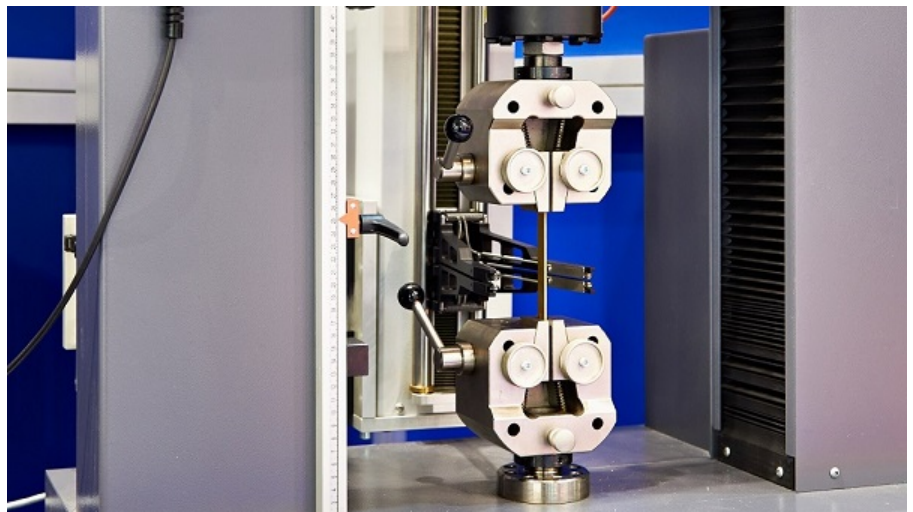




# Modulus of Elasticity

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## What are stress and strain?

### Definition of stress

Stress is defined as the **force per unit area of plastic**. The units of stress are  $\text{N/m}^2$  or Pa.

$$\sigma = F/A$$

where,

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$\sigma$  is the stress (in Newtons per square meter or, equivalently, Pascals),

F is the force (in Newtons, commonly abbreviated N), and

A is the cross-sectional area of the sample.

## Definition of strain

Strain is defined as **extension per unit length**. And, since it is a ratio of lengths, the strain has no units.

$$\epsilon = \Delta L / L_0; \Delta L = L - L_0$$

where,

$\epsilon$  is the strain

$L_0$  is the original length of a bar being stretched,

L is its length after it has been stretched, and

$\Delta L$  is the extension of the bar, the difference between these two lengths.

## What is Young's modulus?

Young's modulus is the **ratio of stress to the strain** applied to the material. The force is applied along the longitudinal axis of the specimen tested. It is the measure of the [stiffness](#) of an elastic material.

The formula of Young's modulus is:

$$E = \sigma / \epsilon$$

where,

E is the Young's modulus

$\sigma$  is the stress and

$\epsilon$  is the strain

Other names include tensile modulus, elastic modulus, or modulus of elasticity.

## The physics behind young's modulus

When a stretching force (tensile force) is applied to an object, it extends. Its behavior can be obtained using stress-strain curve in the elastic deformation region. This is known as **Hooke's Law**. The extension that a force produces depends upon the:

material

dimensions of the object (e.g., length, thickness, etc.)

## What are the units of Young's modulus?

SI unit of Young modulus is Pascal (Pa). It is also equal to newton per square meter ( $\text{N/m}^2$ ).

The practical units used in plastics are:

Megapascals (MPa or  $\text{N/mm}^2$ )

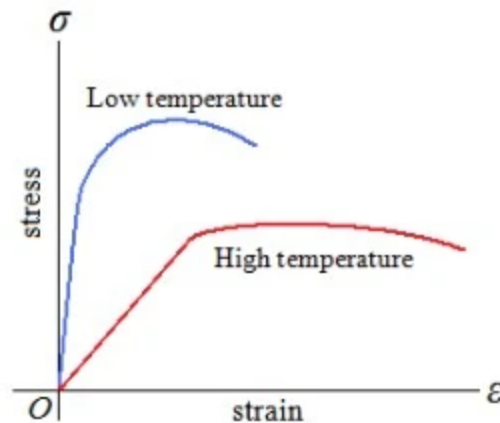
Gigapascals (GPa or  $\text{kN/mm}^2$ )

In the United States customary units, it is often expressed as pounds (force) per square inch (psi).

## What are the factors affecting Young's modulus?

The modulus is closely related to the **binding energies of the atoms**. Binding forces and modulus of elasticity are higher for high melting point materials. Young's modulus depends on the orientation of a single crystal material.

The **higher temperature in the material** increases atomic vibration. This in turn decreases the necessary energy to separate the atoms from one another. This generally decreases the stress needed to produce a given strain.



Relation between tensile properties and temperature (Source: Engineering Archives)

Presence of impurity atoms, alloying atoms, non-metallic inclusions, secondary phase particles, dislocations (shifts or mismatches in the lattice structure), and defects (cracks, grain boundaries, etc.). All of these things can serve to either weaken or strengthen a material.

Anything that impedes the motion of dislocations through the lattice tends to increase the modulus. This will thus the yield strength.

Anything that facilitates dislocation movement or localized stress will decrease strength. An increase in temperature eases dislocation movement. Cracks and inclusions rise localized stress. For example, promoting early onset of failure.

[Get Inspired: Prevent plastics component's failure by understanding the top 3 root causes & implementing corrective](#) [Back to Top](#)

[actions right from the start.](#)

## Which plastics have high or low modulus?

[Polymers with High Modulus - View Product List](#)

[Polymers with Low Modulus - View Product List](#)

## What is the modulus values of plastics vs. others?

The modulus of elasticity of plastics is much smaller than that for metals, ceramics, and glasses. For example:

The modulus of elasticity of [nylon](#) is 2.7 GPa ( $0.4 \times 10^6$  psi)

The modulus of glass fibers is 72 GPa ( $10.5 \times 10^6$  psi)

The Young's modulus of composites such as [glass fiber-reinforced composites \(GFRC\)](#) or [carbon fiber-reinforced composites \(CFRC\)](#) lies between the values for the matrix polymer and the fiber phase (carbon or glass fibers) and depends upon their relative volume fractions.

## What are the applications of Young's modulus?

Elastic modulus is an important mechanical property for:

1. **Material selection** for various purposes. This depends upon how the polymer reacts under different types of forces. For example, high-stiffness materials should have a higher Young's modulus.
2. **Product design** for specific industries. Used in several engineering as well as medical applications.
3. **Performance analysis** determines the batch quality and consistency in the manufacture. This in turn reduces material costs.



MATERIAL  
SELECTION



PRODUCT  
DESIGN



PERFORMANCE  
ANALYSIS

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# What are the test methods to calculate Young's modulus?

In general, “tensile test methods” measure the modulus of elasticity of materials. The common methods used are:

**ASTM D638** - Standard Test Method for Tensile Properties of Plastics

**ISO 527-1:2012** - Determination of tensile properties. General principles

These methods determine the tensile properties of plastics and plastic composites. This is done under defined conditions that can range from:

pretreatment,  
temperature,  
humidity, and  
machine speed

The test specimens are in the form of a standard dumbbell shaped.

For ASTM D638, the test speed is determined by the material specification. For ISO 527, the test speed is typically 5 or 50 mm/min for measuring strength and elongation, and 1 mm/min for measuring modulus.

Apart from Young's modulus, the tensile test results can also calculate:

[Tensile strength](#) (at yield and at break)

Tensile modulus

Strain

Elongation and percent [elongation at yield](#)

Elongation and percent [elongation at break](#)

# Which instrument is used to determine Young's modulus?

An extensometer determines the elongation and tensile modulus. It is a device that measures the changes in the length of an object. It evaluates the stress-strain curve values.

The two main types of extensometers are contact and non-contact.

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1. **Contact extensometers** are further divided into two types:

**Clip-on extensometer:** They can measure displacements from very small to relatively large. That is from less than 1 mm to over 100 mm. Used for applications requiring high-precision strain measurement (most ASTM-based tests). Major advantages include:

Low cost  
Easy to use

**Automated testing clip-ons:** They replace digital "sensor arm" extensometers. They can be applied to the specimen automatically by a motorized system. They produce much more repeatable results than traditional clip-on devices. They measure very high extensions (up to 1000 mm) without losing any accuracy. Major advantages include:

Better linearity,  
reduced signal noise, and  
synchronization with the corresponding force data.

2. **Non-contact extensometers:** These devices are beginning to bring advantages for certain applications. Especially, in industries where it is impractical to use contact extensometers.



Check Out an Interesting Video Showing Method to Test Elastic Modulus (Source: ADMET Testing Systems)

## What are Young's modulus values of several plastics?

*Click to find polymer you are looking for:*

[A-C](#) | [E-M](#) | [PA-PC](#) | [PE-PL](#) | [PM-PP](#) | [PS-X](#)

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|                                                                                        |       |       |
|----------------------------------------------------------------------------------------|-------|-------|
|                                                                                        |       |       |
| <a href="#">ABS - Acrylonitrile Butadiene Styrene</a>                                  | 1.79  | 3.20  |
| <a href="#">ABS Flame Retardant</a>                                                    | 2.00  | 3.00  |
| ABS High Heat                                                                          | 1.50  | 3.00  |
| ABS High Impact                                                                        | 1.00  | 2.50  |
| <a href="#">ABS/PC Blend - Acrylonitrile Butadiene Styrene/Polycarbonate Blend</a>     | 2.00  | 2.20  |
| ABS/PC Blend 20% Glass Fiber                                                           | 6.00  | 6.00  |
| <a href="#">ABS/PC Flame Retardant</a>                                                 | 2.60  | 3.00  |
| Amorphous TPI Blend, Ultra-high heat, Chemical Resistant (High Flow)                   | 3.50  | 3.50  |
| Amorphous TPI, High Heat, High Flow, Lead-Free Solderable, 30% GF                      | 10.53 | 10.53 |
| Amorphous TPI, High Heat, High Flow, Transparent, Lead-Free Solderable (High Flow)     | 3.10  | 3.10  |
| Amorphous TPI, High Heat, High Flow, Transparent, Lead-Free Solderable (Standard Flow) | 3.16  | 3.16  |
| Amorphous TPI, Highest Heat, Chemical Resistant, 260°C UL RTI                          | 3.90  | 3.90  |
| Amorphous TPI, Moderate Heat, Transparent                                              | 3.11  | 3.11  |
| Amorphous TPI, Moderate Heat, Transparent (Food Contact Approved)                      | 3.11  | 3.10  |
| Amorphous TPI, Moderate Heat, Transparent (Mold Release grade)                         | 3.12  | 3.12  |
| Amorphous TPI, Moderate Heat, Transparent (Powder form)                                | 3.11  | 3.11  |
| <a href="#">ASA - Acrylonitrile Styrene Acrylate</a>                                   | 2.00  | 2.60  |
| <a href="#">ASA/PC Blend - Acrylonitrile Styrene Acrylate/Polycarbonate Blend</a>      | 2.00  | 2.60  |
| ASA/PC Flame Retardant                                                                 | 2.50  | 2.50  |
| ASA/PVC Blend - Acrylonitrile Styrene Acrylate/Polyvinyl Chloride Blend                | 2.00  | 2.20  |
| <a href="#">CA - Cellulose Acetate</a>                                                 | 0.60  | 2.80  |
| <a href="#">CAB - Cellulose Acetate Butyrate</a>                                       | 0.40  | 1.70  |
| Cellulose Diacetate-Pearlescent Films                                                  | 2.00  | 2.50  |

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|-------------------------------------------------------------------|-------|-------|
| Cellulose Diacetate-Gloss Film                                    | 2.00  | 2.50  |
| Cellulose Diacetate-Integuard Films                               | 2.50  | 2.90  |
| Cellulose Diacetate-Matt Film                                     | 2.00  | 2.90  |
| Cellulose Diacetate-Window Patch Film (Food Grade)                | 2.00  | 2.50  |
| Cellulose Diacetate-Clareflect metallized film                    | 2.10  | 2.60  |
| Cellulose Diacetate-Colored Films                                 | 2.00  | 2.50  |
| Cellulose Diacetate-Flame retardant Film                          | 2.00  | 2.50  |
| Cellulose Diacetate-High Slip Film                                | 2.30  | 2.80  |
| Cellulose Diacetate-Semitone Films                                | 2.00  | 2.50  |
| CP - Cellulose Propionate                                         | 0.45  | 1.40  |
| <a href="#">COC - Cyclic Olefin Copolymer</a>                     | 2.60  | 3.20  |
| <a href="#">CPVC - Chlorinated Polyvinyl Chloride</a>             | 2.50  | 3.20  |
| ECTFE                                                             | 1.70  | 1.70  |
| <a href="#">ETFE - Ethylene Tetrafluoroethylene</a>               | 0.80  | 0.80  |
| <a href="#">EVA - Ethylene Vinyl Acetate</a>                      | 0.01  | 0.20  |
| <a href="#">EVOH - Ethylene Vinyl Alcohol</a>                     | 1.90  | 3.50  |
| <a href="#">FEP - Fluorinated Ethylene Propylene</a>              | 0.30  | 0.70  |
| <a href="#">HDPE - High Density Polyethylene</a>                  | 0.50  | 1.10  |
| <a href="#">HIPS - High Impact Polystyrene</a>                    | 1.50  | 3.00  |
| HIPS Flame Retardant V0                                           | 2.00  | 2.50  |
| <a href="#">Ionomer (Ethylene-Methyl Acrylate Copolymer)</a>      | 0.80  | 0.40  |
| <a href="#">LCP - Liquid Crystal Polymer</a>                      | 10.00 | 19.00 |
| LCP Carbon Fiber-reinforced                                       | 31.00 | 37.00 |
| LCP Glass Fiber-reinforced                                        | 13.00 | 24.00 |
| LCP Mineral-filled                                                | 12.00 | 22.00 |
| <a href="#">LDPE - Low Density Polyethylene</a>                   | 0.13  | 0.30  |
| <a href="#">LLDPE - Linear Low Density Polyethylene</a>           | 0.266 | 0.525 |
| MABS - Transparent Acrylonitrile Butadiene Styrene                | 1.90  | 2.00  |
| <a href="#">PA 11 - (Polyamide 11)</a> 30% Glass fiber reinforced | 3.80  | 5.20  |
| <a href="#">PA 46 - Polyamide 46</a>                              | 1.00  | 3.30  |

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|-------------------------------------------------------------------------------|-------|-------|
| PA 46, 30% Glass Fiber                                                        | 7.80  | 8.20  |
| <a href="#">PA 6 - Polyamide 6</a>                                            | 0.80  | 2.00  |
| <a href="#">PA 6-10 - Polyamide 6-10</a>                                      | 1.00  | 2.00  |
| <a href="#">PA 66 - Polyamide 6-6</a>                                         | 1.00  | 3.50  |
| PA 66, 30% Glass Fiber                                                        | 5.00  | 8.00  |
| PA 66, 30% Mineral filled                                                     | 1.40  | 5.50  |
| PA 66, Impact Modified, 15-30% Glass Fiber                                    | 2.00  | 11.00 |
| <a href="#">PA 66, Impact Modified</a>                                        | 0.80  | 1.20  |
| Polyamide semi-aromatic                                                       | 2.07  | 2.23  |
| <a href="#">PAI - Polyamide-Imide</a>                                         | 4.00  | 5.00  |
| PAI, 30% Glass Fiber                                                          | 11.00 | 15.00 |
| PAI, Low Friction                                                             | 5.00  | 7.00  |
| PAN - Polyacrylonitrile                                                       | 3.10  | 3.80  |
| <a href="#">PAR - Polyarylate</a>                                             | 2.00  | 2.30  |
| <a href="#">PARA (Polyarylamide)</a> , 30-60% glass fiber                     | 11.50 | 24.00 |
| <a href="#">PBT - Polybutylene Terephthalate</a>                              | 2.00  | 3.00  |
| PBT, 30% Glass Fiber                                                          | 9.00  | 11.50 |
| PC (Polycarbonate) 20-40% Glass Fiber                                         | 6.00  | 10.00 |
| PC (Polycarbonate) 20-40% Glass Fiber Flame Retardant                         | 7.00  | 8.00  |
| <a href="#">PC - Polycarbonate, high heat</a>                                 | 2.20  | 2.50  |
| <a href="#">PC/PBT Blend - Polycarbonate/Polybutylene Terephthalate Blend</a> | 1.80  | 2.30  |
| PC/PBT blend, Glass Filled                                                    | 4.50  | 5.10  |
| <a href="#">PCL - Polycaprolactone</a>                                        | 0.38  | 0.43  |
| <a href="#">PCTFE - Polymonochlorotrifluoroethylene</a>                       | 1.20  | 1.50  |
| <a href="#">PE - Polyethylene</a> 30% Glass Fiber                             | 4.90  | 6.30  |
| PE/TPS Blend - Polyethylene/Thermoplastic Starch                              | 0.19  | 0.30  |
| <a href="#">PEEK - Polyetheretherketone</a>                                   | 3.50  | 3.90  |
| PEEK 30% Carbon Fiber-reinforced                                              | 13.00 | 22.30 |
| PEEK 30% Glass Fiber-reinforced                                               | 9.00  | 11.40 |

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|-----------------------------------------------------------------------|------|-------|
| <a href="#">PEI - Polyetherimide</a>                                  | 3.00 | 3.00  |
| PEI, 30% Glass Fiber-reinforced                                       | 9.00 | 9.00  |
| <a href="#">PEI, Mineral Filled</a>                                   | 5.00 | 7.00  |
| <a href="#">PEKK (Polyetherketoneketone), Low Crystallinity Grade</a> | 3.40 | 3.50  |
| <a href="#">PESU - Polyethersulfone</a>                               | 2.30 | 2.80  |
| PESU 10-30% glass fiber                                               | 3.50 | 8.50  |
| <a href="#">PET - Polyethylene Terephthalate</a>                      | 2.80 | 3.50  |
| PET, 30% Glass Fiber-reinforced                                       | 9.00 | 12.00 |
| PET, 30/35% Glass Fiber-reinforced, Impact Modified                   | 7.00 | 9.00  |
| <a href="#">PETG - Polyethylene Terephthalate Glycol</a>              | 1.90 | 2.00  |
| <a href="#">PFA - Perfluoroalkoxy</a>                                 | 0.70 | 0.80  |
| PGA - Polyglycolides                                                  | 6.50 | 6.90  |
| <a href="#">PHB - Polyhydroxybutyrate</a>                             | 3.10 | 3.30  |
| <a href="#">PI - Polyimide</a>                                        | 1.30 | 4.00  |
| <a href="#">PLA - Polylactide</a>                                     | 3.40 | 3.60  |
| PLA, High Heat Films                                                  | 3.30 | 3.50  |
| PLA, Injection molding                                                | 3.50 | 3.60  |
| <a href="#">PMMA - Polymethylmethacrylate/Acrylic</a>                 | 2.50 | 3.50  |
| PMMA (Acrylic) High Heat                                              | 2.50 | 4.30  |
| <a href="#">PMMA (Acrylic) Impact Modified</a>                        | 1.50 | 3.50  |
| <a href="#">PMP - Polymethylpentene</a>                               | 0.50 | 1.60  |
| PMP 30% Glass Fiber-reinforced                                        | 5.00 | 6.00  |
| PMP Mineral Filled                                                    | 1.70 | 2.00  |
| <a href="#">POM - Polyoxymethylene (Acetal)</a>                       | 2.80 | 3.70  |
| <a href="#">POM (Acetal) Impact Modified</a>                          | 1.40 | 2.30  |
| POM (Acetal) Low Friction                                             | 1.80 | 3.00  |
| <a href="#">POM (Acetal) Mineral Filled</a>                           | 4.00 | 5.50  |
| <a href="#">PP - Polypropylene</a> 10-20% Glass Fiber                 | 2.80 | 4.00  |
| PP, 10-40% Mineral Filled                                             | 1.00 | 3.50  |
| PP, 10-40% Talc Filled                                                | 1.50 | 3.50  |

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|--------------------------------------------------------|-------|-------|
| PP, 30-40% Glass Fiber-reinforced                      | 4.00  | 10.00 |
| <a href="#">PP (Polypropylene) Copolymer</a>           | 1.00  | 1.20  |
| <a href="#">PP (Polypropylene) Homopolymer</a>         | 1.10  | 1.60  |
| PP Homopolymer, Long Glass Fiber, 30% Filler by Weight | 7.00  | 7.00  |
| PP Homopolymer, Long Glass Fiber, 40% Filler by Weight | 9.00  | 9.00  |
| PP Homopolymer, Long Glass Fiber, 50% Filler by Weight | 12.00 | 13.50 |
| <a href="#">PP, Impact Modified</a>                    | 0.40  | 1.00  |
| <a href="#">PPA - Polyphthalamide</a>                  | 3.70  | 3.70  |
| PPA, 33% Glass Fiber-reinforced – High Flow            | 13.00 | 13.20 |
| PPA, 45% Glass Fiber-reinforced                        | 17.10 | 17.30 |
| <a href="#">PPE - Polyphenylene Ether</a>              | 2.10  | 2.80  |
| PPE, 30% Glass Fiber-reinforced                        | 7.00  | 9.00  |
| PPE, Flame Retardant                                   | 2.40  | 2.50  |
| PPE, Impact Modified                                   | 2.10  | 2.80  |
| PPE, Mineral Filled                                    | 2.90  | 3.50  |
| <a href="#">PPS - Polyphenylene Sulfide</a>            | 3.30  | 4.00  |
| PPS, 20-30% Glass Fiber-reinforced                     | 6.00  | 11.00 |
| PPS, 40% Glass Fiber-reinforced                        | 8.00  | 14.00 |
| PPS, Conductive                                        | 13.00 | 19.00 |
| PPS, Glass fiber & Mineral-filled                      | 10.00 | 17.00 |
| <a href="#">PPSU - Polyphenylene Sulfone</a>           | 2.34  | 2.34  |
| PS (Polystyrene) 30% glass fiber                       | 10.00 | 10.00 |
| PS (Polystyrene) Crystal                               | 2.50  | 3.50  |
| PS, High Heat                                          | 3.00  | 3.50  |
| <a href="#">PSU - Polysulfone</a>                      | 2.50  | 2.70  |
| PSU, 30% Glass fiber-reinforced                        | 7.60  | 10.00 |
| PSU Mineral Filled                                     | 3.80  | 4.50  |
| <a href="#">PTFE - Polytetrafluoroethylene</a>         | 0.40  | 0.80  |
| PTFE, 25% Glass Fiber-reinforced                       | 1.40  | 1.70  |

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|-----------------------------------------------------------------------------|-------|-------|
| <a href="#">PVC (Polyvinyl Chloride)</a> , 20% Glass Fiber-reinforced       | 4.50  | 7.00  |
| <a href="#">PVC, Plasticized</a>                                            | 0.001 | 1.800 |
| PVC, Plasticized Filled                                                     | 0.001 | 1.00  |
| <a href="#">PVC Rigid</a>                                                   | 2.40  | 4.00  |
| <a href="#">PVDC - Polyvinylidene Chloride</a>                              | 0.35  | 0.50  |
| <a href="#">PVDF - Polyvinylidene Fluoride</a>                              | 1.50  | 2.00  |
| <a href="#">SAN - Styrene Acrylonitrile</a>                                 | 2.80  | 4.00  |
| SAN, 20% Glass Fiber-reinforced                                             | 8.00  | 11.00 |
| <a href="#">SMA - Styrene Maleic Anhydride</a>                              | 2.40  | 3.00  |
| SMA, 20% Glass Fiber-reinforced                                             | 5.00  | 6.00  |
| SMA, Flame Retardant V0                                                     | 1.80  | 2.00  |
| <a href="#">SMMA - Styrene Methyl Methacrylate</a>                          | 2.10  | 3.40  |
| SRP - Self-reinforced Polyphenylene                                         | 5.90  | 8.30  |
| TPI-PEEK Blend, Ultra-high heat, Chemical Resistant, High Flow, 240C UL RTI | 4.20  | 4.20  |
| <a href="#">TPS, Injection General Purpose</a>                              | 0.80  | 3.00  |
| TPS, Injection Water Resistant                                              | 0.63  | 0.72  |
| <a href="#">UHMWPE - Ultra High Molecular Weight Polyethylene</a>           | 0.30  | 0.60  |
| <a href="#">XLPE - Crosslinked Polyethylene</a>                             | 0.35  | 3.50  |

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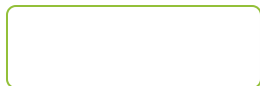
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