WARNING
The use of rope and cordage products has inherent safety risks which are subject to highly variable conditions and which may change over time. Compliance with standards and guidelines of the Cordage Institute does not guarantee safe use under all circumstances, and the Institute disclaims any responsibility for accidents which may occur. If the user has any questions or uncertainties about the proper use of rope or cordage or about safe practices, consult a professional engineer or other qualified individual.

1. Industrial Grade (High Tenacity) Fibers
Fibers are the foundation for all twine, cables, cordage, rope, and netting products. In the past ten years, there have been many new developments in fibers. It is important; therefore, that engineers and users understand and appreciate the "building blocks" of any strength member product.

Historically, cordage, ropes and twines were made from natural (vegetable) fibers. While these are still important for some applications, virtually all modern cordage products are based on synthetic fibers.

For the purpose of this document industrial grade fibers used in quality cordage and rope are synthetic fibers with a tenacity up to 15 grams per denier (gpd). High tenacity fibers used in quality cordage and rope are synthetic fibers with a tenacity above 15 grams per denier (gpd).

Many synthetic fibers can have a pigment added during the manufacturing process resulting in permanent color. A variety of colors are available.

1.1 Polyamide (Nylon)
The first man-made fiber used in cordage was nylon. It is a manufactured fiber composed of linear macromolecules having in the chain recurring amide linkages, at least 85% of which are joined to aliphatic or cycloaliphatic units. Two types of nylon are commonly used in rope making. Nylon 6 is made from amino caprolactam. Nylon 6,6 is made from hexamethylene diamine and adipic acid. The principal property difference is melt point.

The proper chemical name for nylon is polyamide. Chemical abbreviation PA; Chemical formula:

\[-\text{NH}-(\text{CH}_2)_5-\text{CO}]-n \text{ (nylon 6)}, \text{ and}\n\[-\text{NH}-(\text{CH}_2)_6-\text{NH}-\text{CO}(\text{CH}_2)_4-\text{CO}-\]_n \text{ (nylon 6,6)}.

Fiber tenacity ranges are from 7.5 to over 10.5 gpd.
1.2 **Polyester**
A manufactured fiber produced from the linear polymer 'polyethylene terephthalate'.
Chem. abbr. PET (PES is also sometimes used);
Chem. form.: \(-[\text{OC- C6H4 -COO-CH2-CH2-0}]\)-

More generally, polyester includes polymers composed of linear macromolecules having in the chain at least 85% by mass of an ester of a diol and terephthalic acid. Such linear polyesters are fiber forming.

Tenacity ratings of industrial polyester fibers range from 7.0 gpd to over 10.0 gpd.

Higher modulus polyesters, such as PEN (Polyethylene naphthalate) are also available.

1.3 **Polyolefins**
A class of polymers in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85% by weight of ethene (ethylene), propane (propylene), or other olefin units. This class includes Polypropylene and Polyethylene.

1.3.1 **Polypropylene**
A manufactured fiber formed by melt spinning and drawing polymers or copolymers of propylene, an aliphatic saturated hydrocarbon linear macromolecule where one carbon atom in two carries a methyl side chain in an isostatic disposition and without further substitution.
Chem. abbr. PP; chem. form. \(-(\text{CH2-CH})_I\)-
\(\text{CH3}\)

1.3.2 **Polyethylene**
A manufactured fiber formed of polymers of ethylene, synthetic linear macromolecules of unsubstituted aliphatic saturated hydrocarbon.
Chem. abbr. PE; chem. form. \(-(\text{CH2-CH2})_I\)-

1.3.3 **Copolymer Fibers**
Copolymer is the industry term for the melt combination of olefin polymer(s) (polypropylene/polyethylene) together or with other polymer(s) such as polyester. In most cases, copolymer combinations are based on proprietary formulas.

1.4 **Fluoropolymers**
A class of fluorocarbon based polymers with very strong carbon-fluorine bonds which are inherently chemically stable.

1.4.1 **Expanded Polytetrafluoroethylene (ePTFE)**
A manufactured fiber formed of long polymer chains of PTFE stretched into nodes and fibrils.
Chem. form.: \(-(\text{CnF2n})_I\)-

2. **Combination, Duplex, or Blended Fibers**
Cordage and rope can be made with the properties of more than one fiber by combining them in a single construction. In stranded and single-braided ropes, this is usually done by the combining of yarns or filaments of different fibers in the making of strands. In double-braided ropes this can also be done by using one type of fiber in the core and another in the cover, by utilizing differences in the fiber characteristics through the braid design.
3. Natural Fibers

NOTE: Ropes made from natural fibers can lose significant strength under normal storage conditions. For this reason, natural fiber ropes should NOT be used in applications where life and limb is at risk.

Natural fibers are classified as hard fibers and soft fibers. Generally speaking, hard fibers form the structural system of the leaf or plant, and soft fibers are found in the bast layer of the plant stem.

3.1 Abaca (manila): Abaca is obtained from the tropical plant Musa Testilis, a member of the banana plant family. It is commonly known as Manila hemp, which is a misnomer since the hemp plant belongs to the soft fiber group. Abaca is the strongest of the natural fibers. The majority of manila is grown in the Philippines.

3.2 Sisal and henequen: Sisal (Agave sisalana) and henequen (A. fourcroydes) are hard fibers. Henequen is sometimes called Mexican or Cuban sisal. Various sisals are identified by country of origin: Brazil, Haiti, Kenya, Tanzania, and Indonesia being the major producers.

3.3 Others: Jute is a soft fiber and comes from two closely related plants: Corchorous capsularia and C. olitorius. Hemp is a soft fiber and comes from the Cannabis sativa plant. Cotton is a natural fiber widely used in the textile industry, including some cordage and smaller diameter ropes. Cotton is often blended with synthetic staple fibers for additional strength and improved abrasion resistance.

4. High-Performance High-Modulus Fibers

These fibers have a tenacity greater than 15.0 grams/denier (gpd). The first of these was paraaramid (1970’s) followed by High Modulus PolyEthylene (HMPE, 1980’s) and liquid crystal polyester (LCP, 1990’s).

4.1 Para-aramid fibers. A manufactured high-modulus fiber in which the fiber-forming substance is a long chain synthetic aromatic polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings.

4.2 High Modulus PolyEthylene (HMPE). A polyolefin fiber produced by gel spinning or solid-state extrusion of an Ultra High Molecular Weight PolyEthylene (UHMWPE) feedstock to produce extremely high tenacity. Also called Extended-Chain PolyEthylene (ECPE) or High-Performance PolyEthylene (HPPE).

4.3 Liquid Crystal Polyester, (LCP). A thermotropic liquid crystal aromatic polyester fiber produced by melt spinning. It is a high-performance multifilament yarn with high tenacity and modulus. Also known as polyester-arylate.

4.4 PBO. PBO is a poly-para-phenylene bisoxazole fiber. PBO is polymerized from diaminoresocinol dichloride and terephthalic acid in polyphosphoric acid.
Long term properties are dependent on end use and environment. Always consult the rope manufacturer before choosing a rope for extended service.

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### Effects of Chemical Exposure

<table>
<thead>
<tr>
<th>Fiber Description</th>
<th>Physical Properties (see footnotes)</th>
<th>Long-Term / Environmental Properties (see footnotes)</th>
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</thead>
<tbody>
<tr>
<td><strong>Generic Name</strong></td>
<td><strong>Density [g/cm³]</strong></td>
<td><strong>Breaking Tenacity [gpd]</strong></td>
</tr>
<tr>
<td><strong>LCP Polyester-Polyarylate</strong></td>
<td>Vectran®</td>
<td>Light Gold</td>
</tr>
<tr>
<td><strong>Para-Aramid</strong></td>
<td>Kevlar®, Twaron®</td>
<td>Yellow</td>
</tr>
<tr>
<td><strong>Aramid Copolymer</strong></td>
<td>Technora®</td>
<td>Gold</td>
</tr>
<tr>
<td><strong>HMPE (1) (gel spun)</strong></td>
<td>Dyneema®, Spectra®, Doymenton-text®</td>
<td>White</td>
</tr>
<tr>
<td><strong>HMPE (solid state)</strong></td>
<td>Tensylon®, Endumax®</td>
<td>White</td>
</tr>
<tr>
<td><strong>PBO (2)</strong></td>
<td>Gold</td>
<td>1.54-1.56</td>
</tr>
</tbody>
</table>

**Physical Property Definitions:**
- **Breaking Tenacity:** break load in grams force per denier weight.
- **Breaking Strength:** break load divided by fiber cross sectional area.
- **Modulus:** resistance to stretch, or slope of load elongation curve.
- **Elongation at Break:** change in yarn length at break, expressed as percent of initial gage length.
- **Moisture regain tested at standard conditions of 72 deg F at 65% relative humidity.**

**Long-Term / Environmental Property Definitions:**
- **Long term properties are dependent on end use and environment. Always consult the rope manufacturer before choosing a rope for extended service.**
- **Remarks:**
  - Abrasion – Reduction in strength caused by interaction with surrounding fibers or surfaces. Overlay finishes and lubricants can enhance abrasion resistance under both wet and dry conditions.
  - Sunlight-UV: Synthetic fibers are susceptible to degradation on direct exposure to sunlight. Degradation of fibers within a rope can vary depending on rope construction, coatings and other factors.
  - Chemical Exposure – Fibers may be chemically degraded by exposure to specific agents. Data on chemical resistance should be obtained from the fiber companies, as listed on page 7, and the rope manufacturers.

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**Table 2 Cordage Institute High Tenacity Fiber Chart**

(Cordage Institute for purposes of this chart is any fiber with a tenacity greater than 15.0 grams/denier)
Cordage Institute Member Fiber Producers

Beijing Tongyizhong Specialty Fiber Technology & Development Co., Ltd
Nina Zhang
No.16 Zhonghe Street, Economic & Technological Development Area
Beijing, China
Tel: +86 (10) 56710302
Fax: +86 (10) 56710309
E-mail: nina@bjtyz.com, bjtyz@bjtyz.com
Website: http://en.bjtyz.com

Products:
Ultra High Molecular Weight Polyethylene fiber (UHMWPE)
Available in wide range of customized deniers
Colored UHMWPE fiber, like Neon Green, Lemon Yellow, Flame Red, Black, Blue, etc.

Brand Name:
Doyentrontex®

DSM Dyneema
Bill Fronzaglia
1101 Highway 27 South
Stanley, NC 28164
Tel: 704-862-5000
Fax: 704-862-5001
E-mail: bill.fronzaglia@dsm.com
Website: www.dyneema.com

Products:
HMPE Polyethylene. Ten grades (Dyneema® SK38, SK60, SK62, SK65, SK75, SK78, SK99, DM20, SK78XBO & DM20XBO).

Brand Name:
Dyneema®

DuPont Safety and Construction Kevlar® and Nomex® Products
Jack Yant
Spruance Plant
P.O. Box 27001
Richmond, VA 23261
Tel: 302-383-7330, 1-800-4-KEVLAR
Fax: 302-999-4094, 1-800-787-7086
E-mail: Jack.W.Yant@usa.dupont.com
Website: www.dupont.com/afs/

Products:
High Modulus Kevlar® aramid fibers – Deniers: 55-15,000
HMPE Polyethylene Material

Brand Name: Kevlar®, Nomex®, Tensylon™
Hailide America, Inc.
Stuart Smith  
1776 Peachtree St. NW  
710S  
Atlanta, GA 30309  
Tel: (404) 974-3232  
Fax: (404) 974-3233  
E-mail: stuart.smith@hailideamerica.com  
Website: www.hailideamerica.com

**Products:**  

**Brand Name:**  
Halead®

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**Honeywell Advanced Fibers & Composites**  
Brent Gerdes  
15801 Woods Edge Road  
Colonial Heights, VA 23824-0031  
Tel: 302-501-2136  
Alternate Tel: 804-930-7567  
E-mail: brent.gerdes@honeywell.com  
Website: www.spectrafiber.com

**Products:**  

**Brand Name:**  
Spectra®

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**Invista Sarl**  
Steve Clark  
175 Townpark Drive, Suite 300  
Kennesaw, Georgia 30144  
Office: 678-581-6037  
Cell: 316-200-8572  
Email: steve.clark@invista.com  
Website: www.invista.com
Invista - Canada
P.O. Box 2100
455 Front Road
Kingston, Ontario, K7L 4Z6
Canada
Office: 678-581-6037
Cell: 316-200-8572
Email: steve.clark@invista.com

Products:
Nylon 6,6 deniers 210-1050
Packaging: tubes

Brand Names:
Multiplex™ fibers
Cordura™

Kuraray America, Inc.
Forrest Sloan
460-E Greenway Industrial Drive
Fort Mill, SC 29708
Tel: 803-396-7350
Fax: 803-547-5888
E-mail: forrest.sloan@kuraray.com
Website: www.kuraray.us.com

Products:
High tenacity liquid crystal polyester (LCP) fiber

Brand Name:
Vectran® HT, UM

Nexis Fibers
Barbara Danak
Market Manager, North and South America
Nexis Fibers
Tel: 1-770-331-5380
Cell: 1-423-802-6161
Email: Barbara.danak@nexis-fibers.com
Website: www.nexisfibers.com
Twitter: @nexisfibers

Products:
High and Super High Multifilament Fiber in Polyamide 6 & 6,6
Spun Dyed High Tenacity Multifilament Fiber in Polyamide 6
Teijin Aramid USA
Amy Solomon
801 F Blacklawn Rd
Conyers GA 30012
Tel: 800-451-6586
Fax: 770-929-8138
Email: amy.jenkins@teijinaramid.com
Website: www.teijinaramid.com

Products:
Low, intermediate, and high modulus aramid fibers
HMPE material

Brand Names:
Twaron® and Technora®
Endumax®

TP Industrial Yarns
Contact Friso Heeren
8530 Steele Creek Place Drive, Suite A
Charlotte, NC 28273
United States of America
Phone +1-734-548-8046
Email Friso.Heeren@tp-industrial.com
Website https://www.tp-industrial.com/

Products:
TITAN HMPE Polyethylene: Three grades (Type 850, 860 & 850 Spun Dyed Colors)
Aramid: Para Aramid yarns four grades (type 951 (also in black), 961,971,971), Meta Aramid yarns
deniers available 200D, 1200D, 1600D
High Tenacity (HT), Polyester: Available in natural & various colors, deniers, and packaging. High
Tenacity (HT), Super High Tenacity (SHT), Marine Finish.
Polyamide 6: Available in natural & various colors, deniers, and packaging. High Tenacity (HT), Super
High Tenacity (SHT), Low Shrinkage (LS) Marine Finish.
Polyamide 6.6: Available in natural & black, deniers, and packaging. High Tenacity (HT), Super High
Tenacity (SHT), Marine Finish.

Brand Names:
TITAN