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:

\[-\text{NH}\cdot(\text{CH}_2)_5\cdot\text{CO}\cdot\text{Jn}\] (nylon 6), and

\[-\text{NH}\cdot(\text{CH}_2)_6\cdot\text{NH}\cdot\text{CO}(\text{CH}_2)_4\cdot\text{CO}\cdot\text{Jn}\] (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.: -[OC- \text{C}_6\text{H}_4\cdot\text{COO-CH}_2\cdot\text{CH}_2-0]-

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. \(-(CH_2-CH)_n\)

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. \-(CH_2-CH_2)_n\)

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.: \-(CnF_{2n})\)

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 para-aramid (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.

### Table 1: Cordage Institute Industrial Fibers Chart

(Industrial fibers are defined as having an average breaking tenacity between 5 and 15.0 grams/denier)

<table>
<thead>
<tr>
<th>Generic Fiber Description</th>
<th>Density, g/cm³</th>
<th>Breaking Tenacity, (gpd)</th>
<th>Melting Temperature C</th>
<th>Moisture Regain %</th>
<th>Resistance to Abrasion, Creep, and Sunlight Exposure</th>
<th>Chemical Exposure Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyamide (nylon) PA 6 or PA6,6</td>
<td>1.14</td>
<td>7.5 – 10.5</td>
<td>15 – 40</td>
<td>218 (PA6), 258 (PA6,6)</td>
<td>4.0 – 6.0</td>
<td>Very good abrasion resistance when dry. Poor abrasion resistance when wet unless special finishes are applied. Creep resistance is fair, and sunlight resistance is good with appropriate UV inhibitors.</td>
</tr>
<tr>
<td>Polyethylene terephthalate (polyester) PET or PES</td>
<td>1.38</td>
<td>7.0 – 10.0</td>
<td>12 – 18</td>
<td>254 – 260</td>
<td>&lt;0.5</td>
<td>Very good abrasion and sunlight resistance. Good resistance to creep.</td>
</tr>
<tr>
<td>Polyethylene naphthalate PEN</td>
<td>1.40</td>
<td>10</td>
<td>6</td>
<td>275 – 280</td>
<td>&lt;0.5</td>
<td>Very good abrasion and sunlight resistance. Good resistance to creep.</td>
</tr>
<tr>
<td>Polypropylene PP</td>
<td>0.91</td>
<td>6.5</td>
<td>18 – 22</td>
<td>165</td>
<td>0</td>
<td>Abrasion and sunlight resistance is fair. Poor resistance to creep.</td>
</tr>
<tr>
<td>High Modulus Polypropylene HMPP</td>
<td>0.84</td>
<td>8</td>
<td>7-8</td>
<td>165</td>
<td>0</td>
<td>Poor abrasion resistance, fair sunlight resistance, and very good resistance to creep.</td>
</tr>
<tr>
<td>Polyethylene PE or LDPE</td>
<td>0.95</td>
<td>6</td>
<td>20 – 24</td>
<td>140</td>
<td>0</td>
<td>Abrasion and sunlight resistance is fair. Poor resistance to creep.</td>
</tr>
<tr>
<td>Expanded Polytetrafluoroethylene ePTFE</td>
<td>1.8-2.1</td>
<td>5.0 – 6.0</td>
<td>3-5</td>
<td>327</td>
<td>0</td>
<td>Excellent abrasion and sunlight resistance. Resistance to creep is fair.</td>
</tr>
<tr>
<td>Copolymer PP/PPE</td>
<td>0.93</td>
<td>7.5</td>
<td>14 – 18</td>
<td>140</td>
<td>0</td>
<td>Abrasion and sunlight resistance is fair. Poor resistance to creep.</td>
</tr>
<tr>
<td>Copolymer PP/PES</td>
<td>0.99</td>
<td>7.0</td>
<td>12 – 16</td>
<td>196</td>
<td>0</td>
<td>Very good abrasion (with 50/50 blend) and sunlight resistance. Good resistance to creep.</td>
</tr>
<tr>
<td>Cotton (see Note 3) Natural cellulose fiber</td>
<td>1.54</td>
<td>2.0 – 3.0</td>
<td>2 – 3</td>
<td>Chars @ 148</td>
<td>100</td>
<td>Very good resistance to creep and sunlight. Abrasion resistance is fair.</td>
</tr>
<tr>
<td>Natural fiber (see Note 3) Abaca, agave, sisal</td>
<td>1.32</td>
<td>4.0 – 6.0</td>
<td>10 – 12</td>
<td>Chars @ 148</td>
<td>100</td>
<td>Very good resistance to creep and sunlight. Abrasion resistance is fair.</td>
</tr>
</tbody>
</table>

**Physical Property Definitions:**
- **Breaking Tenacity:** break load in grams force per denier weight.
- **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:**
- **Natural fibers are subject to degradation by fungal/bacterial attack during storage.**
- **Ropes made from natural fibers should not be used in applications where life and limb are at risk.**
- **This information is provided by the fiber manufacturers and is not intended as a Cordage Institute endorsement.**
- **Fiber selection should involve discussions with both fiber and cordage manufacturers.**
- **Special overlay finishes are available to enhance the strength and abrasion resistance.**
- **See page 7 for fiber producers contact information.**

**Notes:**
- **Note 1:** Resistance to abrasion is relative to other industrial fibers in this chart
- **Note 2:** LDPE is Low Density Polyethylene
- **Note 3:** Natural fibers are subject to degradation by fungal/bacterial attack during storage. Ropes made from natural fibers should not be used in applications where life and limb are at risk.
Chemical Exposure

Sunlight/UV

Abrasion

Ropemakers should be consulted if ropes are to be used in extreme heat or cold. Creep

Long term properties are dependent on end use and environment. Always consult the rope manufacturer before choosing a rope for extended service.

Ropemakers should be consulted if ropes are to be used in extreme heat or cold. Creep – Gradual change in length under the effects of an applied static tensile load. Influenced by testing temperature and applied load.

Abrasions – 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.

<table>
<thead>
<tr>
<th>Fiber Description</th>
<th>Physical Properties (see footnotes)</th>
<th>Long-Term / Environmental Properties (see footnotes)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generic</strong></td>
<td><strong>Density [g/cm³]</strong></td>
<td><strong>Breaking Tenacity [gpd]</strong></td>
</tr>
<tr>
<td>LCP Polyester-Polyarylate</td>
<td>1.40</td>
<td>20-31</td>
</tr>
<tr>
<td>Para-Aramid</td>
<td>1.44-1.47</td>
<td>18-29</td>
</tr>
<tr>
<td>Aramid Copolymer</td>
<td>1.39</td>
<td>28</td>
</tr>
<tr>
<td>HMPE (1) (gel spun)</td>
<td>0.57</td>
<td>25-44</td>
</tr>
<tr>
<td>HMPE (solid state)</td>
<td>0.57</td>
<td>28</td>
</tr>
<tr>
<td>PBO (2)</td>
<td>1.54-1.56</td>
<td>42</td>
</tr>
</tbody>
</table>

**Physical Property Definitions:**

- **Density:** Mass divided by volume.
- **Breaking Strength:** Maximum stress that a material can withstand while being stretched or pulled. It is calculated as the total force applied to the material divided by the cross-sectional area of the material.
- **Initial Modulus:** The material’s ability to resist deformation under load. It is calculated as the ratio of stress to strain.
- **Elongation at Break:** Change in length at break, expressed as percent of initial gage length. Moisture regain tested at standard conditions of 72 deg F at 65% relative humidity

**Trademarks:**

- Dynema®: Registered to DSM Dyneema
- Dyentron®: Registered to Beijing Tongyizhong
- Spectra®: Registered to Honeywell
- Twaron®, Technora®, Endumax®: Registered to Teijin Aramid
- Vectran®: Registered to Kuraray

**Notes:**

- HMPE is High Modulus Polyethylene.
- PBO is Poly-Paraphenylene-2,6 Benzobisoxazole.

**CI Member Tradenames:**

- ZYLON®: Registered to DSM Dyneema
- Dyentron®: Registered to Beijing Tongyizhong
- Spectra®: Registered to Honeywell
- Twaron®, Technora®, Endumax®: Registered to Teijin Aramid
- Vectran®: Registered to Kuraray

**Special overlay finishes are available to enhance the strength and abrasion resistance. See page 7 for fiber producers contact information.**

See page 7 for fiber producers contact information.
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®
FibrXL
Benno ter Horst
4590 Vawter Avenue
Richmond, VA 23222
Tel: 804 329 4383
Fax: 804-977 5089
Email: Benno.terhorst@fibrxl.com
Website: www.fibrxl.com

Products:
Polyester HT Yarn: Regular Shrink, Low Shrink, dope dyed colors, Marine finish, HMLS
Polyamide 6 HT Yarn: Regular Shrink, low Shrink, dope dyed colors
Polyamide 66 HT Yarn: Regular Shrink, low Shrink
UHMWPE: natural, dope dyed colors, anti-stat, coated
Aramid: Para Aramid, Meta Aramid

Brand Names:
Prisma®: Enhanced coating technology for High Performance Fibers
Oblix™: Impregnated UHMWPE (DSM Dyneema)
Atlas: UHMWPE Yarn
Hercules: Para Aramid Yarn

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:
High Tenacity (HT), Super Low Shrink (LS), High Modulus Low Shrink (HMLS) Polyester yarn.
Available in various colors, deniers, and packaging.
Marine Finish, Anti-Wick, Flame Retardant, and Adhesive Activated finishes available.

Brand Name:
Halead ®
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:**
High Molecular Weight Polyethylene (HMPE) Fiber.

**Brand Name:**
Spectra®

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®

TOYOBO Co., LTD
2-2-8 Dojimahama, Kita-ku, Osaka 530-8230, Japan
Tel: +81-6-6348-3445
Fax: +81-6-6348-3450
Email: go_matsuoka@toyobo.jp
Website: http://www.toyobo-global.com/

Products:
- High Modulus Polyethylene (HMPE)
  Several grades (SK60, SK777, SF600, SF700 and SF800) having different tenacity and deniers are available.

- Poly (p-phenylene-2, 6-benzobisoxazole) (PBO)
  Both regular (AS) and High modulus (HM) grade are available. Range of deniers is between 237 to 3270 dtex.

Brand Names:
IZANAS® (HMPE) and ZYLON® (PBO)
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

⚠️ 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.