FIBERS
For Cable, Cordage, Rope and Twine

CI 2003
November 2004
Comparative Reference
(Supersedes CI 2003, April 2000)

A Service of the

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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:

$[-NH-(CH2)_5-CO-]_n$ (nylon 6), and

$[-NH-(CH2)_6-NH-CO(CH2)_4-CO-]_n$ (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: -[OC-aromatic ring see old CI-2003 or C_6H_4 - 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 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)-
I
CH3

Polyethylene

A manufactured fiber formed of polymers of ethylene, synthetic linear macromolecules of unsubstituted aliphatic saturated hydrocarbon. Chem. abr. PE; Chem. formula $-(CH_2-CH_2)-$

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)

Fiber	Generic Description	Specific Gravity	Melting Temperature C	Breaking Tenacity (gpd)	Elongation at Break %	Abrasion Resistance*	Creep Resistance*	Moisture Regain* %	Microbial Resistance*	Sunlight Resistance*	Chemical Exposure Effects
PA (nylon)	PA 6 Polyamide PA6.6 Polyamide PA 4.6 Polyamide	1.14 1.14 1.17	218 258 279	7.5 – 10.5	15 – 28	Dry: Very Good Wet:: poor **	Fair	4.0 – 6.0	Excellent	Good**	Resistant to weak acids, decomposed by strong mineral acids. Resistant to alkalis. Resistant to organic solvents, soluble in phenols and formic acid.
PET/PES (polyester)	Polyethylene terephthalate	1.38	254 – 260	7.0 – 10.0	12 – 18	Very Good	Good	<0.5	Excellent	Very Good	Resistant to mineral acids, decomposed by strong sulfuric acids. Decomposed by strong alkalis at high temperature. Resistant to organic solvents, soluble in phenols.
PEN	Polyethylene naphthalate	1.40	275 – 280	10	6	Very Good	Good	<0.5	Excellent	Very Good	Resistant to mineral acids, decomposed by strong sulfuric acids. Decomposed by strong alkalis at high temperature. Resistant to organic solvents, soluble in phenols.
PP	Polypropylene	0.91	165	6.5	18 – 22	Fair	Poor	0	Excellent	Fair	Resistant to acids. Resistant to alkalis. Resistant to organic solvents, soluble in chlorinated hydrocarbons.
PE	Polyethylene	0.95	140	6	20 – 24	Fair	Poor	0	Excellent	Fair	Resistant to acids. Resistant to alkalis. Resistant to organic solvents, soluble in chlorinated hydrocarbons.
Copolymer	Polypropylene Polyethylene	0.93	140	7.5	14 – 18	Fair	Poor	0	Excellent	Fair	Resistant to acids. Resistant to alkalis. Resistant to organic solvents, soluble in chlorinated hydrocarbons.
Copolymer	Polypropylene Polyester	0.99	196	7.0	12 – 16	Very Good****	Fair	0	Excellent	Very Good	Resistant to most acids. Degraded by strong sulphuric acids. Resistant to alkalis. Resistant to organic solvents, soluble in chlorinated hydrocarbons.
Cotton	Natural cellulose fiber	1.54	Chars @ 148	2.0 – 3.0	2 – 3	Fair	Very Good	100	Poor	Very Good	Degradation by acids in high concentration or high temperature. Resistant to alkalis. Degradation by organic solvents and sea water.
Manila	Natural fiber from abaca plant	1.32	Chars @ 148	5.0 – 6.0	10 – 12	Fair	Very Good	100	Poor	Very Good	Degradation by acids in high concentration or high temperature. Degradations by alkalis. Resistant to organic solvents.
Sisal	Natural fiber from Agave sisalana plant	1.32	Chars @ 148	4.0 – 5.0	10 – 12	Fair	Very Good	100	Poor	Very Good	Degradation by acids in high concentration or high temperature. Degradation by sea water. Resistant to alkalis. Resistant to organic solvents

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.

Table 2 Cordage Institute High Tenacity Fiber Chart

(High Tenacity for purposes of this chart is any fiber with a tenacity greater than 15.0 grams/denier)

Descriptive Properties					Physical Properties							Environmental Properties		
Generic Description	Trade Name	Yarn Sizes [dpf\denier]	Yarn Finishes	Standard Color	Specific gravity [g/cm^3]	Breaking Tenacity [gpd]	Modulus [gpd]	Elongation at break [%]	Creep Resistance (3)	Abrasion Resistance (4)	Melting Point\ Decompose Temp. [°C]	Moisture Regain (5) [%]	Sunlight (UV) Resistance (6)	Effects of Chemical Exposure (7)
Polyester-Polyarylate	Vectran®	5.0 dpf 100-2250 den.	T-150 weaving finish to aid processing T-97 silicon based for improved abrasion resistance	Gold Other colors also available	1.40	23-29	525-585	3.3- 3.6	Excellent	Very Good	MP: 330 °C	< 0.1	See note 6	Stable to acids <90% concentration and bases <30 % concentration
Para-Aramid	Kevlar®	1.5-2.25 dpf 195-15,000 den	Several available	Yellow Other colors also available	1.44-1.47	18-29	432-1100	1.5- 4.4	Very Good	Fair	Does not melt Decomposes @ 500°C	1.5- 4.0	See note 6	Resistant to weak acids. Bases, water and salt water. Degradation induced by strong acids and bases in high concentration or high temperature.
Para-Aramid	Twaron®	1.0-1.9 dpf 233-27,222 den.	Several proprietary	Yellow	1.44-1.45	20-29	432-983	1.8- 3.6	Very Good	Fair	Does not melt Decomposes @ 500°C	3.5- 6.5	See note 6	Resistant to weak acids. Bases, water and salt water. Degradation induced by strong acids and bases in high concentration or high temperature.
Para-Aramid	Technora®	0.75-5.6 dpf 55-7500 den	Several available	Raw-gold Black also available	1.39	28	590	4.6	Very Good	Good	Does not melt Decomposes @ 500°C	2.0	See note 6	Resistant to acids, bases and organic solvents
HMPE (1)	Spectra®	1.9-10 dpf 75-4800 den.	Standard spin finish	White	0.97	25-41	790-1450	2.8- 3.9	Fair	Excellent	MP 150 °C	0.0	See note 6	Resistant to most concentrated industrial acids, bases, oxidizers, and organic solvents at room temperature. Resistant to many acids/bases/oxidizers/solvents at elevated temperatures.
HMPE (1)	Dyneema®	1-3 dpf 100-1600 den.	Standard spin finish	White	0.97	32- 44	1020-1377	3.5-3.8	Fair	Excellent	MP 144-155 °C	0.0	See note 6	Excellent resistance to water, moisture, most chemicals and micro organisms. Good resistance to acids and alkalis.
PBO (2)	Zylon®	1.5 dpf 250-3000 den.	Standard only	Gold	1.54-1.56	42	1300-2000	2.5-3.5	Excellent	Fair	Does not melt Decomposes @ 650°C	0.6- 2.0	See note 6	Resistant to weak acids, bases, bleach and organic solvents. Degradation induced by strong acids at high temperatures.

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 Polyethlene.
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

Eisterweg 3, 6422 PN Heerlen
P.O. Box 6510, 6401 JH Heerlen
The Netherlands
Tel: #-31- 45-543-6734; Fax: #-31-45-543-6778
E-mail: info.dyneema@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

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Fax: (800) 653-1411, (423) 875-7872
E-mail: Jennifer.D.Lansden@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
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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®