Section 5

Plastic & Thermoplastic Elastomer Materials

Plastic & Thermoplastic Elastomer Materials

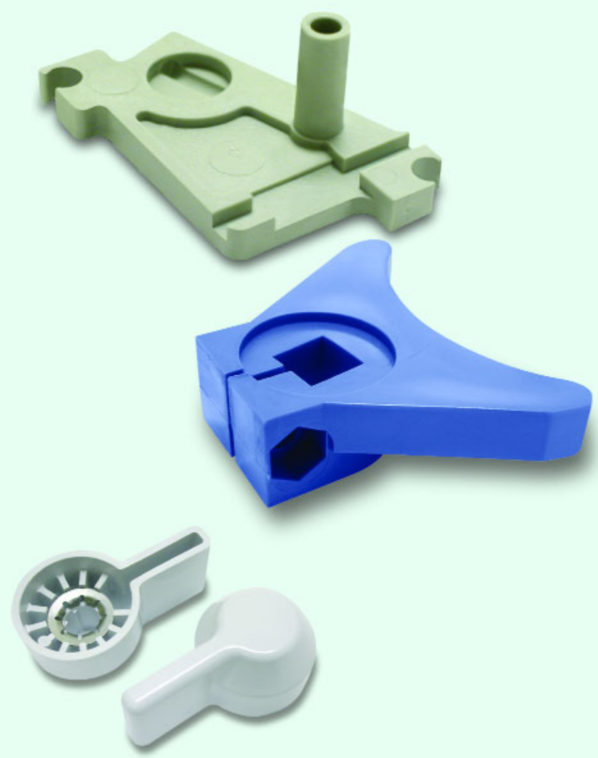
QMR Plastics specializes in the design and molding of close tolerance, high performance thermoplastics and thermoplastic elastomers. We also work with engineered plastics and specialize in finding the most efficient and innovative means of reducing costs while improving product performance.

Our specialty services include hot plate welding, two shot molding, product testing, assembly and packaging. In addition, our unified project management system accelerates product launch and time-to-market.

High Performance Plastics

Not every plastics molder can produce high quality components from high performance materials. Even fewer offer the range of high performance – high temperature materials found at QMR Plastics. These materials, and our hot manifold and hot runner systems, represent our core business. And our customers have come to rely on our ability to develop, design and produce their components, and assemblies, cost-effectively from a wide range of material offerings.

High performance materials have extensive performance ranges and unique property attributes. As manufacturers require higher levels of performance and lower costs from materials, we continue to meet their needs for a wide range of markets from aerospace and automotive to consumer and off-road.



High Temperature Resistant Thermoplastics:

Abbreviation	Polymer	Continuous Use Temp	Glass Transition Temp	HDT @ 264 psi	HDT @ 66 psi
Torlon® PAI	**Polyamide Imide**	**482°F (250°C)**	**527°F (275°C)**	**534°F (279°C)**	–
Aurum® PI	**Polyimide**	**550°F (288°C)**	**482°F (250°C)**	**475°F (246°C)**	–
PES	Polyethersulfone	350-400°F (177-204°C)	435°F (224°C)	400-460°F (204-238°C)	420-460°F (216-238°C)
PEI	Polyetherimide	350-400°F (177-204°C)	415°F (213°C)	390-420°F (199-216°C)	400-440°F (204-227°C)
PSO-PSU	Polysulfone	300-340°F (149-171°C)	374°F (190°C)	340-360°F (171-182°C)	350-370°F (177-188°C)
PEEK® PK	**Polyetheretherketone**	**400-450°F (204-232°C)**	**290°F (143°C)**	**350-610°F (177-321°C)**	**500-640°F (227-338°C)**
PPA	Polyphthalamide	400-450°F (204-232°C)	274°F (134°C)	530-545°F (277-285°C)	560-574°F (293-301°C)
PPS	Polyphenylene Sulfide	400-450°F (204-232°C)	198°F (92°C)	300-550°F (149-288°C)	400-500°F (204-260°C)

Superior Performance

For applications that include unique or demanding requirements, a high performance polymer often provides an effective material and design solution.

From mechanical to unique thermal properties, high performance polymers provide design engineers with valuable design and end use options.

Performance Attributes Include:

- Chemical resistance
- Conformability
- Dimensional Stability
- Flexibility
- Injection moldable
- Lightweight
- Metal replacement
- Noise reducing
- Self lubricating
- Temperature extremes

End Use Applications Include:

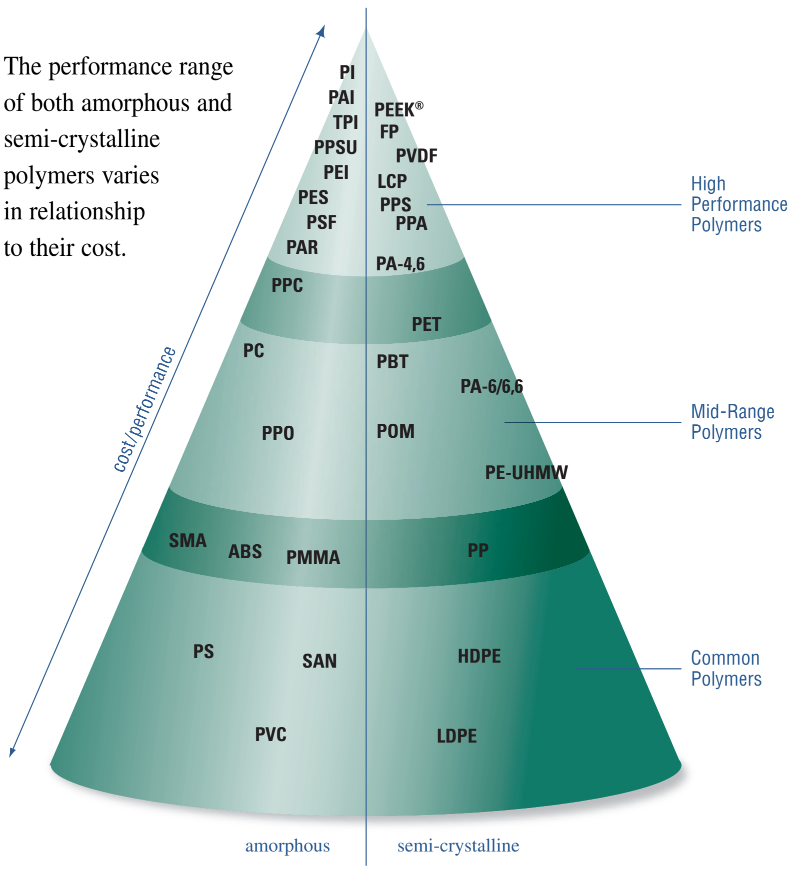
- Bearings
- Bushings
- Retainers
- Thrust Plates
- Thrust washers
- Rotary Seal Rings
- Gears
- Poppets

Application Environments Include:

- Valves
- Pumps
- Compressors
- Fuel Systems
- Transmission
- Steering Systems
- Suspension Systems
- Torque Converters

This performance and cost illustration is a partial list depicting the spectrum of low-end to high-end performance materials.

The performance range of both amorphous and semi-crystalline polymers varies in relationship to their cost.



Abbreviation	
ABS	acrylonitrilebutadienestyrene
FP	fluoropolymers
HDPE	high density polyethylene
LCP	liquid crystal polymers
LDPE	low density polyethylene
PA-4,6	polyamide-4,6
PA-6/6,6	polyamide-6/6,6
PAI	**polyamideimide (Torlon®)**
PAR	polyarylate
PBT	polybutylene terephthalate
PC	polycarbonate
PE-UHMW	ultrahigh molecular weight polyethylene
PEEK®	**polyetheretherketone**
PEI	polyetherimide
PES	polyethersulfone
PET	polyethylene terephthalate
PI	**polyimide (Aurum®)**
PMMA	polymethyl methacrylate
POM	polyoxymethylene (also polyacetal)
PP	polypropylene
PPA	polyphthalamide
PPC	polyphthalate carbonate
PPO	polyphenylene oxide
PPS	polyphenylene sulfide
PPSU	polyphenylsulfone
PS	polystyrene
PSF	polysulfone
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
SAN	styrene acrylonitrile
SMA	styrene maleic anhydride
TPI	thermoplastic polyimide

Thermoset Plastics vs Thermoplastics

When classified by chemical structure, there are two generally recognized classes of plastic materials: Thermosets, having cross-linked molecular chains and Thermoplastics, which are made up of linear molecular chains.

Thermoset polymers require a two-stage polymerization process. The first is done by the material supplier which results in a linear chain polymer with partially reacted portions. The second is done by the molder, who controls final cross--linking. Short chains with many cross-links form rigid thermosets, while longer chains with fewer cross-links form more flexible thermosets. With all thermosets, the polymerization is permanent and irreversible.

Thermoplastic polymers require no further chemical processing before molding. There are two types of thermoplastic polymers: Crystalline and Amorphous. The pyramid graphic on page 5-3 identifies many of our common thermoplastic materials.

Crystalline Polymers:

1. Have a relatively sharp melting point.
2. Have an ordered arrangement of molecule chains.
3. Generally require higher temperatures to flow well when compared to Amorphous.
4. Reinforcement with fibers increases the load-bearing capabilities considerably.
5. Shrink more than Amorphous, causing a greater tendency for warpage.
6. Fiber reinforcement significantly decreases warpage.
7. Usually produce opaque parts due to their molecular structure.

Amorphous Polymers:

1. Have no true melting point and soften gradually.
2. Have a random orientation of molecules; chains can lie in any direction.
3. Do not flow as easily in a mold as Crystalline Polymers.
4. Shrink less than Crystalline Polymers.

5, Generally yield transparent, water-clear parts.

Long Glass and Short Glass

How long is long?

Long glass is typically 11mm long x .3mm in diameter. Normally the glass fibers lay parallel within the strand.

Short glass is usually 3mm long x .3mm in diameter.

Normally when we make reference to "Glass Filled" we are referring to short glass unless otherwise specified.

Temperature Resistance of Thermoplastics

There are many ways to measure the heat resistance of thermoplastics. These include heat deflection temperatures (HDT) which are normally measured under a load of 264 or 66 psi, melt temperatures, and glass transition temperature (Tg).

However, over time it has been determined that one of the most useful physical properties of a high temperature resistant thermoplastic is that of the glass transition temperature. (Tg is the temperature at which a material begins to soften.)

Temperature Resistance of Thermoplastics

Abbreviation	Polymer	Tg
PAI	Polyamideimide (Torlon®)	527°F (275°C)
PI	Polyimide (Aurum®)	482°F (250°C)
PES	Polyethersulfone	435°F (224°C)
PEI	Polyetherimide	415°F (213°C)
PSO	Polysulfone	374°F (190°C)
PC	Polycarbonate	302°F (150°C)
PEEK®	Polyetheretherketone	290°F (143°C)
PPA	Polyphthalamide	274°F (134°C)
PTFE	Polytetrafluoroethylene	266°F (130°C)
PS	Polystyrene	219°F (104°C)
ABS	Acrylonitrilebutadienestyrene	219°F (104°C)
PPS	Polyphenylene Sulfide	198°F (92°C)
PVC	Polyvinyl Chloride	176°F (80°C)
PA	Polyamide 6/6,6	167°F (75°C)
PA	Polyamide 4,6	133°F (56°C)

By means of independent tests, QMR Plastics has published performance results that demonstrate continuous use temperature above the Tg. The same is true for heat deflection temperatures. However, it is important to remember that performance ultimately depends upon the application. Normally, a material is in danger of failure when it begins to soften (Tg). Therefore, as a general guide, the Tg must be a major consideration when selecting a high temperature resistant thermoplastic.

A material listing helps to clarify and place into perspective common thermoplastic materials showing the Tg of several high performance materials.

Thermoplastic Elastomers

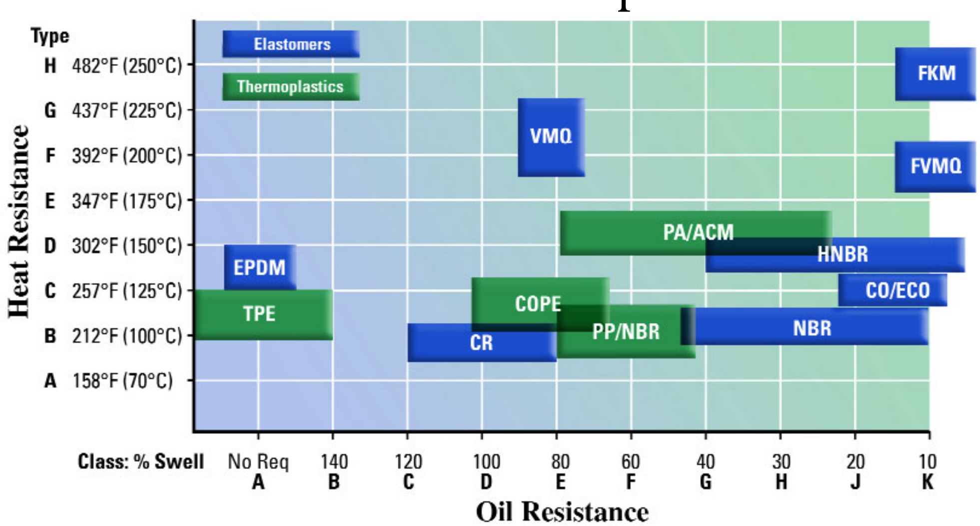
Engineered thermoplastic elastomers (TPE's), are one of the most versatile plastics available today. Our wide range of TPE's combine many of the performance properties of thermoset rubber with the processing ease of plastic thereby providing design options and greater cost-reduction opportunities. QMR Plastics has pioneered the molding of TPE's in part by converting thermoset rubber parts to lower cost TPE components.

TPE's offer a wide range of performance attributes including: heat and oil resistance, improved adhesion, tear resistance, surface appearance and low permeability. And our experience allows us to know when to recommend a TPE over thermoset rubber. In addition, TPE's are colorable and can be specified in a variety of hardness grades.

Process and design flexibility are important features and advantages TPE's offer over thermoset rubber. They can be processed with the speed, efficiency and economy of thermoplastics and can be insert molded with other olefin-based materials, such as polypropylene, without the use of adhesives. With other substrates like polyamides, (nylon), or acrylonitrile butadiene styrene (ABS), mechanical interlocks can be designed into the part to ensure a tight fit.

Thermoplastic elastomers serve a wide range of markets:
- Agriculture & Off Road
- Appliance
- Automotive & Transportation
- Consumer
- Electrical & Industrial Controls
- Food & Beverage
- Hydraulics & Pneumatics
- Marine
- Medical & Safety
- Plumbing & Irrigation

Heat & Oil Resistance Comparison



Abbreviation	
COPE	Copolyester
CO/ECO	Epichlorohydrin
EPDM	Ethylene-propylene terpolymer
FKM	Fluorocarbon
FVMQ	Fluorosilicone
HNBR	Highly saturated Nitrile Butadiene Rubber
NBR	Nitrile Butadiene Rubber
PA/ACM	Nylon PolyAcrylic
CR	Polychloroprene (Neoprene)
PP/NBR	Polypropylene & Nitrile Butadiene Rubber
VMQ	Silicone
TPE	Thermoplastic Elastomer

Thermoplastics and Materials List

Generic Type	Aliphatic Hydro-carbons	Aromatic Hydro-carbons	Oils, Fats, Waxes	Full Halo genated Hydrocarbons	Partly Halo genated Hydrocarbons	Alcohols Mono Hydric	Alcohols PolyHydric	Phenols	Ketones	Esters	Ethers
ABS	Fair	Poor	Good	Poor	Poor	Fair	Good	Poor	Poor	Poor	Poor
Acetal	Good	Good	Good	Good	Fair-Good	Good	Good	Poor	Good	Good	Good
Acrylic	Good	Poor	Good	Poor	Poor	Poor	Good	Good	Poor	Poor	Poor
Polyamide (Nylon)	Good	Fair	Good	Fair	Poor	Good	Good	Poor	Good	Fair	Good
Polycarbonate	Poor-Fair	Poor	Poor-Fair	Good-Fair	Poor	Good	Good	Poor	Poor	Poor	Poor
Polyester	Good	Poor-Fair	Unknown	Poor-Good	Poor	Good-Exc.	Exc.	Poor	Poor	Poor-Fair	Poor
Polyetheretherketone (PEEK®)	Exc.	Fair	Exc.	Fair	Fair	Good	Exc.	Fair-Good	Good	Fair	Good
Polyether Sulfone	Exc.	Poor	Exc.	Poor	Poor	Good	Fair	Poor	Good	Poor	Good
Polyethlyene	Fair	Fair	Exc.	Poor	Poor	Fair	Good	Exc.	Good	Good	Good
Polyamideimide	Exc.	Exc.	Exc.	Exc.	Exc.	Exc.	Exc.	Good	Exc.	Exc.	Exc.
Polyphenylene Oxide	Good	Good	Exc.	Good	Good	Exc.	Exc.	Good	Good	Good	Exc.
Polyphenylene Sulfide	Exc.	Good	Unknown	Fair	Poor	Exc.	Exc.	Good	Good	Exc.	Good
Polyproplylene	Fair	Fair	Good	Poor	Poor-Fair	Good	Exc.	Good	Good	Good	Fair
Polystyrene	Fair-Poor	Poor	Poor	Poor	Poor	Good	Good	Poor	Poor	Poor	Poor
Polysulfone	Poor	Poor	Fair	Poor	Poor	Poor-Fair	Good	Poor	Poor	Poor	Poor
Polyurethane	Fair	Poor	Good	Poor	Poor	Poor	Fair-Good	Poor	Poor	Poor	Poor
Styrene Acrylonitrile	Good	Poor	Good	Poor	Poor	Fair	Good	Poor	Poor	Poor	Poor

Inorganic Acids (Conc.)	Inorganic Acids (Dilute)	Bases (Conc.)	Bases (Dilute)	Salts (Acid)	Salts (Neutral)	Basic	Organic Acids (Conc.)	Organic Acids (Dilute)	Oxidising Acids (Conc.)	Oxidising Acids (Dilute)	Sunlight & Weathering
Good	Good	Good	Good	Good	Exc.	Good	Poor	Fair-Poor	Poor	Good	Fair-Good
Poor	Poor	Poor	Poor	Fair	Good	Good	Poor	Fair	Poor	Poor	Fair-Good
Poor	Good	Fair-Poor	Good	Good	Good	Good	Poor	Fair	Poor	Fair	Good
Poor	Good	Good	Exc.	Poor	Good	Fair	Poor	Fair	Poor	Poor	Fair-Good
Fair	Good	Poor	Poor	Good	Exc.	Fair	Fair	Fair	Poor	Good	Good
Good-Fair	Good	Poor	Poor-Fair	Good	Good	Poor-Fair	Poor-Fair	Good	Poor	Fair-Poor	Good
Dissolves	Poor	Good	Poor	Good	Good	Good	Fair-Good	Fair-Good	Poor	Exc.	Good
Dissolves	Poor-Good	Good	Poor	Fair	Fair	Fair	Fair-Good	Fair-Good	Dissolves	Fair	Good
Good-Exc.	Exc.	Good	Good	Exc.	Exc.	Exc.	Exc.	Exc.	Poor	Good	Poor
Fair	Good	Poor	Fair	Good	Good	Poor	Good	Exc.	Poor	Good	Exc,
Good	Exc.	Good	Exc.	Exc.	Exc.	Exc.	Good	Exc.	Good	Exc.	Exc.
Good	Good	Good	Exc.	Good	Good	Good	Good	Good	Poor	Fair	Good
Exc.	Exc.	Exc.	Exc.	Exc.	Exc.	Exc.	Good	Exc.	Poor	Good	Poor
Fair	Good	Fair	Exc.	Good	Exc.	Good	Poor	Fair	Poor	Fair	Fair
Good	Good	Good	Exc.	Good	Exc.	Good	Fair	Good	Poor	Good	Good-Exc.
Poor	Fair	Good	Good	Good	Exc.	Exc.	Poor	Fair	Poor	Poor	Fair
Good	Good	Good	Exc.	Good	Exc.	Good	Fair	Good	Poor	Good	Fair