A Brief Description of High Performance Thermoplastics (HPTP):

Plastic materials fall into two basic categories: Thermosets, which can be molded only once, and Thermoplastics, which can be reheated and remolded several times. Thermoplastics breakdown into three further categories: commodity thermoplastics, engineering thermoplastics (ETP) and high performance thermoplastics (HPTP) with HPTP being the pinnacle of performance and cost: HPTP are on average 10 times more expensive than general purpose plastics. A distinguishing feature of HPTP is heat-deflection temperatures above 2000C, which is 50% to 100% higher than standard engineering thermoplastics.

High performance thermoplastics (HPTPs) are used in specialized applications that require a combination of extraordinary properties. HPTPs have superior short- and long-term thermal stability (higher melting point, glass transition temperature, heat deflection temperature, and continuous use temperature), chemical and radiation resistance, resistance to burning, and improved mechanical properties (stiffness, strength, toughness, creep, wear, and fatigue).

These materials occupy a wide range of niche applications in markets as diverse as aerospace, automotive, electrical, electronic, medical devices, computers & peripherals, telecommunications, dairy and food service, semiconductor fabrication and testing, environmental monitoring, safety products and many other specialty applications. HPTPs typically offer the greatest margin for the injection molding company, based on several factors: extensive up front applied engineering input, the inherent high value of the material, the specialized equipment required for drying and molding the materials, the relative difficulty of molding, and relatively small production volumes.

The key categories of high performance thermoplastics are listed below:

- Fluoropolymers
- High-performance polyamides (HPPAs)
- Liquid crystal polymers
- Polyamideimides (PAIs)
- Polybenzimidazoles (PBIs)
- Polybutylene terephthalates (PBTs)
- Polyetherimides (PEIs)
- Polyimides (PIs)
- Polyketones
- Polyphenylene sulfides
- Polysulfone derivatives-a
- Polycyclohexane dimethyl-terephthalates (PCTs)
- Syndiotactic polystyrene

High Performance Thermoplastics: Properties and Characteristics

Thermoset plastics: Thermoset plastics were the original, modern synthetic plastics, made by irreversible chemical reactions. Once reacted and formed, the material remains stable and cannot be reformed. “Ebonite” hard rubber was discovered in 1851, followed soon by Colloidon, a by-product of cellulose nitrate used in the then emerging photographic industry in 1850s. The modern era of plastics was ushered in about 1910, after the development of “Bakelite” phenol-formaldehyde resin. There are other types of thermoset materials and composites, typically used in applications where heat resistance and high stiffness is required. Typical end uses can be found in aerospace composite structures, trailer truck bodies, and high-voltage electrical insulation. Today thermosets represent only 3% of the total US market for molded plastics.

Thermoplastic materials: represent the widest variety and largest percentage of plastics use in the world. “Thermoplastic” means that the plastic can be melted and reformed with heat, making it ideal for multiple reuses in the manufacturing process, thus offering the greatest long-term value. Thermoplastic materials derive from a variety of oil-based feed stocks, and will be more fully categorized later in this report. The first modern thermoplastics were commercially developed in the period 1930-1940. These included polyvinyl chloride (PVC), low density polyethylene (LDPE), polystyrene (PS), and polymethyl methacrylate (PMMA). The advent of World War II in 1939 brought plastics into great demand, largely as substitutes for materials in short supply, such as natural rubber. In the United States, the crash program leading to large-scale production of synthetic rubbers resulted in extensive research into the chemistry of polymer formation and, eventually, to the development of more plastic materials.

Thermoplastics break down into three general categories. The categories are defined by the performance properties of given polymer families, typically characterized first by its thermal resistance, then by its physical properties. One must realize that with thermoplastics, the inherent nature of the material to soften with heat is the first order property that will affect most other mechanical and functional properties of the given thermoplastics material. Underwriters Labs, the independent regulatory organization, ranks the performance of plastic materials by their continuous use temperature, otherwise known as CUT. This rating becomes more important as the requirements of a given plastic part demand. Following are the three main categories of thermoplastic materials, and the relative thermal range for molding:

- Commodity thermoplastics, known as high volume thermoplastics that have been around for years, are typically used for packaging (extruded film and sheet for thermo-forming) and high volume injection molded items such as low-cost disposable cutlery. Examples of these materials are polyethylene, polypropylene, and polystyrene. These materials mold in the range of 350°-450°F.

- Engineering thermoplastics (ETPs), which have enhanced specialty properties designed for specific applications used in durable goods, automotive and electrical products, sporting goods, and any application that requires a combination of mechanical performance and precision form. At the beginning of the performance range of ETPs may be found materials such as acrylic (CUT of 175°F, and an acrylic copolymer engineered for toughness known as ABS (short for Acrylinitrile-Butadene-Styrene), CUT of 180°F having melt temperatures of between 4500 and 5000 Fahrenheit. Next come materials such as high-impact polycarbonate (PC), CUT of 250°F and high-wear resistance polyurethane (PU), CUT of 195°F and have melt temperatures of 5500 to 6000 Fahrenheit. Other materials in this higher temperature range include acetal, the common name for polyoxymethylene (POM), polybutylene-terephtalate (PBT), and nylon, also known as polyamide (PA).

- High performance thermoplastics (HPTP), also known as high temperature thermoplastics, have melting points of between 6500 and 7250 Fahrenheit. Examples of high temperature thermoplastics are Polysulfone (PSO) made by BASF and Solvay Advanced Polymers Plastics, and polyetherimide (PEI), made by GE Plastics. High temperature thermoplastics are used in applications requiring heat tolerance, chemical resistance, transparency, dimensional integrity, fire resistance and other specialized properties. These particular HPP materials are described as amorphous thermoplastics, i.e., built of large polymer chains, with tough linkages and multi-functional side chains that contribute to the high-performance properties. Amorphous materials are known for toughness, impact resistance, and good surface appearance making them ideal for "visual" end-use applications.[1]

- There is yet one additional type of polymer structure, the crystalline thermoplastic polymer, represented by materials such as polyphenylene sufide (PPS), trade-marked by Phillips Corp. as Ryton™, and liquid crystal polymer (LCP), made by the Ticona Division of Hoechst Co. These polymers are characterized by closely bound crystalline structure, making them extremely stable to environmental agents such as solvents, fuels, and organic chemicals. They lack ductility and impact strength, are inherently opaque, and rely on fiber reinforcement to achieve practical use. Both amorphous and crystalline HPP materials are used in the automotive, aerospace, medical, food services and electrical industries where demanding properties are required.

HPTPs are defined as engineering thermoplastics (ETPs) with a Relative Thermal Index (RTI) of 160°C or above. The RTI is also known as the continuous use temperature, as determined by Underwriters' Laboratories Inc. (UL), Standard for Polymeric Materials-Long Term Property Evaluations, UL 746B . RTI is considered as the maximum useful service temperature for a material, where a class of critical property will not be unacceptably compromised through chemical thermal degradation, over the reasonable life of an electrical product, relative to a reference material having a confirmed, acceptable corresponding performance-defined RTI. There are three classes of property-specific performance testing relative to plastic material RTI:

1. Electrical RTI, associated with critical electrical insulating properties.
2. Mechanical Impact RTI, associated with critical impact resistance, resilience and flexibility.
3. Mechanical Strength (Mechanical without Impact) RTI, associated with critical mechanical strength where impact resistance, resilience and flexibility are not essential.

As an example, it is possible to obtain different RTI values for a material, based on whether it can retain the necessary characteristics to meet one of the three test categories above.

[1]As an example, below please find the properties and applications listed by GE for its plastic material Polyetherimide, which is sold under the trade name Ultem. ULTEM® resins offer:

Inherent flame resistance	Low smoke evolution
Dimensional stability	Strength and modulus at elevated temperatures
Hydrolytic and chemical stability	Resistance to wave and vapor soldering
Heat resistance: RTI to 356°F (180°C)	FDA and NSF grades

Typical applications for ULTEM® resins:

Electrical/electronic applications	Aircraft/aerospace interiors
Food service (ovenable)	High-temperature lighting bezels & reflectors
Under-hood automotive applications	Medical instrument trays
Institutional kitchenware	HVAC applications
Hardware and fasteners	

One note of caution—as in any industry, the terms defined above blur in everyday usage: people will often make no distinction between the three different kinds of thermoplastics. Some plastics, depending on their properties can fall into more than one category: for example, ABS can be either a volume or an engineering thermal plastic depending on specific properties.