FIBERS
For
Cable, 
Cordage, 
Rope and 
Twine

CI 2003
January 2005
Comparative Reference
(Supercedes CI 2003, April 2000)

A Service of the

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Telephone: 610-971-4854 
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Industrial Grade (High Tenacity) Fibers

Fibers are the foundation for all twine, cables, cordage, rope, and netting products. At no time in the history of cordage and rope has there been so many developments in fibers as in the last ten years. 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 man-made fibers.

Man-made fibers used in quality cordage and ropes are industrial-grade with a tenacity ranging up to 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.

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), and} \\
\[-\text{NH-}(\text{CH}_2)_6\text{-NH-CO(CH}_2)_4\text{-CO-}]_n \text{ (nylon 6.6).}

Fiber tenacity ranges are from 7.5 to over 10.5 gpd.

Polyester

A manufactured fiber produced from the linear polymer 'polyethylene terephthalate'. Chem. abr. PET (PES is also sometimes used); chem. formula: \-[\text{OC-aromatic ring see old CI-2003 or C}_6\text{H}_4 - \text{COO-CH}_2-\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 start at 7.0 gpd going up to over 10.0 gpd.

Higher modulus polyesters, such as PEN are also available.
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.

Polypropylene

A manufactured fiber formed by melts 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. Chemical abbreviation PP; Chemical formula -(CH2-CH)-

\[ \text{CH}_3 \]

Polyethylene

A manufactured fiber formed of polymers of ethylene, synthetic linear macromolecules of unsubstituted aliphatic saturated hydrocarbon. Chem. abr. PE; Chem. formula -(CH2-CH2)-

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.

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.
### Table 1  Cordage Institute Industrial Fibers Chart

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

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Generic Description</th>
<th>Specific Gravity</th>
<th>Melting Temperature °C</th>
<th>Breaking Tenacity (gpd)</th>
<th>Elongation at Break %</th>
<th>Abrasion Resistance*</th>
<th>Creep Resistance*</th>
<th>Moisture Regain* %</th>
<th>Microbial Resistance*</th>
<th>Sunlight Resistance*</th>
<th>Chemical Exposure Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>PA 6 Polyamide</td>
<td>1.14</td>
<td>218</td>
<td>7.5 – 10.5</td>
<td>15 – 28</td>
<td>Dry: Very Good</td>
<td>Fair</td>
<td>4.0 – 6.0</td>
<td>Excellent</td>
<td>Good**</td>
<td>Resistant to weak acids, decomposed by strong mineral acids. Resistant to alkalis. Resistant to organic solvents, soluble in phenols and formic acid.</td>
</tr>
<tr>
<td></td>
<td>PA 6.6 Polyamide</td>
<td>1.14</td>
<td>258</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PA 4.6 Polyamide</td>
<td>1.17</td>
<td>279</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PET/PES</td>
<td>Polyethylene terephthalate</td>
<td>1.38</td>
<td>254 – 260</td>
<td>7.0 – 10.0</td>
<td>12 – 18</td>
<td>Very Good</td>
<td>Good</td>
<td>&lt;0.5</td>
<td>Excellent</td>
<td>Very Good</td>
<td>Resistant to mineral acids, decomposed by strong sulfuric acids. Decomposed by strong alkalis at high temperature. Resistant to organic solvents, soluble in phenols.</td>
</tr>
<tr>
<td>PEN</td>
<td>Polyethylene naphthalate</td>
<td>1.40</td>
<td>275 – 280</td>
<td>10</td>
<td>6</td>
<td>Very Good</td>
<td>Good</td>
<td>&lt;0.5</td>
<td>Excellent</td>
<td>Very Good</td>
<td>Resistant to mineral acids, decomposed by strong sulfuric acids. Decomposed by strong alkalis at high temperature. Resistant to organic solvents, soluble in phenols.</td>
</tr>
<tr>
<td>PP</td>
<td>Polypropylene</td>
<td>0.91</td>
<td>165</td>
<td>6.5</td>
<td>18 – 22</td>
<td>Fair</td>
<td>Poor</td>
<td>0</td>
<td>Excellent</td>
<td>Fair</td>
<td>Resistant to acids. Resistant to alkalis. Resistant to organic solvents, soluble in chlorinated hydrocarbons.</td>
</tr>
<tr>
<td>PE</td>
<td>Polyethylene</td>
<td>0.95</td>
<td>140</td>
<td>6</td>
<td>20 – 24</td>
<td>Fair</td>
<td>Poor</td>
<td>0</td>
<td>Excellent</td>
<td>Fair</td>
<td>Resistant to acids. Resistant to alkalis. Resistant to organic solvents, soluble in chlorinated hydrocarbons.</td>
</tr>
<tr>
<td>Copolymer</td>
<td>Polypropylene</td>
<td>0.93</td>
<td>140</td>
<td>7.5</td>
<td>14 – 18</td>
<td>Fair</td>
<td>Poor</td>
<td>0</td>
<td>Excellent</td>
<td>Fair</td>
<td>Resistant to acids. Resistant to alkalis. Resistant to organic solvents, soluble in chlorinated hydrocarbons.</td>
</tr>
<tr>
<td></td>
<td>Polyethylene</td>
<td>0.99</td>
<td>196</td>
<td>7.0</td>
<td>12 – 16</td>
<td>Very Good***</td>
<td>Fair</td>
<td>0</td>
<td>Excellent</td>
<td>Very Good</td>
<td>Resistant to most acids. Degraded by strong sulphuric acids. Resistant to alkalis. Resistant to organic solvents, soluble in chlorinated hydrocarbons.</td>
</tr>
<tr>
<td>Cotton</td>
<td>Natural cellulose fiber</td>
<td>1.54</td>
<td>Chars @ 148</td>
<td>2.0 – 3.0</td>
<td>2 – 3</td>
<td>Fair</td>
<td>Very Good</td>
<td>100</td>
<td>Poor</td>
<td>Very Good</td>
<td>Degradation by acids in high concentration or high temperature. Resistant to alkalis. Degradation by organic solvents and sea water.</td>
</tr>
<tr>
<td>Manila</td>
<td>Natural fiber from abaca plant</td>
<td>1.32</td>
<td>Chars @ 148</td>
<td>5.0 – 6.0</td>
<td>10 – 12</td>
<td>Fair</td>
<td>Very Good</td>
<td>100</td>
<td>Poor</td>
<td>Very Good</td>
<td>Degradation by acids in high concentration or high temperature. Degradation by alkalis. Resistant to organic solvents.</td>
</tr>
<tr>
<td>Sisal</td>
<td>Natural fiber from Agave sisalana plant</td>
<td>1.32</td>
<td>Chars @ 148</td>
<td>4.0 – 5.0</td>
<td>10 – 12</td>
<td>Fair</td>
<td>Very Good</td>
<td>100</td>
<td>Poor</td>
<td>Very Good</td>
<td>Degradation by acids in high concentration or high temperature. Degradation by sea water. Resistant to alkalis. Resistant to organic solvents.</td>
</tr>
</tbody>
</table>

### Definitions:
- Specific Gravity: Ratio of yarn density to that of water
- Moisture Regain: As tested at standard conditions (72 degrees F/65% R.H.)
- Breaking Tenacity: Grams/denier; tested per ASTM D885.
- Elongation at Break: Percent of length change; tested per ASTM D885.

### Industrial Fiber Notes:
- 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.

*Relative to standard and high tenacity fibers

** abrasion resistance of wet nylon fiber is generally poor, but can be improved with special finishes

*** improved with UV inhibitors

**** if 50/50 blend

See page 7 for fiber producers contact information.

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<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Polyester-Polyarylate</td>
<td>Vectran®</td>
<td>5.0 dpf 100-2250 den.</td>
<td>T-150 weaving finish to aid processing T-97 silicon based for improved abrasion resistance</td>
<td>1.40 23-29 525-585</td>
<td>3.5-3.6</td>
<td>Excellent</td>
<td></td>
<td></td>
<td></td>
<td>MP: 330 ºC</td>
<td>&lt; 0.1</td>
<td>See note 6</td>
<td>Stable to acids &lt;90% concentration and bases &gt;30 % concentration</td>
</tr>
<tr>
<td>Para-Aramid</td>
<td>Kevlar®</td>
<td>1.5-2.25 dpf 195-15,000 den.</td>
<td>Several available</td>
<td>Yellow</td>
<td>1.40 1.47</td>
<td>18-29</td>
<td>432-1100</td>
<td>1.5-4.4</td>
<td>Very Good</td>
<td>Fair</td>
<td>Does not melt Decomposes @ 500ºC</td>
<td>1.5- 4.0</td>
<td>See note 6</td>
</tr>
<tr>
<td>Para-Aramid</td>
<td>Twaron®</td>
<td>1.0-1.0 dpf 233-27,222 den.</td>
<td>Several proprietary</td>
<td>Yellow</td>
<td>1.44 1.45</td>
<td>20-29</td>
<td>432-983</td>
<td>1.8-3.6</td>
<td>Very Good</td>
<td>Fair</td>
<td>Does not melt Decomposes @ 500ºC</td>
<td>3.5- 6.5</td>
<td>See note 6</td>
</tr>
<tr>
<td>Para-Aramid</td>
<td>Technora®</td>
<td>0.75-1.6 dpf 55-7500 den.</td>
<td>Several available</td>
<td>Raw-gold Black also available</td>
<td>1.39 28</td>
<td>590</td>
<td>4.6</td>
<td>Very Good</td>
<td>Good</td>
<td>Does not melt Decomposes @ 500ºC</td>
<td>2.0</td>
<td>See note 6</td>
<td>Resistant to acids, bases and organic solvents</td>
</tr>
<tr>
<td>HMPE (1)</td>
<td>Spectra®</td>
<td>1.9-10 dpf 75-4800 den.</td>
<td>Standard spin finish</td>
<td>White</td>
<td>0.97 25-41</td>
<td>750-1450</td>
<td>2.8- 3.9</td>
<td>Fair</td>
<td>Excellent</td>
<td></td>
<td>MP 150 ºC</td>
<td>0.0</td>
<td>See note 6</td>
</tr>
<tr>
<td>HMPE (1)</td>
<td>Dyneema®</td>
<td>1.3 dpf 100-1600 den.</td>
<td>Standard spin finish</td>
<td>White</td>
<td>0.97 32-44</td>
<td>1020-1377</td>
<td>3.5-3.8</td>
<td>Fair</td>
<td>Excellent</td>
<td></td>
<td>MP 144-155 ºC</td>
<td>0.0</td>
<td>See note 6</td>
</tr>
<tr>
<td>PBO (2)</td>
<td>Zylon®</td>
<td>1.5 dpf 250-3000 den.</td>
<td>Standard only</td>
<td>Gold</td>
<td>1.54 1.56</td>
<td>42</td>
<td>1300-2000</td>
<td>2.5-3.5</td>
<td>Excellent</td>
<td>Fair</td>
<td>Does not melt Decomposes @ 650ºC</td>
<td>0.6- 2.0</td>
<td>See note 6</td>
</tr>
</tbody>
</table>

**Definitions:**
- **Specific Gravity:** Ratio of yarn density to that of water.
- **Breaking Tenacity:** in grams/denier, tested per ASTM D885-98.
- **Elongation at Break:** Yarn elongation expressed as percent of length change, tested per ASTM D885-98.
- **Modulus:** Reflects stretch resistance or stiffness versus load, tested per ASTM D885-98.
- **Yarn Sizes:** dpf is denier per filament; den. is denier.

**Notes:**
- Note 1: HMPE is High Modulus Polyethylene.
- Note 2: PBO is Poly-Paraphenylene-2 6 Benzobisoxazole.
- Note 3: Estimated for each fiber relative to other fibers.
- Note 4: Overlay finishes can enhance abrasion resistance under both dry and wet conditions.
- Note 5: As tested at standard conditions of 72 deg F at 65% RH.
- Note 6: Synthetic fibers are susceptible to UV degradation. When a fiber is used in a rope, the UV resistance can vary depending on the construction and other factors. Specific values should be obtained from the individual fiber companies, as listed on page 7 and the rope manufacturers.

**Trademarks:**
- Dyneema: Registered to DSM High Performance Fibers
- Kevlar: Registered to DuPont
- Spectra: Registered to Honeywell Performance
- Technora: Registered to Teijin Twaron USA, Inc., Ltd
- Twaron: Registered to Teijin Twaron USA, Inc., Ltd
- Vectran: Registered to Celanese Advanced Materials
- Zylon: Registered to Toyobo Co., Ltd Tel: Toyobo America Inc 212-317-9245, www.toyobo.co.jp
Natural Fibers

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.

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.

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.

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.

High-Performance High-Modulus Fibers

These fibers have a tenacity greater than 15.0 grams/denier (gpd). The first of these was a para-aramid. The aramids have been followed by Ultra High Molecular Weight Polyethylenes (HMPE) and liquid crystal polymers (LCP).

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. Examples are ‘Kevlar’, ‘Twaron’ and ‘Technora’.

High Modulus PolyEthylene (HMPE). A polyolefin fiber produced by gel spinning of an Ultra High Molecular Weight PolyEthylene (UHMWPE) feedstock to produce extremely high tenacity. The strength of the fiber is 10 times that of steel on a weight for weight basis. Also called extended-chain PE or HPPE (High Performance PolyEthylene). Examples are ‘Dyneema’ and ‘Spectra’.

Liquid Crystal Polymer, (LCP). A thermotropic liquid crystal aromatic polyester produced by melt spinning. It is a high-performance multifilament yarn with high tenacity and modulus. Example is Vectran.

PBO. PBO is a poly-para-phenylene bisoxazole fiber. PBO is polymerized from diaminoresocinol dichloride and terephthalic acid in polyphosphoric acid.
Fiber Producers

**DSM Dyneema**
Rich Miller  
1101 Highway 27 South  
Stanley, NC 28164  
Tel: 704-862-5156  
Fax: 704-862-5001  
E-mail: rich.miller@dsm.com  
Website: www.dyneema.com

*Products:*
HMPE Polyethylene. Two grades (Dyneema SK60 and SK75) reflecting different tenacities (g/d).

*Brand Name:*
Dyneema®

---

**DuPont Kevlar® Fibers**
Ralph Smith  
Spruance Plant  
P.O. Box 27001  
Richmond, VA 23261  
Tel: 302-999-5931, 1-800-4-KEVLAR; Fax: 302-999-4094, 1-800-787-7086  
E-mail: Ralph.F.Smith@USA.dupont.com  
Website: www.dupont.com/afs/

*Products:*
High Modulus Kevlar® aramid fibers – Deniers: 55-15,000

*Brand Name:*
Kevlar®

---

**Honeywell Advanced Fibers & Composites**
Rich Capuano  
15801 Woods Edge Road  
Colonial Heights, VA 23824-0031  
Tel: 401-254-0565  
E-mail: richard.capuano@honeywell.com  
Website: www.spectrafiber.com

*Products:*
High Molecular Weight Polyethylene (HMPE).  
Three grades, Spectra® 900, Spectra® 1000, Spectra® 2000 (reflecting different tenacities).  
Available in a wide range of deniers

*Brand Name:*
Spectra®
INVISTA
Tina Ingle
4501 N. Access Road
Chattanooga, TN 37415
Tel: 800-660-2210
Fax: 800-653-1411
E-mail: cordage@usa.dupont.com
Website: www.invista.com

INVISTA - Canada

P.O. Box 2100
455 Front Road
Kingston, Ontario, K7L 4Z6
Canada
Tel: 800-660-2210
Fax: 800-653-1411
E-mail: cordage@usa.dupont.com

Products:
Nylon 6.6 deniers 210-15, 120
Dacron® Industrial Polyester: deniers 220-1,800
DuPont Multiplex: deniers 3, 140-45,000
Polyester: deniers 70-500; 840; 1,000; 1,300; 1,500; 2,000; 2,600, 5,200
Marine finish polyester: deniers 1,100; 2,200
PEN: High modulus polyester 1,000 denier FR Polyester: 1,000 denier
Packaging: Beams, tubes, plied to 20,000 denier
Nylon 6 white: denier 840, 1,260

Brand Names:
Dacron® fibers
Multiplex™ fibers
Performance Plus™ finish
**KORDSA International, LLC**  
Mike Lindler  
P.O. Box 968  
Fort Mill, SC 29716-0968  
Tel: 800-853-4555, 803-547-5653  
Fax: 803-547-5801  
E-mail: Michael.Lindler@kordsa-intl.com  
Website: www.kordsa-intl.com  

**Products:**  
High Tenacity nylon filament yarns  

Types:  
- Nylon 6: 840-1890 deniers  
- Nylon 66: 840-15,120 deniers  
- Bulked Industrial Nylon 66: 1000-3000 deniers  

Special cordage marine finishes available.

**Kuraray America, Inc.**  
Bob Knudsen  
460-E Greenway Industrial Drive  
Fort Mill, SC 29708  
Tel: 704-554-3148  
Fax: 704-554-3101  
E-mail: robert_knudsen@kuraray-am.com  
Website www.vectranfiber.com  

**Products:**  
High tenacity liquid crystal polymer fiber. (multifilament, cut)  

**Brand Name:**  
Vectran®

**Performance Fibers**  
15801 Woods Edge Road  
Colonial Heights, VA 23824-0031  
Tel: 804-520-3629  
Fax: 804-520-3033  
Website: www.performancefibers.com  

**Products:**  
- Industrial Polyester: denier 500-60,000  
- Industrial PEN: denier 500-2000  

**Brand Names:**  
A.C.E. polyester  
SeaGard Marine Finish  
Pentex (high modulus PEN)
Rhodia Polyamide
6021 Emmenbruecke Switzerland
Tel: +41 41-267-8279
Fax:+41 41-267-9217
Website: www.rhodia-iy.com
www.rhodia.com

Products:
Polyamide 6  deniers 210 - 1680, light or heat protected
Polyamide 6.6  deniers 100 - 1890, light or heat protected
Solution dyed polyamide 6: denier 840, various colors available
Polyester: deniers 1000, 1500
Packaging: Tubes
Plies, twines and braids available upon request

Teijin, Ltd Mitsui Plastics, Inc.

2500 Windy Ridge Parkway
Suite 1570
Atlanta, GA 30339
Tel: 770-563-0140
Fax: 770-563-0150
E-mail: Tsekii@atl.mitsui.com
Website: www.mitsuiplastics.com

Products:
Technora® aramid fibers – Deniers: 55-7,500

Brand Name
Technora®

Teijin Twaron USA

801-F Blacklawn Road
Conyers, GA 30012
Tel: 800-451-6586
Fax: 770-929-8138
Web: www.twaron.com

Products:
Low, intermediate and high modulus aramid fibers Deniers: 380-7,245

Brand Name:
Twaron®

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