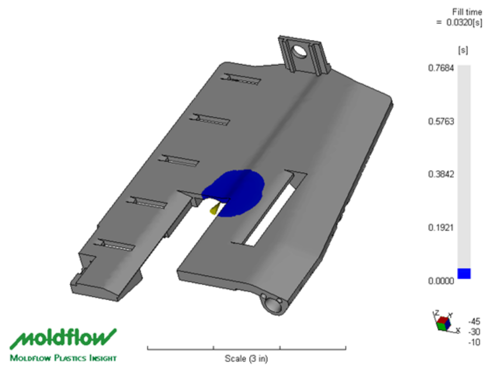
DIFFERENTIAL AREA SHRINKAGE EXAMPLE



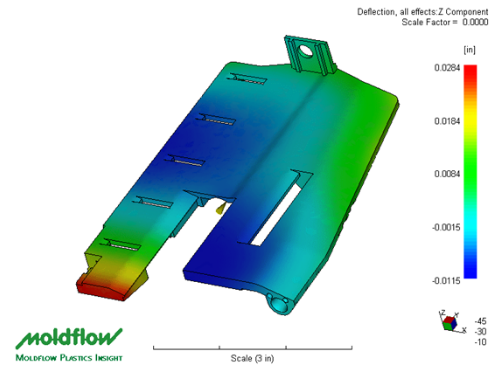
DIFFERENTIAL AREA SHRINKAGE EXAMPLE



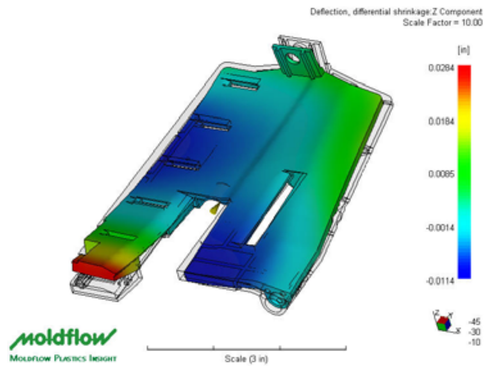
ORIGINAL GATE LOCATION – FILL PATTERN



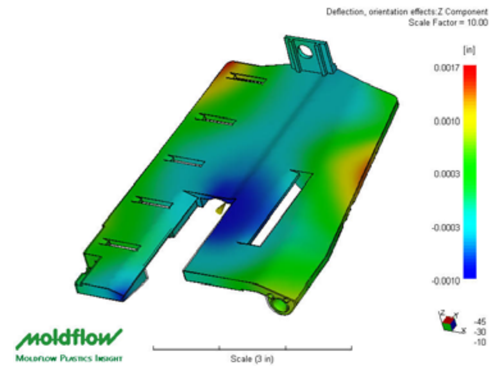
ORIGINAL GATE LOCATION - WARP



WARP DUE TO DIFFERENTIAL SHRINKAGE



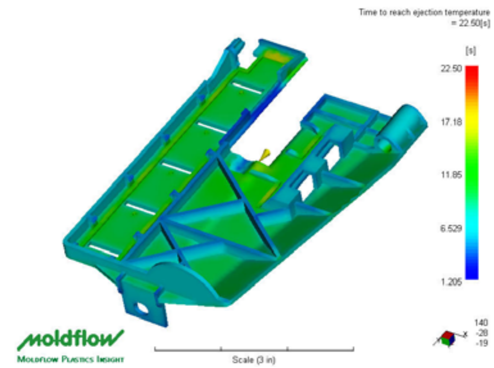
WARP DUE TO ORIENTATION EFFECTS



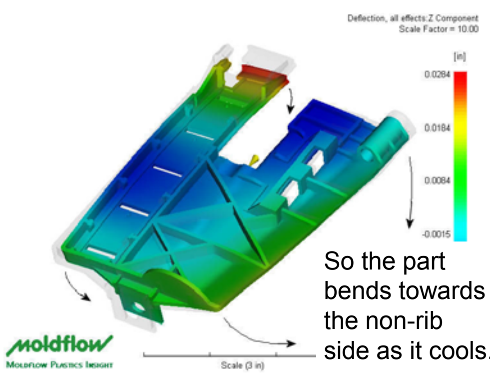
CONCLUSION

The primary cause of the warp is differential shrinkage.

EXPLANATION OF DIFFERENTIAL SHRINKAGE

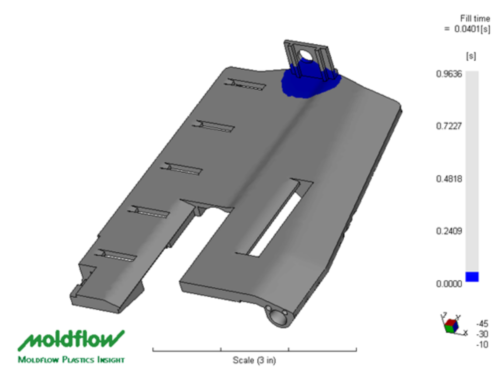


EXPLANATION OF DIFFERENTIAL SHRINKAGE

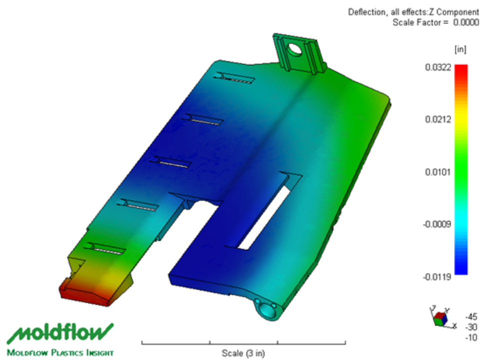


So the part bends towards the non-rib side as it cools.

OPPOSITE GATE LOCATION – FILL PATTERN



OPPOSITE GATE LOCATION - WARP



CONCLUSIONS

- The primary cause of the warp is differential shrinkage due to wall thickness variations
- A different gate location will improve the fill pattern but it will not improve differential shrinkage warp
- Wall thickness changes and packing pressure profiles may reduce warp

PART DESIGN TO AVOID DIFFERENTIAL SHRINKAGE

- Uniform wall thickness to allow uniform cooling rate
- Balance thin ribs onto both sides of nominal wall

REDUCING DIFFERENTIAL AREA SHRINKAGE

- Uniform wall thickness
- Lower shrink materials
- Adjust the wall thickness/rib structure
- Packing profile during molding
- Tooling inserts such as beryllium copper
- Move gate to allow packing of thick areas

WHAT WE WILL COVER

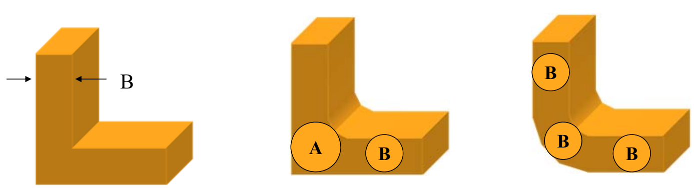
- Material Issues/Concerns with Structural Composites
- Part Design Guidelines – Common Mistakes
- Warpage
- **Structural Failures**

STRUCTURAL WEAKNESS OR FAILURES

Mechanical failures happen when the **loading** of the part **exceeds the capability of the material** in a specific area

COMMON STRUCTURAL FAILURES

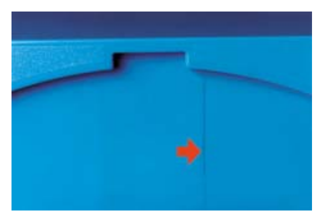
- Stress concentrators (such a sharp edges or corners)

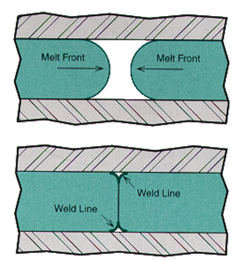


High stresses/warpage potential | Better…but | Best

COMMON STRUCTURAL FAILURES

- Stress concentrators (such a sharp edges or corners)
- Weld lines





COMMON STRUCTURAL FAILURES

- Stress concentrators (such a sharp edges or corners)
- Weld lines
- Poor fiber orientation
- Poor properties due to voids
- Wrong material

DESIGN TO AVOID STRUCTURAL FAILURES

- Work with material supplier
- Radius corners and edges
- Thicker is not always better
- Gate to allow flow that orients fiber in the principal direction of the structural load

OTHER STRUCTURAL CONSIDERATIONS

- Fatigue
- Creep
- Moisture, UV, temperature and other environmental concerns

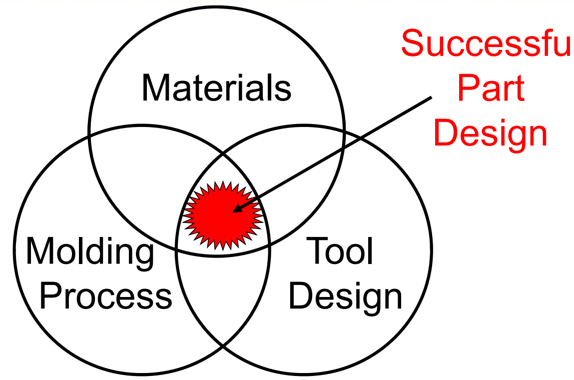
OTHER TOOLING CONSIDERATIONS

- Draft
- Surface Finish
- Undercuts
- Venting

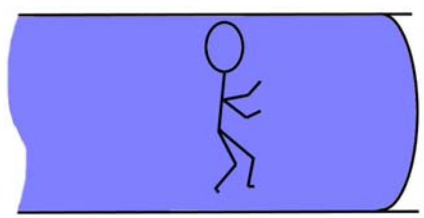
SUMMARY

- Understand your material needs and understand the material
- Design parts with relatively uniform wall thickness
- Keep the fill pattern simple

DESIGN FOR INJECTION MOLDING



Live in the Wall Section!



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

RTP Co.
Imagineering Plastics®

Taking Charge of Resistivity: An Introduction to Conductive Plastics Technology

Steve Maki | VP of Technology
smaki@rtpcompany.com
(507) 474-5371

1:45 p.m.

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

Taking Charge of Resistivity: An Introduction to Conductive Plastics Technology

Steve Maki
Vice President Technology

rtpcompany.com • rtp@rtpcompany.com

OVERVIEW

Conductive Classification and Testing

Overview of Conductive Modifiers

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

More Specialized Technology

- EMI Shielding

Wrap Up and Questions

CONDUCTIVE CLASSIFICATION

Antistatic

- Cleanliness
- Prevent Dirt & Dust build up

Static Dissipative

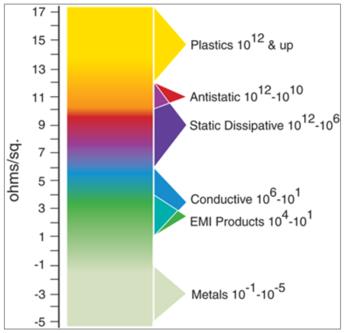
- Protect Delicate Electronics
- Prevent Explosions

Conductive (Current-Carry Devices)

- Electrical Contacts
- Electrical Circuits

Shielding

- Provide Protection against RFs



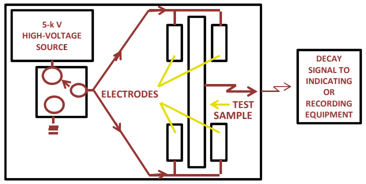
STATIC DECAY TESTING

Static Decay Rate

- Measures seconds to decay
- 5000V to 50V
- 12% Relative Humidity

Standards/Specifications

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



SURFACE TESTING

Surface Resistivity (ohms/square)

Surface Resistance (ohm)

Standards/Specifications

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

SURFACE RESISTIVITY TEST

- Small Samples
- Irregular Part Shapes
- In-Field Test
- Units = ohms/square

Voyager SRM-110

SURFACE RESISTIVITY TEST

Guarded Ring Electrode

Flat Specimen

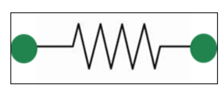
Precise Measurement

Units = ohms/square

SURFACE RESISTANCE TEST

Surface Resistance Meter

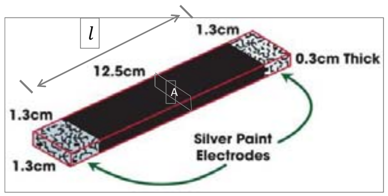
- Point to Point
- Measuring small & critical areas on part
- Units = ohm



VOLUME RESISTIVITY TEST

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

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



Units = ohm-cm
ASTM D-257

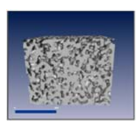
OVERVIEW

- Conductive Classification and Testing
- **Overview of Conductive Modifiers**
  - Migratory Anti-Stats
  - Inherently Dissipative Polymers
  - Carbon (Powder, Fiber, Nanotubes)
- More Specialized Technologies
  - EMI Shielding
  - Thermal Conductivity
- Wrap Up and Questions

CONDUCTIVE MODIFIERS

Migratory Antistats

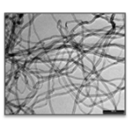
Inherently Dissipative Polymers (IDPs)



Carbon Black

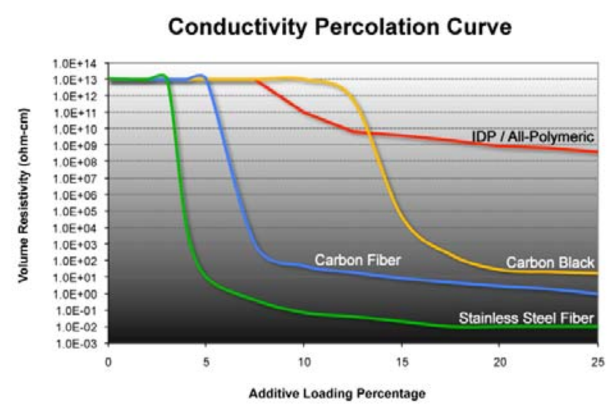
Carbon Fiber

Carbon Nanotubes



Metallic Additives

PERCOLATION CURVE



MIGRATORY ANTI-STATIC AGENTS

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

INHERENTLY DISSIPATIVE POLYMERS (IDP)

All-polymeric, based on IDP

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

Over 20 different resin systems

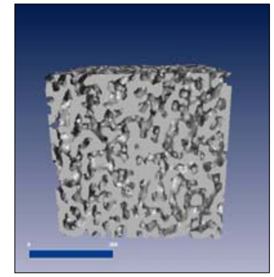
- Limited process temps (< 520 ºF)

Surface resistivity

- Standard: 1010 to 1012 ohm/sq
- PLUS: 108 to 109 ohm/sq

Static decay rate

- Standard < 2.0 s
- PLUS < 0.5 s



PermaStat®

PERMASTAT® TECHNOLOGY BENEFITS

- Permanent ESD protection – not dependent on migration, humidity or temperature
- Clean Technology – non sloughing with FDA and Biocompatible grades available
- Transparent grades available and fully colorable
- Base resin properties retained
- PermaStat PLUS® can meet ATEX requirements

TYPICAL APPLICATIONS

Reticle Boxes
ABS, PMMA

Inhalers
ABS, PP, PMMA

Gas Cap
POM

ATEX IBC
PE

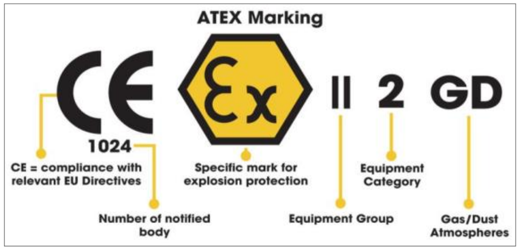
WHAT IS ATEX?

ATMOSPHERE EXPLOSIVE

- Potentially explosive environments

Began as a European Directive

- Standardize compliance procedure
- Now seen in US and other countries (IECEx)



ATEX TESTING

Actual requirements defined by customer

All tests are on actual parts

Tests could include:

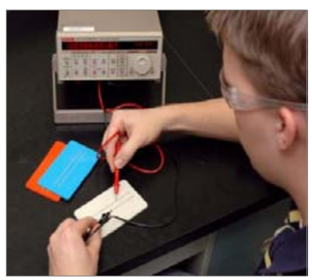
- Surface Resistance (almost always included)
- Relative Thermal Index (RTI)
- Chemical Resistance
- Impact (Low temperature)
- Ultra Violet (UV)
- High Humidity Aging Testing
- Flame Retardant (FR)

Need to fully identify all requirements for proper material selection

ATEX SURFACE RESISTANCE

Specific test

- Isolation resistance <1 Gohm at 50% R.H.
- Tested at 500 V



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

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

No real correlation

ATEX MARKETS

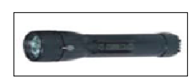
Mining

Personal protective equipment

Food, chemicals, and paint industries

Hand-held equipment

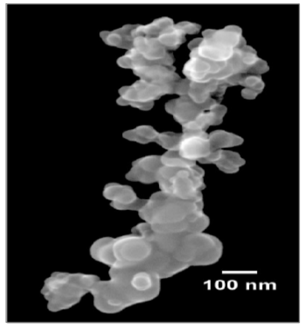
Industrial equipment
(pneumatic, hydraulic, venting systems, pumps)



CONDUCTIVE CARBON BLACK

Characterized by:

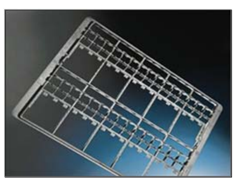
- Structure
- Size of particles
- Porosity
- Surface Chemistry



CONDUCTIVE CARBON BLACK

- Permanent
- Black color only
- Sloughing / Marking / Crayoning
- Economical
- Dissipative or conductive
  - SR 10^3 to 10^9 ohm/sq
  - VR 10^0 to 10^6 ohm-cm

CARBON BLACK APPLICATIONS



Electronic device trays
PP, PS, PC

Pipette tips
PP

Storage bins & totes
PP

Fuel filler tubes
PE

CARBON / GRAPHITE FIBER

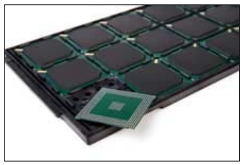
- Non-sloughing
- Colorable
- Anisotropic shrinkage
- Reinforcing
- Dissipative or conductive
  - SR 10^2 to 10^6 ohm/sq
  - VR 10^{-1} to 10^4 ohm-cm

Chopped Fiber
¼" long "bundles"

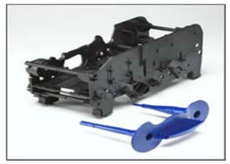
Milled Fiber
pulverized

CARBON FIBER APPLICATIONS

Full Line components
PPA, Nylon, Acetal



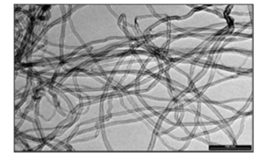
Chip transport/Storage trays
PC, PSUL, PES

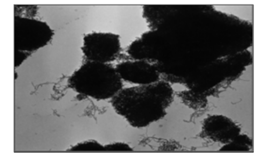


Card printer chassis
PC

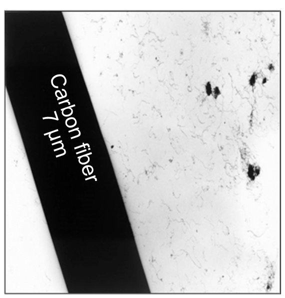
CARBON NANOTUBES (CNT)

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





CNT SIZE DIFFERENCE



A carbon fiber surrounded by CNTs

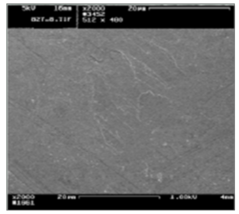
PRIMARY BENEFITS OF CNTS

- **Uniform electrical conductivity** – prevent hot spots and protect sensitive electronics
- **Effective at low loadings** – clean product with low SG and good surface finish
- **Isotropic Properties** – non reinforcing, behaves like neat resin
- **Ability to use regrind** – maintains conductivity with additional processing

ELECTRICAL CONDUCTIVITY

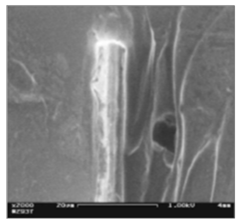
SEM (2000x) of typical CNT compound

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

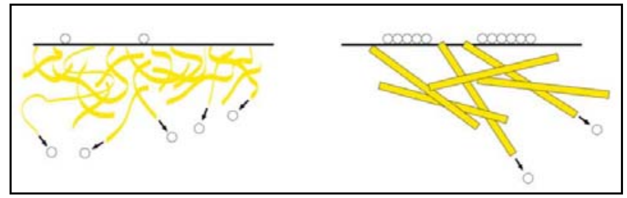


SEM (2000x) of typical CF compound

- Rough surface finish
- White shading indicates a point of high conductivity - "Hot spot"
- Possible conductive particle generation site



HOT SPOTS

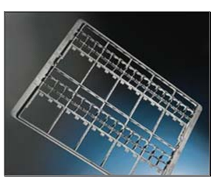


CNT CF

- Fewer Hot Spots
- Lower Voltage Retention
- Reduced Tribocharging

ELECTRONICS INDUSTRY APPLICATIONS

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



Trays

Wafer Caddy

HDD

OVERVIEW

Conductive Classification and Testing

Overview of Conductive Modifiers

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

More Specialized Technology

- EMI Shielding

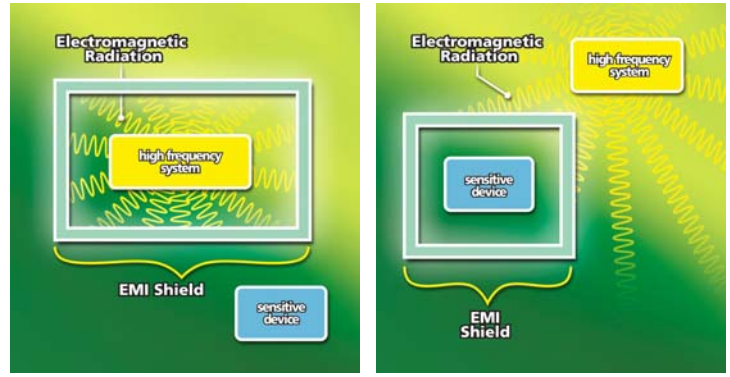
Wrap Up and Questions

EMI SHIELDING

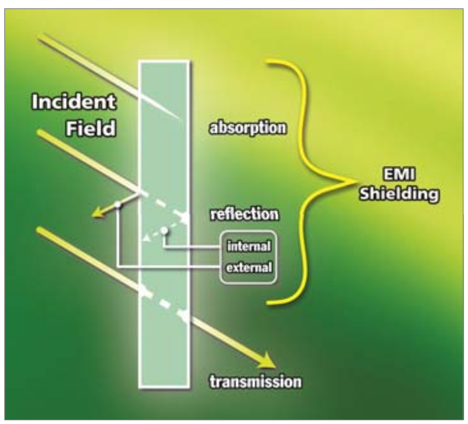
- **E**lectro**M**agnetic **I**nterference = EMI
- Emitted from a source *or* Received by a device
- Frequency range of 1 kHz to 10 GHz
- Faraday Cage Principle:
  - Barrier that reflects or conducts signals to ground
- Shielding provides “Immunity”

EMI IN ACTION

EMI shields protect sensitive devices



EMI IN ACTION



EMI SHIELDING FILLERS

Electrically Conductive modifiers:

- Carbon Powder
- Carbon fiber
- Graphite
- **Stainless steel fiber**
- **Nickel-coated carbon fiber**
- Other metallic additives

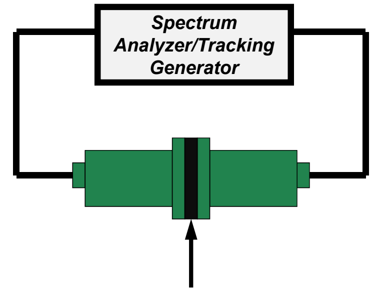
ADDITIVE COMPARISON

Stainless Steel Fiber
- Non-Reinforcing
- Equivalent shrinkage to neat resin
- Moderate shielding performance
- Colorable

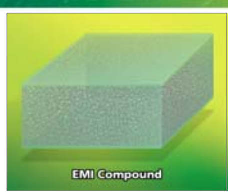
Nickel-Coated Carbon Fiber
- Reinforcing
- High shielding performance
- Higher cost
- Less colorable

COAXIAL TRANSMISSION LINE TEST

- ASTM D 4935
- Direct Measurement on Flat Specimens
- Fast and Repeatable
- Relative Ranking
- Frequency range of 30 MHz to 1.5 GHz
- Units = Decibels of SE

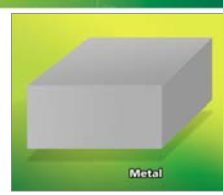


REVIEW OF SHIELDING OPTIONS



- VR is key parameter
- SR is misleading
- SE dependent on filler loading and wall thickness
- Easily Grounded

- SR key parameter
- Other surfaces insulative
- SE depends on coating conductivity & thickness
- Care in grounding required
- Can flake or chip off



- Uniform Conductivity
- SR easily measured
- Easily grounded
- Design limitations

EMI APPLICATIONS

Shielding gasket
TPO/SS

Motor Housing
PC/NCCF

CONDUCTIVE MODIFIERS: PROS AND CONS

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

Imagineering Plastics ®

Wear in the World of Plastics

Ben Gerjets | Product Development Engineer
bgerjets@rtpcompany.com
(507) 474-5381

2:30 p.m.

WEAR AND FRICTION

"My application is wearing out!"

Fatigue?

?

Chemical Attack?

?

Abrasion?

?

Weather/UV Resistance?

?

WEAR AND FRICTION

WEAR AND FRICTION

Be Specific!

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

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

Internally Lubricated Thermoplastics

AGENDA

I. **Wear Definitions & Test Methods**

II. Friction Definitions & Test Methods

III. Additive Technologies

IV. Application Examples

V. Extreme Conditions – Ultra Wear

WEAR DEFINITIONS

Tribology

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




WEAR DEFINITIONS

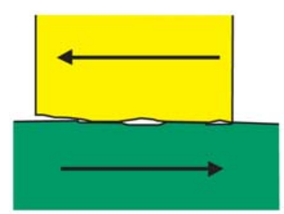
Recall: Sliding surfaces

Wear = Loss of material over time

WEAR DEFINITIONS

Adhesive Wear Mechanism

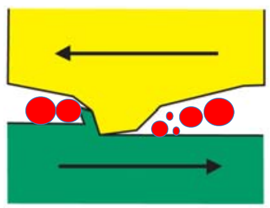
- The primary mechanism for thermoplastic wear
- Characterized by transfer of material from one part to the other caused by frictional heat



WEAR DEFINITIONS

Abrasive Wear Mechanism

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



WEAR TESTING

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

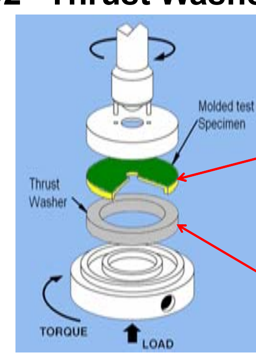
Answer: RTP uses **ASTM D-3702** wear test to quantify the amount of material a sample loses over time under specific conditions (pressure, speed, temperature)

WEAR TESTING

ASTM D-3702 "Thrust Washer" Wear Test

Adjustable:

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



Rotating
Molded or machined sample

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

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

WEAR TESTING

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

WEAR TESTING

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

Lower Value = Better Wear Resistance!

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

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

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

F = Force: *lb or N*

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

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

WEAR TESTING

Standard Conditions:

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

PV = (Pressure · Velocity)

Conditions often used together to characterize severity of a wear environment

2,000 PV = (40 psi · 50 ft/min)

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

WEAR TESTING

RTP Wear Brochure

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

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

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

WEAR TESTING

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

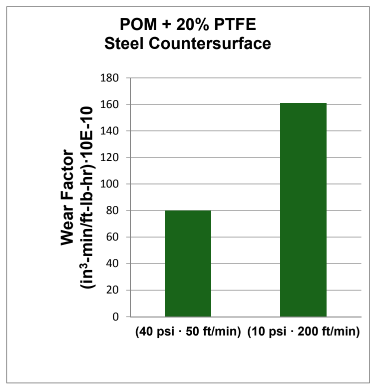
Standard Conditions: PV = 2,000

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

Non-Standard Conditions: PV = 2,000

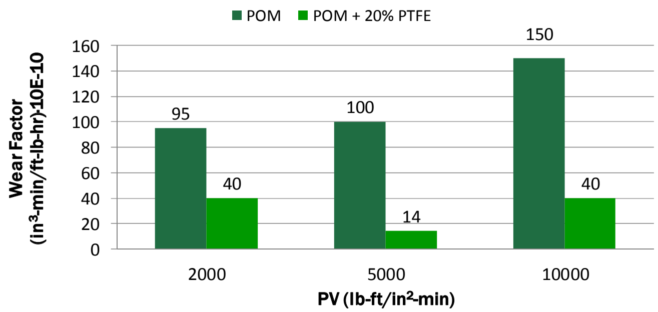
- P = 10psi
- V = 200 ft./min

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



WEAR TESTING

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



Wear per ASTM D 3702 against C1018 Steel

AGENDA

I. Wear Definitions & Test Methods

II. Friction Definitions & Test Methods

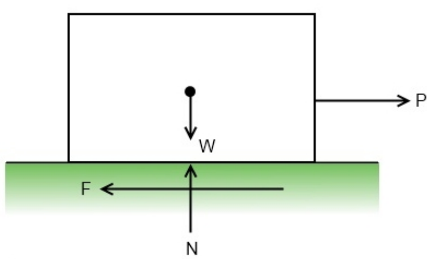
III. Additive Technologies

IV. Application Examples

V. Extreme Conditions – Ultra Wear

FRICTION DEFINITIONS

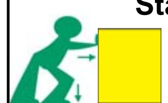
Coefficient of Friction (μ)
Ratio of the force of friction between two bodies and the force pressing them together



$\mu = F/N$

FRICTION DEFINITIONS

Coefficient of Friction (μ)



Static coefficient of friction (μ_s) = Fx/Fy
Fx = Force to *initiate* motion
Fy = Normal force holding surfaces together

Dynamic coefficient of friction (μ_k) = Fx/Fy
Fx = Force to *sustain* motion
Fy = Normal force holding surfaces tog

FRICTION DEFINITIONS

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

FRICTION TESTING

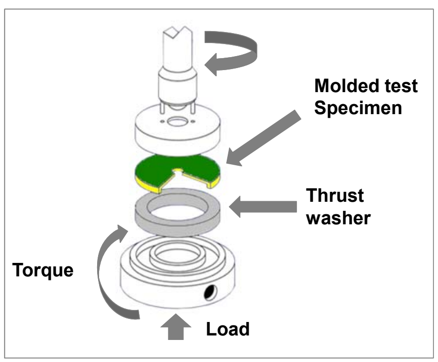
ASTM D 1894 "sled test"

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

FRICTION TESTING

RTP Modified ASTM D3702 Friction Test

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



TESTING REVIEW

Question: How does RTP measure wear resistance?
Answer: ASTM D3702 Thrust Washer wear test; Wear Factor (K)

Question: How does RTP measure Friction?

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

Answer 2: Modified ASTM D3702 Thrust washer friction test.
(Glide Factor[SM])

AGENDA

I. Wear Definitions & Test Methods

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ADDITIVE TECHNOLOGIES

ADDITIVE TECHNOLOGIES

PTFE – Polytetrafluoroethylene (5-20%)

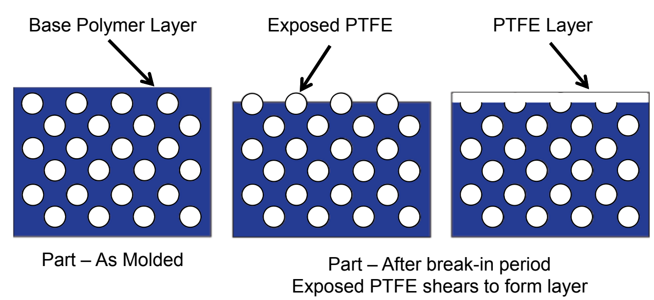
- Workhorse additive – solid white powder
- Compatible with nearly all thermoplastic resins

Limitations

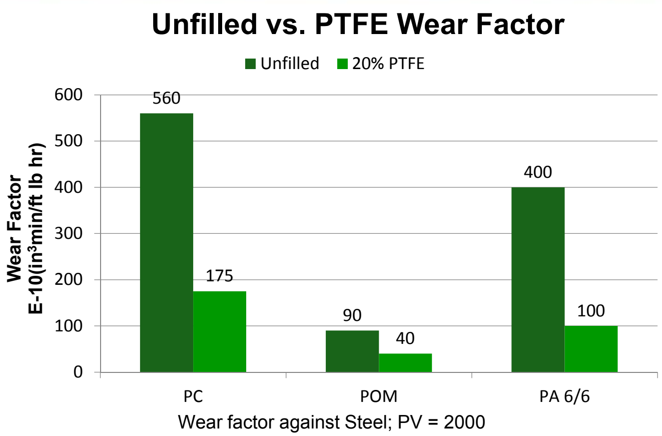
- Fluorine content
- Die plate-out
- Relatively high loadings
- Cost fluctuation

ADDITIVE TECHNOLOGIES

PTFE Wear Mechanism



ADDITIVE TECHNOLOGIES



APPLICATION EXAMPLE

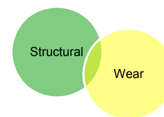
Laser Printer Fuser Gears

Requirements

- High Operating Temperatures
- Good wear Resistance

Solution

- Glass fiber reinforced and PTFE lubricated PPS



ADDITIVE TECHNOLOGIES

PTFE

Silicone

ADDITIVE TECHNOLOGIES

Silicone – Polydimethylsiloxane (1-3%)

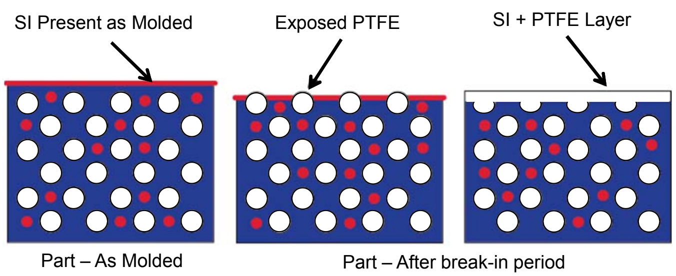
- Boundary lubricant which migrates to the surface over time
  - Migration rate is viscosity dependent
- Excellent friction reducer
- Best in high speed/low load applications

Limitations

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

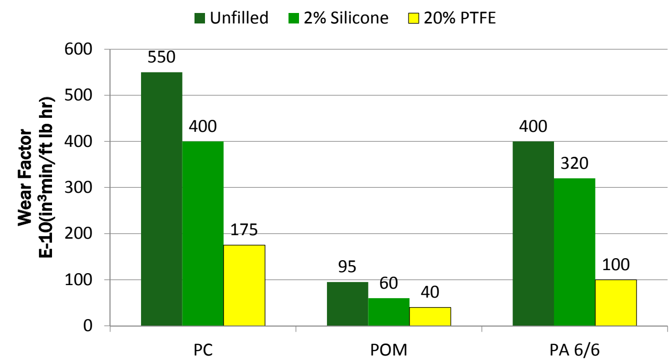
ADDITIVE TECHNOLOGIES

PTFE + Silicone Wear Mechanism



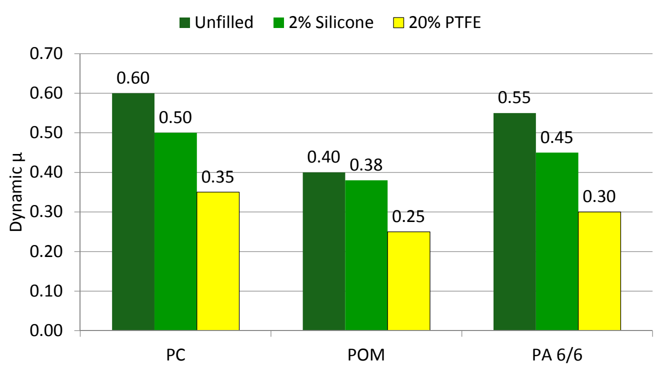
ADDITIVE TECHNOLOGIES

Wear Resistance with PTFE and Silicone



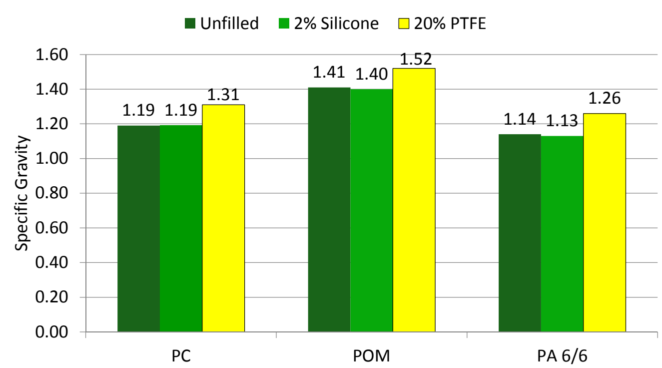
ADDITIVE TECHNOLOGIES

Friction Reduction with PTFE and Silicone



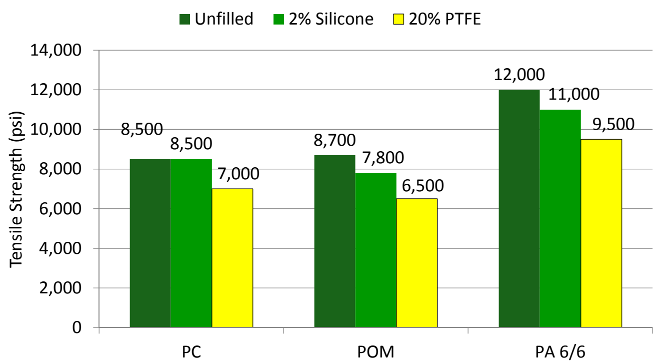
ADDITIVE TECHNOLOGIES

Specific Gravity Differences with PTFE and Silicone



ADDITIVE TECHNOLOGIES

Tensile Strength with PTFE and Silicone



ADDITIVE TECHNOLOGIES

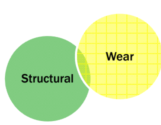
	PC			PA 6/6			POM		
	Unfilled	PTFE (20%)	Silicone (2%)	Unfilled	PTFE (20%)	Silicone (2%)	Unfilled	PTFE (20%)	Silicone (2%)
Specific Gravity	1.19	1.31	1.19	1.14	1.26	1.13	1.41	1.52	1.40
Tensile Strength (psi)	8,500	7,000	8,500	12,000	9,500	11,000	8,700	6,500	7,800
Flexural Modulus (psi)	340,000	320,000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

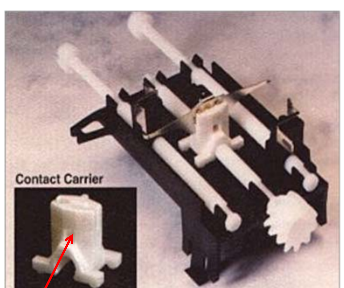
APPLICATION EXAMPLE

Garage Door Opener Limit Switch

Requirements
- Dimensional stability
- Good strength and stiffness

Solution
- Silicone lubricated PC

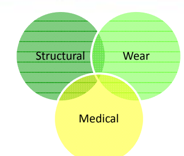




Not Transparent! More on this later…

APPLICATION EXAMPLE

Drug Delivery Pen Components



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

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

Fiber reinforced and internally lubricated PC or PBT

Internally lubricated POM or PBT

ADDITIVE TECHNOLOGIES

PTFE

Silicone

PFPE

ADDITIVE TECHNOLOGIES

PFPE – Perfluoropolyether Oil (< 1%)

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

Limitations

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

APPLICATION EXAMPLE

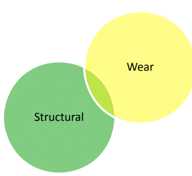
Agricultural Pump

Requirements

- Chemical and Wear Resistance

Solution

- PFPE lubricated PP



APPLICATION EXAMPLE

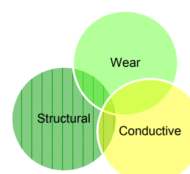
Universal Conveyor Roller

Requirements

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

Solution

- Carbon fiber reinforced and PTFE/PFPE lubricated PPS



ADDITIVE TECHNOLOGIES

Additives Reduce Clarity!

ADDITIVE TECHNOLOGIES

ADDITIVE TECHNOLOGIES

Graphite Powder (5-30%)

- Aqueous environments
- Excellent temperature resistance
- Black color

Molybdenum Disulfide - MoS_2 (1-5%)

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

Limitations

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

APPLICATION EXAMPLE

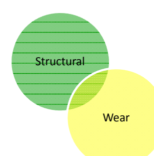
Water Meter Valve

Requirements

- Dimensional stability, potable water contact - NSF listed

Solution

- Graphite lubricated PS and SAN



ADDITIVE TECHNOLOGIES

ADDITIVE TECHNOLOGIES

Reinforcing Fibers and Wear Resistance

Glass Fiber | Carbon Fiber | Aramid Fiber

Glass Fiber
- Improved bearing capabilities/wear resistance
- Very abrasive

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

Aramid Fiber
- Little strength improvement
- Very gentle to mating surface

ADDITIVE TECHNOLOGIES

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

Glass | **Carbon** | **Aramid**

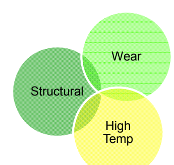
Aluminum Contact Surface

APPLICATION EXAMPLE

Copier Bushings

Requirements
- High HDT and good wear resistance

Solution
- Aramid fiber reinforced and PTFE lubricated PPA



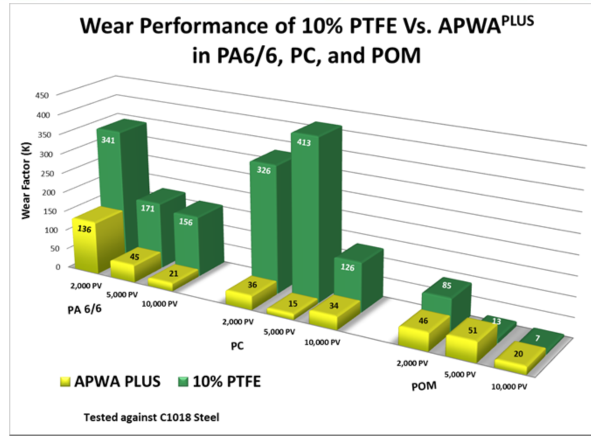
ADDITIVE TECHNOLOGIES

APWA^{PLUS}:
All Polymeric Wear Alloy

A Unique Polymer Alloy Technology Offering:

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

ADDITIVE TECHNOLOGIES



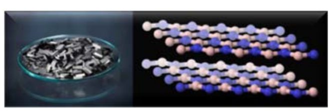
ADDITIVE TECHNOLOGIES

Additive Synergies

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

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

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



AGENDA

I. Wear Definitions & Test Methods

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EXTREME CONDITIONS

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

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

Excellent Mechanical Properties
Injection Molded Parts

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

EXTREME CONDITIONS

Ultra Wear Products Developed for Demanding applications

Transmission Seal
High Load Thrust Washers
Pipe Gaskets

Off-Shore Drilling
Construction Vehicles
Oil and Gas Industry

EXTREME CONDITIONS

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

Resins

- PEEK
- PPS
- PPA

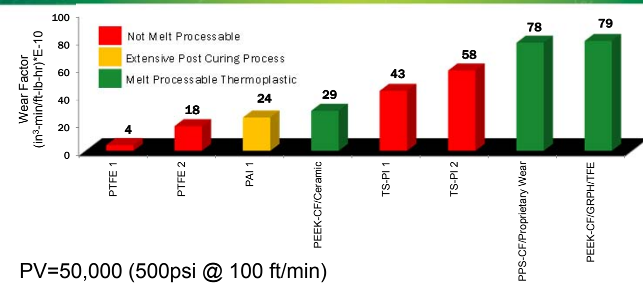
Additives

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

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

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

EXTREME CONDITIONS

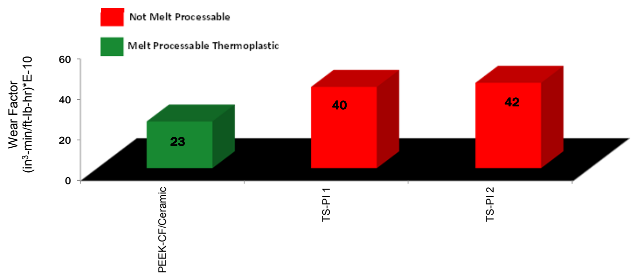


PV=50,000 (500psi @ 100 ft/min)

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

Wear per ASTM D-3702 against Steel

EXTREME CONDITIONS



Disc Material	Wear Factor (in^3-min/ft-lb-hr)*E-10	Dynamic μ
PEEK-CF/Ceramic	23	0.05
TS-PI 1	40	0.10
TS-PI 2	42	0.07
PTFE 1	Wear Limit	NA
PAI 1	Wear Limit	NA
PPS-CF/Proprietary Wear	Wear Limit	NA

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

EXTREME CONDITIONS

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

APPLICATION EXAMPLE

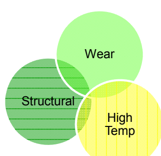
AC Compressor Scroll Seal

Requirements

- High temperature, chemical and wear resistance

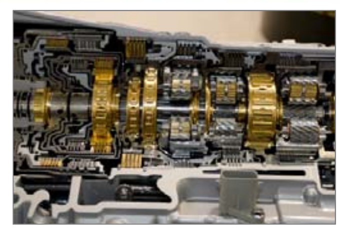
Solution

- Carbon fiber reinforced and PTFE/Graphite lubricated PEEK



APPLICATION EXAMPLE

Transmission Seal Rings/ Thrust Washers

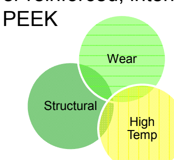


Requirements

- Ability to survive extremely high PV conditions with external lubrication

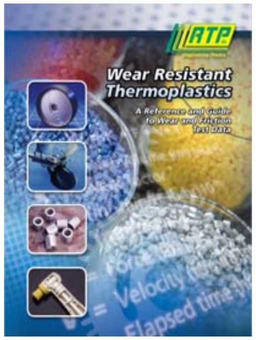
Solution

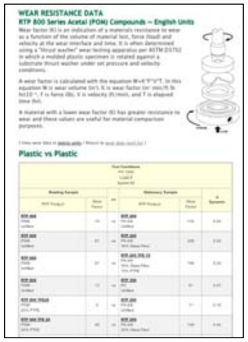
- Carbon fiber reinforced, internally lubricated PEEK



WEAR AND FRICTION

ADDITIONAL INFORMATION





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

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

Color - More than Meets the Eye

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

3:15 p.m.

TOPICS

Brief introduction to RTP Company Color Division

Color Fundamentals

- Three Sciences of Color
- Colorant Types & Limitations
- Evaluation & Control
- Effective Color Communication

Light Diffusion

- Types
- Applications

Questions

RTP COMPANY COLOR DIVISION

Color virtually all resins

- Engineering resins
- Styrenic resins
- Polyolefin resins

Color in multiple formats

- Masterbatches
- Precolored resins
- Cube blends

Advanced Color Development

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

GLOBAL COLOR CONSISTENCY

8 Color Labs

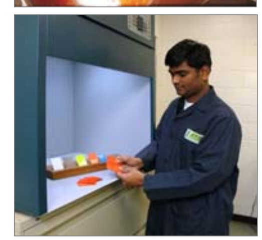
- USA, France, China, Singapore, Mexico

Color Control

- Consistent raw materials
- Consistent hardware
- Consistent software
- Global database

Speed

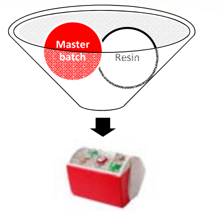
- Fast color matching service
- Transfers across regions
- Global color palette



COLORING OPTIONS

Masterbatches

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



Precolor

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

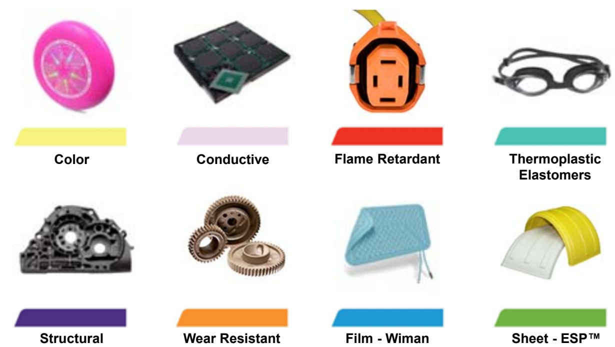
Cube blend

- Masterbatch is blended with resin (two or more pellet solution)

Your Color – Your Way

PRODUCT FAMILIES

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



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COLOR SCIENCE

Biology

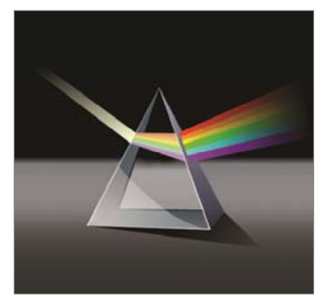
- Color perception

Physics

- Light interactions

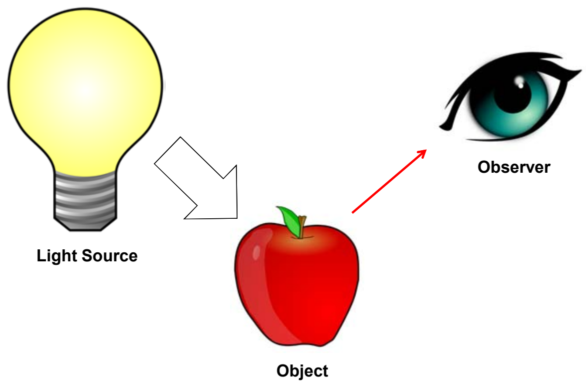
Chemistry

- Colorants

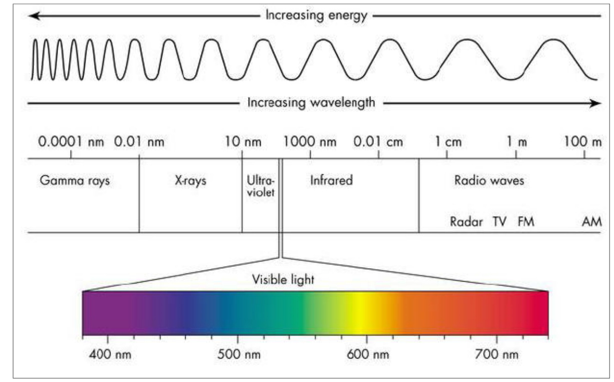


BIOLOGY

How do we see color?

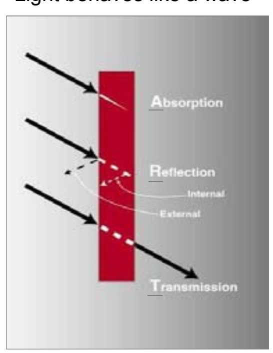


PHYSICS



ART OF COLOR

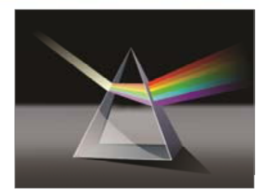
Light behaves like a wave

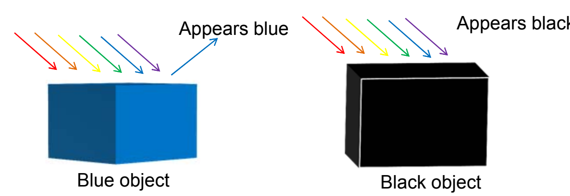


PHYSICS

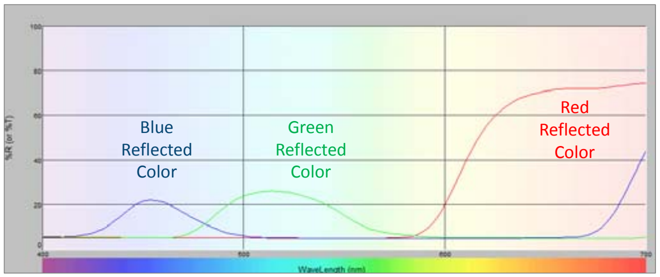
White light is made up of all wavelengths of visible light.

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





SPECTRAL REFLECTANCE



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

CHEMISTRY – COLORANT TYPES

Inorganic Pigments

- Pigments from various metals or other substances from nature

Organic Pigments

- Pigments made synthetically

Dyes

- Synthetic substances that are soluble

ORGANIC VS. INORGANIC

Organic Pigments:

- Small particle size
- Difficult to disperse
- Limited heat stability (300 °C max)
- High color strength
- Light fastness
  - Evaluated on individual basis

Inorganic Pigments:

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

DYES

Soluble

- Migration concerns

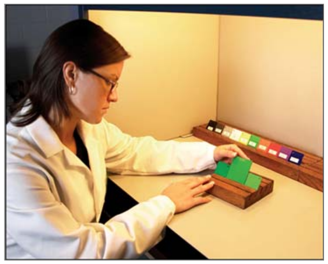
High color strength

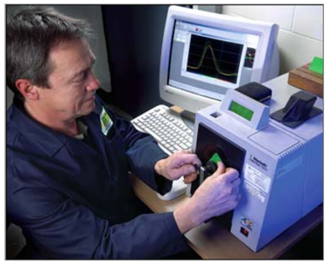
Transparent

Commonly used in:

- Styrenic Resins
- Engineering Resins

COLOR EVALUATION & CONTROL





Visual Color Evaluation
- Confirmed color vision
- Color standards for reference
- Controlled light
- Agreed upon color space

Instrumental Color Evaluation
- Calibrated instruments
- Color standards for reference
- Controlled temperature
- Agreed upon color space

ENVIRONMENTAL FACTORS

Observer
- Each person sees color uniquely

Light Source
- Different spectral distributions (D65, CWF, Incandescent)

Background
- Contrast difference makes colors appear different

Viewing Angle
- Most common 45º

Keep viewing conditions **CONSTANT**

SPECIFICATION & TOLERANCES

Numeric Color Modeling

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

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

COMMON COLOR TERMS

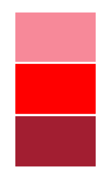
Hue
- Color perceived

Chroma (Saturation)
- Vividness of a color

Lightness
- Measure of brightness (think about gray scale)

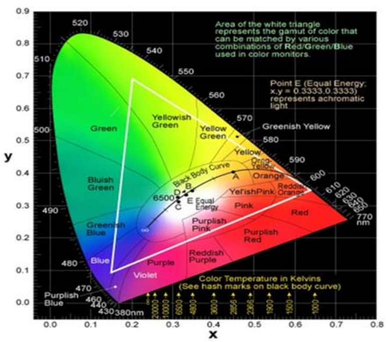
Tint: Hue has been lightened
- Pink is a tint of red

Shade: Hue has been darkened
- Maroon is shade of red



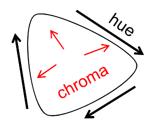
COLOR SPACE

CIE 1931 Yxy



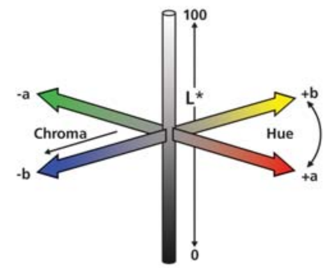
Non-Uniform Color Scale

- Uses numeric values Yxy
  - Y - Luminance
  - x,y - Chromaticity values
- Only x,y chromaticity values shown
- Hue changes around color gamut
- Chroma increases from center towards edge



COLOR SPACE

CIE L*a*b* Model (Traditional X-Y-Z coordinate system)



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

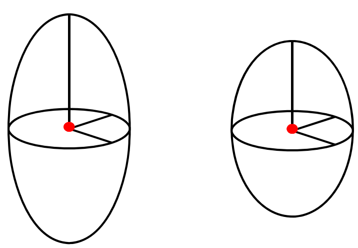
$$\Delta E^* = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

- Developed in 1976
- Most popular color space
- Uniform color space
- Identified by numeric values
  - L* = lightness to darkness (0-100)
  - a* = redness to greenness
    b* = yellowness to blueness
  - ΔE* = total color shift (dimensionless)

COLOR SPACE

CMC l:c (1984)

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



l:c = 2:1 l:c = 1.5:1

TOLERANCES

- Tolerances developed around variation in raw materials, processing, customer goals for visual appearance

* *Asymmetrical color tolerances are perfectly acceptable to use*

COLOR COMMUNICATION

It's important to specify all targets through color communication

APPLICATION REQUIREMENTS/TARGET

Application Requirements

- Resin/Compound
- Regulatory Restrictions
- Processing Method
- Secondary Operations

Color Target

Physical Color

Grass Green
Pantone: 347

Color Reference

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

Color Space Values

SATISFYING EXPECTATIONS

Color nomenclature

- Identifies both regulatory and formulation commitment

Lot control

- Ingredient traceability

Process control

- Defined manufacturing specifications
- Engineering review during development and continuous improvement
- Contributes to consistency

Color quality control

- Color meets defined requirements
- Physical properties
- Composition consistency

TOPICS

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Light Diffusion

- Types
- Applications

Questions

LIGHT DIFFUSING


- Electronics, outdoor lighting & signage, automotive
- More consistent and pleasing light for consumers
- Eliminates Hot Spots
- LED Color Variation
- Protects/hides light source
- Expands Design Space
- Popular for LEDs
- PC, Acrylic

LIGHT DIFFUSION

- Two basic automotive applications…
  - Attenuation and color

Various buttons

HVAC Displays

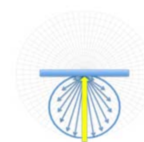
LIGHT DIFFUSION

Or is it three?

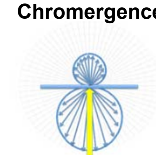
- How do we eliminate projected “hot spots”?
- Light pipes are used to direct source lighting, balancing output to achieve a consistent harmonious display!

LIGHT DIFFUSION TYPES

Brilliant

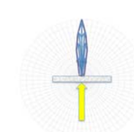


Emergence & Chromergence



Veil & Eclipse

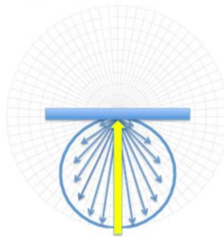
Pure



BRILLIANT

Features
- High opacity
- 95%+ reflectivity
- Spectrally neutral

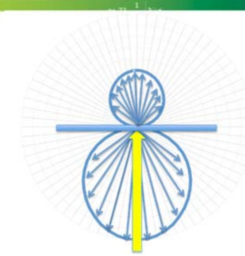
Common Uses
- LED Reflectors
- Light boxes for LCD backlighting
- Illuminated pushbutton actuators
- Reflective light guides
- Light isolators



EMERGENCE & CHROMERGENCE

Features
- High contrast
- Easily backlit
- Tunable transmission
- Neutral or tuned
- Laser etch-able, paintable, printable

Common Uses
- Multi-shot graphics
- Illuminated Indicators
- Graphics with LED color correction
- Paint and laser etched graphics
- in white and colors



VEIL & ECLIPSE

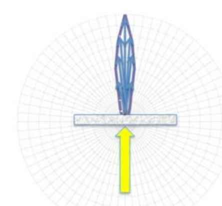
Features
- Wide angle diffuser
- High transmission and efficiency
- Laser etch-able, printable, paintable
- Neutral transmission and/or color

Common Uses
- LED hotspot elimination
- Hidden-until-lit graphics in color
- LED color tuning diffusers
- Substrate for surface decorated illuminated graphics

PURE

Features
- Very high light transmission
- Color tunable
- Available in wide variety of scatter angles
- from very narrow to wide angles

Common Uses
- Long light path light pipes
- LED color correcting lenses
- Point source softening elements
- Complex light distribution covers



SO HOW DO WE BEGIN?

- Data from LED bins used
- Actual LED on a PCB to be lighted at RTP
- Drawing with dimensions/thicknesses included
- OEM color and chromaticity specifications
- Painted clear chip if paint layer is involved
- Molded parts and data

RTP COMPANY TYPICAL PARAMETERS

- Luminance tolerance of +/- 5 %
- Chroma tolerance of +/- 0.01 CIE 1931 x, y
- 1- 4mm specimen thickness
- Spectrophotometer for standard quality assurance needs
- Spectroradiometer for development and, as needed, QA

OUR RESOURCES

- Standard Products
  - Translucent White, Color Options, and 'clear or colorless'
  - Various levels of diffusion and optical performance
- OEM approvals on Lighting materials
- Specific Controls for manufacture and quality control
- Global Lighting Products Available
  - Local development with Global support
- Compounding Process for Lighting Materials
- Quality Assurance Controls for Lighting Materials

CHALLENGES TO OVERCOME

- Missing or incomplete information
  - Changing targets
  - Lessons learned
- Limited access to light source
  - Light source is critical
  - PCB source is preferred
- Not enough data points
  - Often best to offer 2 or more samples for expediency
  - Sample plaques maybe used to define goals
- Distance of light path and part geometry

COMMUNICATION IS KEY

How do we share information?

- Luminance transmission
- Spectral transmission
- Most applications require reporting “Day and Night” performance
- X-Rite I7 Spectrophotometer
  - D65 SCI 10 degree, LAV
  - Black and white background defined thickness
- Minolta CS-2000
  - Preferred customer source
  - RTP source as alternative

LIGHT DIFFUSION REVIEW

SUMMARY

- RTP Company supplies innovative colors and functional additives
- Color communication is crucial to color matching and tolerancing
  - Application is key to setting tolerance!
- Light diffusion applications and types
- Communication is key and we are here to help!

QUESTIONS

Any Questions


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

Everything You Need to Know about TPEs

Karl Hoppe | Senior Product Development Engineer
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(507) 474-5367

4:00 p.m.

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

Everything You Need to Know about TPEs

Karl Hoppe
Senior Product Development Engineer

rtpcompany.com • rtp@rtpcompany.com

TPE DIVISION

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

GOALS:
- A basic understanding of various TPEs
- Relate this knowledge to the RTP TPE Product line

DEFINITION

THERMOPLASTIC ELASTOMER

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

"…Any of various elastic substances resembling rubber…"

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

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

WHAT IS TPE

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

Thermoset

Thermoplastic

HOW TPES WORK

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

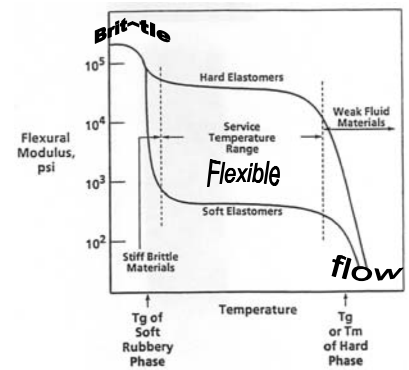
Hard phase contributes "plastic" properties such as:

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

Soft phase contributes "elastomeric" properties:

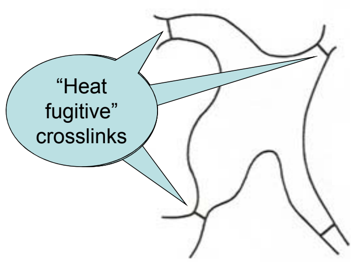
- Low-temperature performance
- Hardness
- Flexibility
- Compression & tension set

BUT WHY ARE TPE'S RUBBERY?



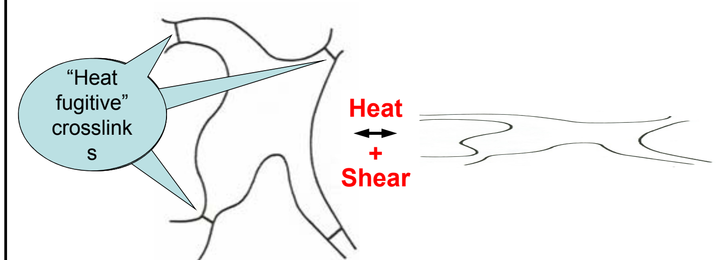
The design temperature range of a TPE is bounded by the glass transition temperature of the rubbery phase and the glass transition or melt temperature of the hard phase.

SO, HOW CAN TPE'S BE MELT PROCESSABLE?



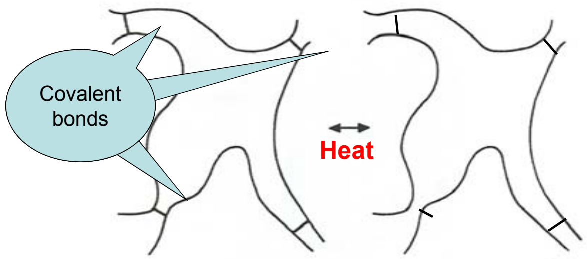
By raising the temperature of the TPE above the glass transition or melting temperature of the **plastic phase**.

SO, HOW CAN TPE'S BE MELT PROCESSABLE



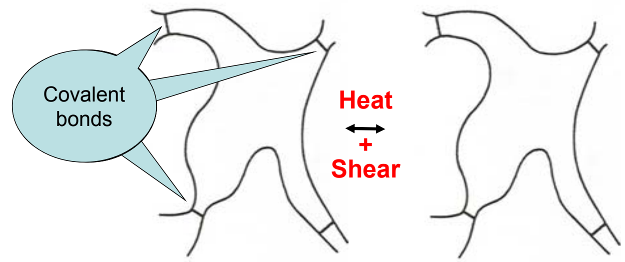
And applying shear forces typical of thermoplastic processes.

UNLIKE THERMOSET RUBBER…



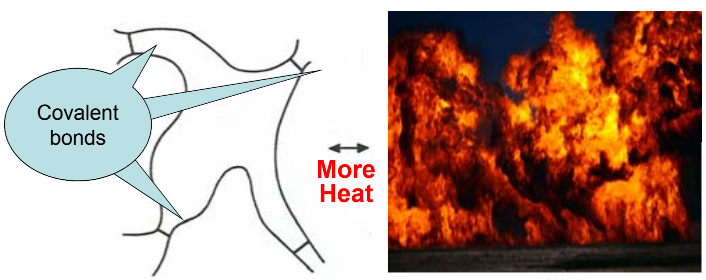
By comparison, thermoset rubbers (TSRs) are **single phase** materials with **non-reversible** chemical (covalent) bond cross-links.

UNLIKE THERMOSET RUBBER…



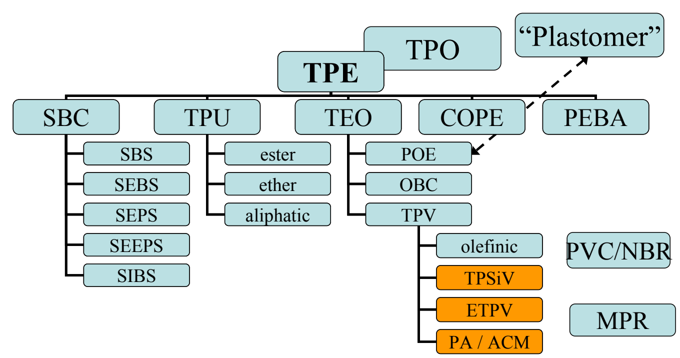
And are unaffected by shear forces.

UNLIKE THERMOSET RUBBER…



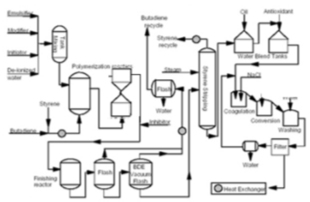
Or increasing heat…

LINEAGE (ALPHABET SOUP)

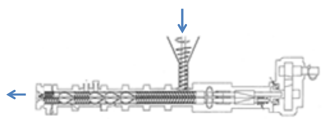


NEAT POLYMER VS COMPOUND

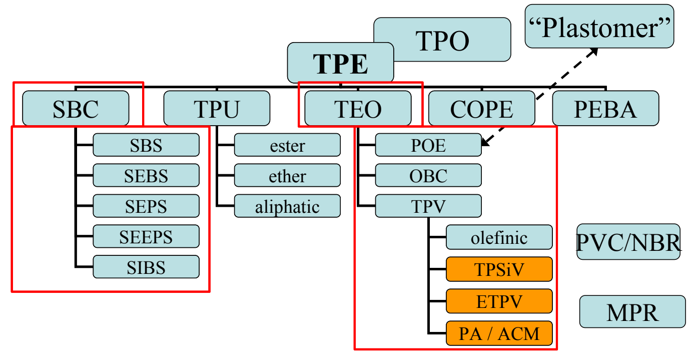
NEAT POLYMER
Created in a reactor, polymerizing thermoplastics chemically from feedstock



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



LINEAGE (ALPHABET SOUP)



Most Commonly seen as compounds

CLASSIFICATION & NOMENCLATURE

Performance (heat & oil resistance following ASTM, SAE, etc.)

Chemistry (styrenic, olefinic, urethane, etc.)

Structure

- Block copolymers
- Blends & alloys
- Dynamic vulcanizates

BLOCK COPOLYMERS - MECHANISM

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

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

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

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

BLOCK COPOLYMERS - EXAMPLES

Styrenic block copolymers "SBC"
- SBS, SEBS, SIS, SIBS, SEEPS (neat rubber)
- Rarely used in their neat form

Polyolefin elastomer "POE"

Thermoplastic urethane "TPU"

Copolyether-ester "COPE"

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

BLENDS & ALLOYS - EXAMPLES

Styrenic block copolymers "SBC"
- SBS, SEBS, SIS, SIBS, SEEPS → Styreflex Compounds
- Most frequently compounded with PP, PE, or POE

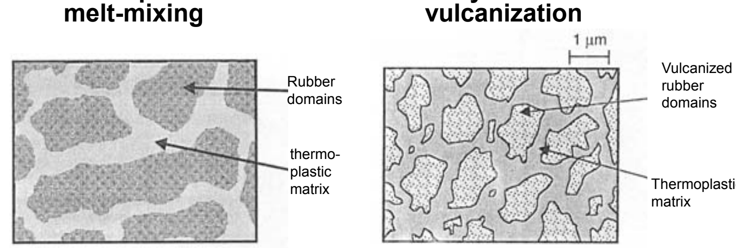
Bondable TPES
- Polabond
- Nylabond

FOCUS – SBC BASED TPE'S

COMPOSITION	DESIGN FLEXIBILITY
OIL *(white mineral, other)* **SBC POLYMER(S)** *(type, MW, and structure)* **FILLER** *(CaCO3, talc, none)* **POLYPROPYLENE** (lots of choices) **Stabs, pigments, etc**	**Hardness –** Gels (Shore OOO) to 50D **Viscosity –** Extrusion to ultra-high flow **Clarity –** Opaque to water clear **Properties –** Tailored elasticity, strength **Feel –** Super grippy to dry **Fillers –** Throw in the kitchen sink
STRENGTHS	**LIMITATIONS**
Elasticity– Highly elastic to "dead" **Versatility–** Broad range of customizations **Low temp and RT –** Great CS and flexibility **Cost–** General purpose to boutique compounds **Aesthetics–** Excellent moldability, consistency **Colorability–** Very bright colors possible **Bond to PP**	**Oil resistance–** High affinity for absorption **High Temp–** Max CUT ~100C **High Temp #2–** Properties drop off as temp ↑ **Reputation–** A few bad apples . . . **Balance –** Formulations flexibility is capped by inverse requirements – no free lunch

DYNAMIC VULCANIZATES - MORPHOLOGY

Simple melt-mixing | **Dynamic vulcanization**

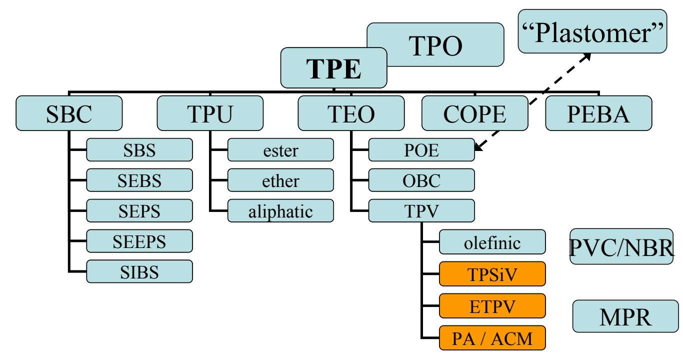


***Coarse** morphology* TPO | ***Fine** morphology* TPV

FOCUS – TPV'S

COMPOSITION	DESIGN FLEXIBILITY
EPDM RUBBER *(non-vulcanized bale)* **POLYPROPYLENE** *(usually GP grades)* **FILLER** *(CaCO3 or talc, low %)* **CURE PACKAGE** (phenolic, peroxide, etc) **Oil** (generally low % add) **Stabs, pigments,etc**	**ALLOYS** **Hardness** – 35A to 50D **Viscosity** – Shear dependent flow **Clarity** – Opaque, nat color vs cure pkg **Properties** – Driven by hardness **Feel** – Most "rubber-like" feel **Fillers** – Crosslinked EPDM limits filler
STRENGTHS **"Industrial"**– Higher temp property retention Long term sealability (think auto) Great inherent UV stability Chemical and oil *resistance* **Rubber-like**– Most similar TPE to rubber **Commoditized**– Standard products and stocks **Bond to PP**	**LIMITATIONS** **Customization**– Technology and mfg limited **Aesthetics**– Shear sensitivity and gate defects **RM flexibility**– TPV does not drive inputs **Color**– Opaque natural, cure technology driven **Regulatory vs Cost**– Control capable, but "true" TPV has major cost implications

LINEAGE (ALPHABET SOUP)



TPE ≠ RUBBER

Keep in mind:

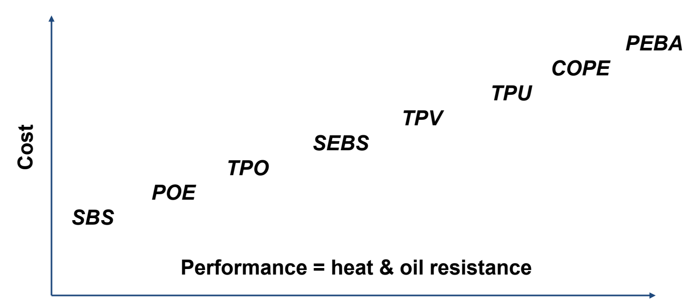
This is a broadbrush of many (very) different technologies that make up generic "TPE", relative to many (very) different technologies making up thermoset elastomers.

PRO's	CON's
• Recyclable	• High Temp Performance
• Mass Reduction	• Material Cost
• Manufacturing Cost	• Elastomeric Properties
• Design Flexibility	• No in-house compounding

TPE's are not a one to one replacement for Thermoset Elastomers

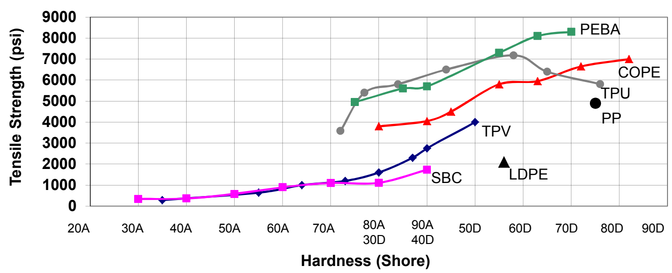
Proper material selection is highly dependent on the application requirements, design, and ability to take advantage of the strengths inherent to TPE or Thermoset Elastomers

RELATIVE VALUE OF TPE'S

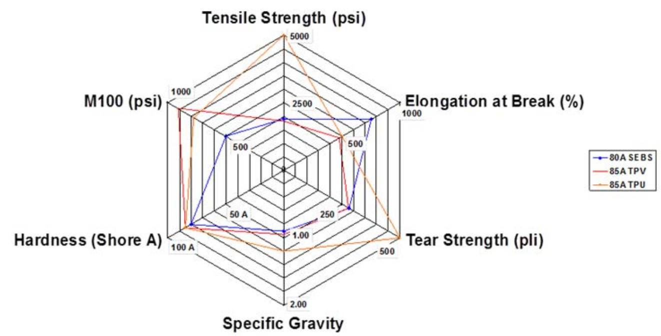


THE PROBLEM WITH HARDNESS

TPE Strength and Hardness Comparison



THE PROBLEM WITH HARDNESS



WHY RTP?

RTP has been built on several basic principles:

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

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

TPE compounding requires the exact same approach – Only Different?

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

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

STYRENIC BASED TPE'S

Styreflex™ 2700S & 2740S Standard Products

Styreflex™ 2700 S Series - *30A to 80A unfilled*
- Translucent to clear, low gravity, excellent elasticity
- Medical and FDA compliant grades available (MD and Z)

Styreflex™ 2740S Series - *30A to 80A filled SBC*
- Opaque, higher gravity, FDA compliant grades available

Attributes
- *Highly Elastic*
- *Highly Customizable*
- *Design Flexibility*
- *Broad Cost Spectrum*
- *Great RT Compression Set*

2799 SX Design Flexibility

- Water clear
- Increased Elasticity
- Low Hardness + Strength
- EU food contact compliant
- Processing Tweaks
- Haptics (Touchy-Feely)

VULCANIZATE BASED TPE'S

Permaprene™ 2800B & 2840B Standard Products

Permaprene™ 2800 B Series - *45A to 50D TPV Products*
- HF Grades preferred for cost & appearance improvement
- FDA compliant grades available in non-HF only

Permaprene™ 2840 B Series – *55A to 90A TPV VA/VE Option*
- Higher Gravity, Lower temp, good extrusion, smoother feel

Attributes
- *Broad temp range*
- *Improved chem resistance*
- *Easily Colorable*
- *Broad Cost Spectrum*
- *Great RT Compression Set*

2899 X Design Flexibility
- Targeted Viscosity
- Targeted Properties
- Improved UV (good to great)
- Application Tailoring
- Splitting the Difference
- Haptics (Touchy-Feely)

NYLABOND™

Nylabond™ 6091 Series: Nylon Bondable TPVs
- Formulated specifically for melt bonding to Nylon 6 and 6/6
- Available in durometer levels of 55A to 85A
- TPV based product based on Santoprene® technology
- Market leading technology, unequalled property set
- Significant value in automotive – temp & chem resistance

COMPETITION

ALL SEBS BASED
- Tekbond 1158A&C, 1372A *[Teknor Apex]*
- Versaflex OM-6059, OM-6200 *[GLS]*
- *Thermolast K CO PA, CO NY [Kraiburg]*
- Starbond *[Star Polymers]*

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

POLABOND™

Polabond 6042 Series: *ABS, PC, and PC/ABS Bondable SEBS Alloys*
- Excellent Bonding due to unique technology
- Great grip and feel, very durable
- Good aging properties relative to competitors
- Excellent processability and aesthetics
- Specialty versions available for unique applications

COMPETITION
- Various Tekbond Products *[Teknor Apex]*
- Versaflex OM-3060, OM-1000 series *[GLS]*
- *Thermolast AD1 Grades [Kraiburg]*
- Starbond *[Star Polymers]*

Polabond 6041 Series: *55A and 70A TPV based*
- Excellent Bonding to PC, ABS, PMMA, RTPU
- Premium polar bonding product
- Excellent chemical resistance at high temps
- Superior weatherability

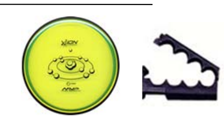
ADDITIVE INCORPORATION

Color Conductive Structural Wear FR

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

RTP's Bread & Butter, Applied to TPE
- Strong Market Leadership
- Leverage Expertise and Resources
- Deliver Unique Solutions & Functionality

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



Side Benefit - Uniquely Experienced with all TPE chemistries
- Technical acumen to create custom formulations and alloys
- Culture of customer co-development – create what you NEED

WHAT TO TAKE AWAY FROM TODAY

Styreflex™ - SBCs

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

Permaprene™ –TPV Alloys

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

Nylabond™ Polabond™

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

Specialty

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

APPLICATION GUIDELINES

- What is the operating temperature range for my application?
- What chemical and/or environmental exposures might there be?
- What are the key performance requirements for the application (beyond just shore hardness)?

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